

Lead and Cadmium Levels in musculature of Wild and Farmed Tilapia Fish sold in Assiut City, Egypt

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ABSTRACT

The objective of current study was to assess and compare the concentrations of lead (Pb) and cadmium (Cd) in flesh of wild and farmed Tilapia fish available in markets in Assiut city, Egypt. A total of 66 Tilapia fish samples (36 wild and 30 farmed) were randomly collected from the markets and Pb and Cd concentrations were determined in their flesh using Inductively Coupled Plasma Emission Spectrometer. Mean values for Pb and Cd in wild and farmed Tilapia were 1.507 ± 0.180 & 0.379 ± 0.053 ; and 2.178 ± 0.260 & 0.437 ± 0.084 mg kg⁻¹ (wet basis), respectively. Most of the wild (80.6 & 83.3%) and farmed (90.0 & 80.0%) samples exceeded the permissible limit set by Egyptian standards for Pb and Cd, respectively. In conclusion, flesh of either wild or farmed Tilapia from markets in Assiut city, constitute a potential public health hazard for lead and cadmium toxicity. Farmed Tilapia is more dangerous in this respect.

Key words: Heavy Metals, Lead, Cadmium, Fish, Wild, Farmed, Tilapia.

INTRODUCTION

Fish is a vital source of nutritious food for hundreds of millions of people worldwide. The annual total fisheries and aquaculture production in Egypt in 2011 was 1.4 million tons with 46% freshwater fish out of which 0.61 million tons was for Nile tilapia alone. The average per capita consumption of fish in Egypt is 20.8 kg/year (i.e. 56.99g/days) of which 72% come from aquaculture (FAO, 2011).

Heavy metals, inorganic compounds that have high density (Kalay et al., 1999), pose a serious threat because of their toxicity, long time persistence, bioaccumulation, and bio-magnifications in the food chain (Papagiannis et al., 2004; Karadede-Akin et al., 2007). Fish lie at the top of the aquatic food chain and they can accumulate large amounts of heavy metals from their living environment (Suhaimi et al., 2006).

During the past decades, the concentrations of heavy metals in fish have been extensively studied in various places around the world, as the diet is the main route of human exposure to heavy metals (Bolawa and Gbenle, 2010; Olusola et al., 2012; Damodharan and Reddy, 2013; Jinadasa and Edirisinghe, 2013; Regina and Kingsley, 2016; Hemmatinezhad et al., 2017; Juniavto et al., 2017).

Lead (Pb) and Cadmium (Cd) are among the main toxic metals that accumulate in fish and have a multitude of toxic effects (Cunningham and Saigo, 1997). Lead, a toxic substance with low rate of elimination from body, mostly taken via drinking water, food and air (Gavaghan, 2002). Over exposure to it increase the risk of premature birth, as well, it causes anemia (inhibits the biosynthesis of haem), renal tubular dysfunction, circulatory disorders, nervous manifestations and death. Severe vomiting and intestinal cramps are among the common symptoms of sever lead poisoning (Cunningham and Saigo, 1997; Malhat, 2011). Cadmium is classified as a probable human carcinogen. Major cadmium exposure in human is through food (WHO, 1985). Chronic exposure to it is associated with heart diseases, anemia, skeletal weakening, depressed immune system response, hepatic dysfunction, hypertension and poor reproductive capacity. It had a significant role in the incidence of chronic renal failure. Cadmium causes the painful Itai-Itai disease and damages the lungs (Codex, 2001).

Lead and Cadmium levels are elevated in natural waters as the result of increased industrialization and agricultural activities. River Nile subjected to contamination with such metals since most activities in Egypt are around the Nile as it passes through agricultural and industrial fields where most of the poorly treated municipal wastewater and drain water discharged into the River Nile (Malhat, 2011).

Nile tilapia (Pisces: Cichlidae), primarily native to Africa, has a wide distribution in Egypt (River Nile and its tributaries, coastal Lakes and Lake Nasser) (Bishai and Khalil, 1997). It is very important protein source and a popular target for artisanal and commercial fisheries. Tilapia has been used in toxicological studies "as a biological monitor of environmental water pollution". It can bio-accumulate heavy metals e.g. lead and cadmium in different tissues and organs at varying degrees, from the surrounding environments (Rashed, 2001; Authman, 2008, Atli and Canli, 2010; Authman et al., 2012).

In recent years, there was rapid growth in the fishery culture, in particular Tilapia culture, worldwide (Qiu et al., 2011). Tilapia has been artificially introduced "cultured" in at least 57 tropical and subtropical countries of the world [e.g. Palastine "occupied", Indonesia, USA, and Brazil], being one of the most widely and successfully cultured fresh water fish worldwide (Pullin et al., 1997; Grammer et al., 2012). In Egypt many Tilapia fish farms were recently established to supplement the deficiency in the quantities of fish sold in local markets (GAFRD, 2010).

Commercial aquaculture facilities require abundant clean water with suitable levels of oxygen, pH and nutrients to achieve a product with a minimum of pollutants [30]. However, the illegal use of agricultural drainage water, contain high concentrations of contaminants such as heavy metals, in some aquaculture farms causes accumulation of such contaminants in fish reared in these farms (Authman, 2008; Authman et al. 2012; Alne-na-ei, 2003; Khallaf et al., 2003; Tayel et al., 2007).

The potential accumulation of heavy metals in the muscle of fish available in markets to such a degree that may constitute a potential threat to human health when ingested is of great concern. Hence, it is important to determine the concentrations of heavy metals in commercial fish musculatures in order to evaluate the possible risk of its consumption.

Several studies conducted on wild Tilapia of the River Nile collected from different Governorates in Egypt indicate the presence of varied levels of lead and/or cadmium in fish musculature (Gomaa et al., 1995; Sayed, 1995; Khallaf et al., 1998; El ghobashy et al., 2001; Mansour and Sidky, 2002; Alne-na-ei, 2003; Authman and Abbas, 2007;; Authman, 2008;; Malhat, 2011; Abd El-Malek and Ammar, 2013; Ibraheim et al., 2015; Abdelbary, 2016; Ibrahim et al., 2016). As well, the potential accumulation of such toxic compounds in farmed tilapia fishes has been addressed in a number of studies (Alne-na-ei, 1998, 2000; Ali and Abdel-Satar, 2005; Kaoud and El-Dahshan, 2010; Fallah et al., 2011; Abd El-Azeem et al., 2012; Authman et al, 2012; Abd El-Malek and Ammar, 2013).

Maximum safe levels of Pb and Cd in fish flesh have been enforced by the government of Egypt (EOS, 2010). However, data whether dietary lead and cadmium exposure set well below the provisional tolerable weekly intake, recommended by the UN Food and Agricultural Organization, is not yet available in Egypt "according to our knowledge". As well, except for a limited study, which dealt with comparing lead and cadmium levels in wild and farmed fish in Egypt (Mansour and Sidky, 2002; Abd El-Malek and Ammar, 2013), no further information is yet available.

Accordingly, the objective of the current study was to assess and compare the concentrations of lead (Pb) and cadmium (Cd) in flesh of farmed and wild Tilapia fish available in markets in Assiut city, Egypt. As well to compare these concentrations with the safe permissible limits stipulated by Egyptian Organization for Standardization (EOS, 2010) and to ascertain the suitability of these fishes for human consumption.

MATERIAL AND METHODS

Study area

Assiut city is located in Assiut Governorate, Egypt, on latitude $27^{\circ} 10' 58''$ N and longitude $31^{\circ} 10' 58''$ E, and 56 meters above sea level with a population of 745,544 (Figure 1)

N.B. Fish-farms in Kafr El Sheikh, Gharbia Governorate, Egypt (located on latitude $31^{\circ} 6' 22.75''$ N and longitude $30^{\circ} 56' 31.11''$ E) are the major source of farmed tilapia available for public consumption in Assiut city.

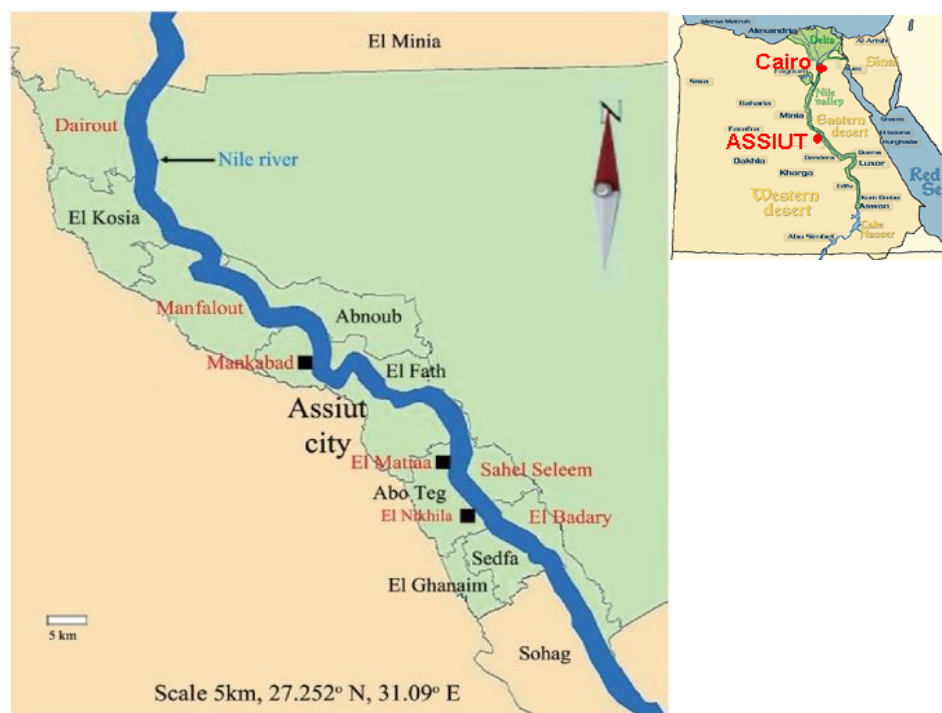


Figure 1. Map shows study area.

Collection of samples

Tilapia fish samples (36 wild and 30 farmed) were randomly obtained from fish-sellers in Assiut city, Egypt, over a 6 months period. They were transported immediately with a minimum of delay to the Meat Hygiene Laboratory, Faculty of Veterinary Medicine, Assiut University, and stored at 4°C till being soon prepared. The type of fish selected for analysis was based on general abundance in the area and their potential to be consumed by local people (Figure 2).

Preparation of samples

In the laboratory, fish samples were washed off to remove external dirties and slime if present, then subjected to sensory assessment (inspected for any external abnormalities and for the signs of freshness) according to (FAO, 1995). The scales, fins and skin were then removed and the muscular tissue was taken out, homogenized thoroughly and kept frozen at -20°C until analysis.

Digestion of samples

The method described by Finerty et al. (1990) was used with slight modification. Briefly, of each prepared sample 1 gram was removed into clean capped glassware "previously washed with deionized water and dried", followed by addition of 5 ml of conc. nitric acid of analytical reagent grader " HNO_3 (AR)". The samples was left overnight for cold digestion in the acid, then heated at 70°C (hot plate) until all vapors " NO_2 " ceased and the sample become clear (~5-7 hrs). The digested samples were allowed to cool to room temperature, diluted with 10 ml deionized water, then filtered and the filtrate made up to 50 ml volume with de-ionized water. Analytical blank was run in the same way as the samples using deionized water instead of the sample.

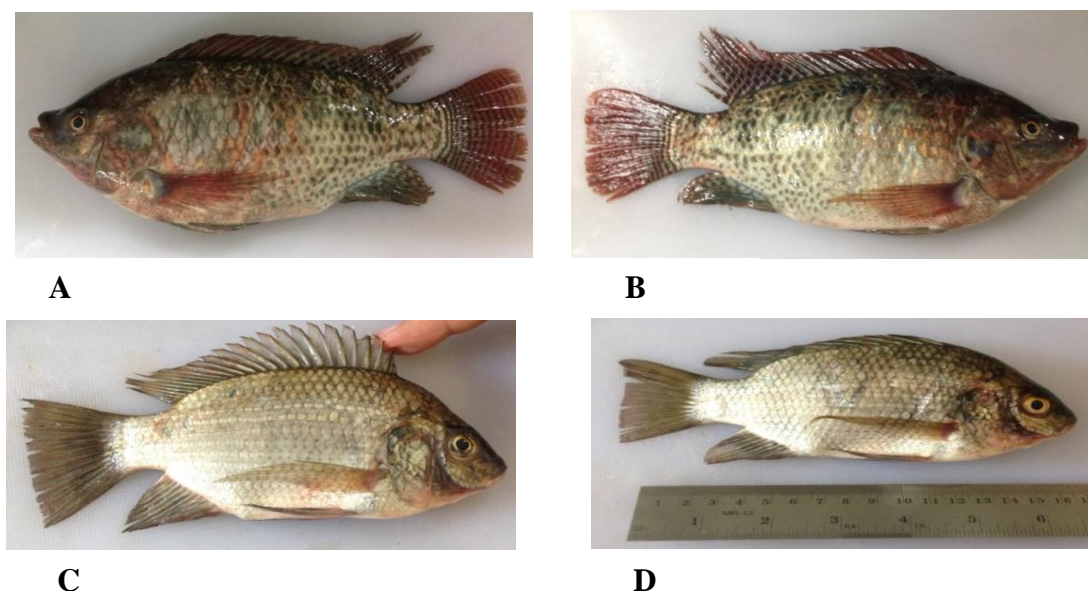


Figure 2. Pictures of the studied farmed (A and B) and wild (C and D) Tilapia fish.

Quantitative determination of lead and cadmium

Inductively Coupled Plasma Emission Spectrometer, iCAP 6200 (Thermo Scientific, USA) at "Central laboratory for chemical analysis, Faculty of Agriculture, Assiut University, Assiut, Egypt" was used for the determination of lead and cadmium concentrations in the filtered digests. Each sample was measured as triplicate. Lead was measured at wave length of 220.353 nm with minimum detection limit of 1.06 $\mu\text{g/L}$, while cadmium was measured at wave length of 214.438 nm with minimum detection limit of 0.07 $\mu\text{g/L}$. concentrations were quoted as mg kg^{-1} on wet weight base.

Health-risk assessment of fish consumption

According to FAO (2011) the average consumption of fish in Egypt is about 20.8 kg/person per year, which is equal to 56.99 g/person/day. When such value "i.e. 56.99 g is multiplied by the mean concentration of the metal in the analyzed fish, the average daily intake of the metal through consumption of such fish can be calculated for a person. Assuming an average body weight of 60kg for an Egyptian, and based on FAO/WHO (2004) and Türkmen et al. (2009) data, the permissible tolerable daily intake "PTDI60" for the metal ($\mu\text{g/person/day}$) can be calculated, and so the amount of the fish required to be consumed to attain the PTDI60.

Statistics

Data of metals concentrations in fish tissue samples were statistically analyzed with one-way analysis of variance (ANOVA) using SPSS 13 for Windows (2001). Significance was assumed at $P < 0.05$. The data are shown as mean \pm standard error in mg/kg wet weight.

RESULTS

Table 1. Concentrations (mg kg^{-1} wet weight) of lead and cadmium in the examined wild and farmed Tilapia fish samples

	Lead		Cadmium	
	Wild Tilapia*	Farmed Tilapia**	Wild Tilapia***	Farmed Tilapia**
Min	0.020	0.035	0.008	0.010
Max	3.950	5.300	1.050	2.050
Mean \pm SE	1.507 \pm 0.180 ^b	2.178 \pm 0.260 ^a	0.379 \pm 0.053 ^a	0.437 \pm 0.084 ^a

*n= 34 **n= 30 ***n=36

Means with different superscript within a row of each element are significantly different ($P < 0.05$)

Table 2. Acceptability (%) of the examined wild and farmed Tilapia fish samples based on their lead or cadmium content

	Lead		Cadmium	
	Wild Tilapia	Farmed Tilapia	Wild Tilapia	Farmed Tilapia
Samples tested	36	30	36	30
Samples positive (%)	34 (94.4%)	30 (100%)	36 (100%)	30 (100%)
Samples (%) within the permissible limit	7 (19.4%)	3 (10%)	6 (16.7%)	6 (20%)
Samples (%) exceed the permissible limit	29 (80.6%)	27 (90%)	30 (83.3%)	24 (80%)
Permissible limits*	0.3 mg kg ⁻¹		0.05 mg kg ⁻¹	

*Permissible limits in fish muscles according to the Egyptian standards (EOS, 2010)

Table 3. The estimated daily intake (EDI) of lead/cadmium (µg/day/person) through consumption of wild or farmed tilapia fish by adult people (assuming 60 kg person) in Egypt

	Wild Tilapia	Farmed Tilapia	PTDI ^a	PTDI ₆₀ ^b
Lead	85.88 (142.14) ^c	124.12 (98.35)	3.57	214.2
Cadmium	21.60 (158.31)	24.90 (137.30)	1	60.0

^a PTDI: provisional permissible tolerable daily intake (µg/kg body weight/day) (FAO/WHO, 2004)

^b PTDI₆₀: permissible tolerable daily intake for 60 kg person (µg/day)=PTDI x 60 kg.

^c Values between brackets are the daily intake (in grams) of wild or farmed tilapia that should be consumed in order to attain the permissible tolerable daily intake of metal for 60 kg person (=PTDI₆₀ (µg/day) /metal concentration (µg/g)), according to FAO/WHO (2004).

The results registered in Table 1 showed that, lead concentrations (mg/kg wet basis) ranged from 0.02 to 3.95, with a mean value of 1.507±0.18 in wild Tilapia fish samples, while in farmed tilapia the concentrations ranged from 0.035 to 5.3, with a mean value of 2.178±0.26. As for cadmium, the concentrations (mg/kg wet basis) ranged from 0.008 to 1.05 and from 0.01 to 2.05, with a mean value of 0.379±0.053 and 0.437±0.084 in muscles of wild and farmed Tilapia fish, respectively. Mean concentration of lead was significantly (P<0.05) higher in farmed than in wild Tilapia fish. However, means concentration of cadmium was insignificantly (P>0.05) differ despite numerically higher for farmed fish.

As declared in Table 2, of the 36 examined wild tilapia samples, 34 (94.4%) showed detectable levels of lead, while in the remaining 2 (5.6%) samples, lead concentration was below the detection limit (1.06 ppb) of the apparatus used. On the other hand, all of the 30 (100%) examined farmed Tilapia samples showed detectable values of lead in their musculature. Of the 36 wild samples, 29 (80.6%) showed lead levels exceeded the permissible limit (0.3mg/kg wet basis), set by the Egyptian Organization for Standardization and quality control for the fish muscles, while only 7 (19.4%) samples showed levels below the permissible limit. Regarding the farmed tilapia, out of the 30 samples, 27 (90%) showed levels exceed the permissible limit and only 3 (10%) showed levels within the limit.

On the other hand, all the examined samples of wild (36, 100%) and farmed (30, 100%) Tilapia fish showed detectable concentrations of cadmium in their musculature. Of the 36 examined wild samples, 30 (83.3%) were found to have cadmium concentrations exceeded the permissible limit (0.05 mg/kg wet basis), set by the Egyptian Organization for Standardization and quality control,

and only 6 (16.7%) were have concentrations within the permissible limit. Likewise, out of the 30 farmed samples, 24 (80%) were found to have concentrations of cadmium exceeded the limit and 6 (20%) were found to have concentrations within the limit (Table 2).

As declared in Table 3, the estimated (average) daily intake "EDI" of lead, (= mean concentration of the metal "measured" X daily fish consumption rate "i.e 56.99g"), through consumption of wild and farmed Tilapia flesh will be 85.88 and 124.12 ug/day, while that of cadmium will be 21.6 and 24.9 ug/day, respectively. The permissible tolerable daily intake (PTDI) for lead is 3.57 and for cadmium is 1 µg/kg body weight/day, i.e. an adult weighing 60kg should not take more than 214.2 µg of lead per day and not more than 60.0 µg of cadmium per day (PTDI60). The fish quantity required to be consumed by a person weighing 60 kg to attain the permissible tolerable level of lead will be 142.14 g/day of wild Tilapia fish or 98.35 g/day of farmed fish. As for cadmium, the required quantity will be 158.31 g/day of wild or 137.30 g/day of farmed Tilapia fish as illustrated in Table 3.

DISCUSSION

Fish are at the top of the aquatic food chain. It may concentrate large amounts of some metals, such as lead and cadmium. These metals can accumulate in fish musculature and cause serious health hazards to humans. For this, the problem of fish contamination by toxic metals has received much attention (Ibrahim, 1996; Bolawa and Gbenle, 2010; Kaoud and El-Dahshan, 2010; Authman et al., 2012; Elnabris et al., 2013; Mohamedien et al., 2015; Ibrahim et al., 2016; Regina and Kingsley, 2016).

The present study was undertaken to investigate and compare lead and cadmium concentrations in muscular tissue of wild and farmed Tilapia fish sold in markets of Assiut city, Egypt, as muscles is the most consumed portion of fish by people in Egypt.

Heavy metals accumulation commonly causes pathological changes and diseases in fish, as well; it may affect flesh quality (Ferreira et al., 2010). Sensory assessment of the samples proved that all were accepted from the organoleptic point of view, however wild fish samples were less in sensory scores than farmed ones. The wild fish samples "69.4 and 30.6%" were of good and fair qualities, while most of farmed fish samples "60.0 and 36.7%" were of excellent and good qualities, respectively.

Lead (Pb) and cadmium (Cd) exhibit extreme toxicity even at trace levels (Fianko et al., 2007). They have no known biological function and show carcinogenic effect on aquatic biota and humans. Moderate exposure can significantly reduce human semen quality and is related to many diseases in adults and children alike (ATSDR, 2007; Qiu et al., 2011; Vieira et al., 2011).

The current investigation showed that the different fish items contained different concentrations of lead and cadmium in their muscles. Mean concentration of lead was significantly ($P < 0.05$) higher in farmed (2.178 ± 0.26) than in wild (1.507 ± 0.18) Tilapia fish. However, means concentration of cadmium was insignificantly ($P > 0.05$) differ despite numerically higher for farmed fish (0.437 ± 0.084 vs. 0.379 ± 0.053) as shown in Table 1.

The concentrations of metals estimated in the muscular tissue of either wild or farmed Tilapia fish sold in markets of Assiut, were much higher than those recorded in some studies and lower than some others (Table 4 and 5). This may be attributed to the environmental variations and the conditions under which the fish is reared, where geographical location (the type and level of water pollution) and season of catch beside chemical form of metal in the water, water temperature, pH value, dissolved oxygen concentration, and water transparency are all influence the heavy metal concentrations in the fish (Dural et al., 2007; Bahnasawy et al., 2009).

Table 4. Lead and cadmium concentrations (mg kg⁻¹ wet basis) in Tilapia fish muscles in comparison to some other studies in Egypt

Location/Country	Fish species	lead	Cadmium	Ref.
Assiut, Egypt	Tilapia (wild)	1.507	0.379	Current study
	Tilapia (farmed)	2.178	0.437	
Ismailia, Egypt	<i>O. niloticus</i> (wild)	1.22	0.52	Abdelbary et al. (2016)
New Valley, Egypt	<i>O. niloticus</i> (wild)	1.89	0.01	Ibrahim et al. (2016)
Behira, Egypt	<i>O. niloticus</i> (wild)	0.0198-0.0250	0.0002-0.0003	Bayomy et al. (2015)
Sohag, Egypt	<i>Tilapia nilotica</i> (wild)	0.479-48.75 (10.9218)	0.080-6.55 (1.4078)	Ibraheim et al. (2015)
Menofia, Egypt	<i>Tilapia nilotica</i>	0.08	0.10	Shalout et al. (2015)
Assiut, Egypt	<i>O. niloticus</i> (wild)	0.7331	0.7229	Abd El-Malek and Ammar (2013)
	<i>O. niloticus</i> (farmed)	0.2993	0.1157	
Ismailia, Egypt	<i>O. niloticus</i> (farmed)	0.128	0.018	Abd El-Azeem et al. (2012)
Kafer Al-Sheikh, Ismailia, Kaliobea, Damietta, Behera, Al-Fayum, Egypt	<i>O. niloticus</i> (farmed)	1.52	1.21	Kaoud and El-Dahshan (2010)
Fayoum, Egypt	Tilapia sp (wild)	0.0587-1.653	0.0782-0.1596	Mansour and Sidky (2002)
	Tilapia sp (farmed)	0.0059-6.3812	0.0109-0.09	
Cairo, Egypt	<i>O. niloticus</i> (wild)	0.22-3.2 (1.1214)	0.002-0.53 (0.1527)	Elghobashy et al. (2001)
Aswan, Egypt	<i>Tilapia nilotica</i> (wild)	0.13	0.018	Rashed (2001)
Al Minufya, Egypt	<i>O. niloticus</i> (wild)	48.7	5.3	Khallaf et al. (1998)
Permissible limit (mg kg ⁻¹ wet weight)				
	EOS	0.3	0.05	EOS (2010)
	EC	0.3	0.05	EC (2006)
	FAO/WHO	0.5	0.5	FAO/WHO (1989)
	Saudi Arabia	2.0	0.5	SASO (1997)

Elghobashy et al. (2001), Cheung et al. (2008), Saeed and Shaker (2008), Sohsah (2009), Olusola et al. (2012), Damodharan and Reddy (2013), Bayomy et al. (2015), El-Shafei (2015), Mohamedien et al. (2015) and Abdelbary et al. (2016) recorded lower lead values in wild Tilapia. Meanwhile, Khallaf et al. (1998), Ibraheim et al. (2015) and Juniavto et al. (2017) recorded higher values.

Mohamed (1993) detected higher mean concentration (4.98 – 8.04 mg kg⁻¹) of lead in wild *Tilapia nilotica* collected from different localities in Assiut Governorate. However, Sayed (1995) recorded lead mean values ranged from 0.1 to 1.74, which is nearly parallel to the current findings.

Lower mean values of lead in farmed tilapia were reported by Farag et al. (2000), Lin et al. (2005), Bin-Mokhtar (2009), Kaoud and El-Dahshan (2010), Abd El Azeem et al. (2012), Elnabris et al. (2013), Jinadasa and Edirisinghe (2013) and Emara et al. (2015). Higher concentrations were found by Authman et al. (2012) and Ibraheim et al. (2016).

Table 5. Lead and cadmium concentrations (mg kg⁻¹ wet basis) in Tilapia fish muscles in comparison to some other studies world wide

Location/Countr y	Fish species	lead	Cadmium	Ref.
Isfahan, Iran	Tilapia fillets	0.638 Dry basis	0.136 Dry basis	Hemmatinezhad et al. (2017)
West Java, Indonesia	<i>O. niloticus</i> (wild)	2.504-3.871 (3.05467)	ND	Juniavto et al. (2017)
Ogoni land, Nigeria	<i>Tilapia guineensis</i> (wild)	5 Dry basis	1.7 Dry basis	Regina and Kingsley (2016)
Gaza Strip (Palestine)	<i>O. niloticus</i>	0.115	<0.002	Elnabris et al. (2013)
India	<i>O. mossambicus</i> (wild)	0.004-0.026 (0.015) Dry basis	0.008-0.011 (0.0095) Dry basis	Damodharan and Reddy (2013)
Sri Lanka	Oreochromis sp (farmed)	0.26 Dry basis	0.03 Dry basis	Jinadasa and Edirisinghe (2013)
Oyo State, Nigeria	<i>O. niloticus</i> (wild)	0.031	0.019	Olusola et al. (2012)
Lagos, Nigeria	<i>Tilapia oreochromis</i> (wild)	1.57-3.25 Dry basis	1.13-4.49 Dry basis	Bolaw and Gbenle (2010)
Sri Lanka	<i>O. niloticus</i> (farmed)	-	<0.15	Allison et al. (2009)
Pakistan	<i>O. mossambicus</i>	2.4 Dry basis	1.39 Dry basis	Arian et al. (2008)
China	<i>O. mossambicus</i> (wild)	0.29	0.09	Cheung et al. (2008)
China	<i>O. mossambicus</i>	1.71	0.03	Kong et al. (2005)
Tiwan	<i>O. mossambicus</i> (farmed)	0.183	0.011	Lin et al. (2005)

Lead mean concentration in farmed Tilapia muscles were significantly ($P<0.05$) higher than those in wild Tilapia (Table 1). This was in agreement with the finding of Mansour and Sidky (2002) and Gonzalez et al. (2006), but opposite to the findings of Abd El-Malek and Ammar (2013).

Lead higher concentrations had occurred in aquatic ecosystem as a result of industrial and agricultural discharges; as well fish may be exposed to lead contamination in feed (Farag et al., 2000 and Adefemi et al., 2008). Lead accumulates in the human body and affects many body systems. It adversely affects CNS resulting in psychopathological symptoms including restlessness, dullness, irritability and memory loss (Manahan, 1992).

Cadmium is highly toxic non-essential heavy metal, have no role in biological processes in living organisms. It could be harmful even in low concentration (Burden, 1998).

Lower levels of cadmium, than currently recorded in wild Tilapia musculature, were detected by Elghobashy et al. (2001), Cheung et al. (2008), Saeed and Shaker (2008), Sohsah (2009), Olusola et al. (2012), Damodharan and Reddy (2013), Hamed et al. (2013), Bayomy et al. (2015) El-shafei (2015), Mohamedien et al. (2015) and Juniavto et al. (2017). However, higher values were found by Seddek et al. (1996), Khallaf et al. (1998), Ibraheim et al. (2015) and Abdelbary et al. (2016).

Mohamed (1993) detected cadmium means concentration of 0.293 – 0.389 mg kg⁻¹ in wild Tilapia collected from different sites in Assiut Governorate which is nearly parallel to the present findings, however Sayed (1995) recorded lower concentrations (0.012 to 0.15mg kg⁻¹).

Farag et al. (2000), Lin et al. (2005), Bandara et al. (2008), Allinson et al. (2009), Bin-Mokhtar (2009), Abd El-Azeem et al. (2012), Elnabris et al. (2013), Jinadasa and Edirisinghe (2013), Emara et al. (2015) and Ibraheim et al. (2016) found lower cadmium concentrations in farmed Tilapia fish. Meanwhile, Kaoud and El-Dahshan (2010) and Authman et al. (2012) detected higher concentrations (Tables 4 and 5).

Despite it is numerically higher in farmed Tilapia, the means value of cadmium in wild and farmed Tilapia fish was not differ significantly ($p>0.05$). Mansour and Sidky (2002), Gonzalez et al. (2006) and Abd El-Malek and Ammar (2013) registered lower cadmium concentrations in farmed than in wild Tilapia fish muscles which disagree with the present findings.

The high levels of Cadmium in the environment may be attributed to industrial and mining operations as well, to the phosphate fertilizer "the main source of Cd in the environment" (Dimari et al., 2008). Cadmium accumulation may induce nausea, insomnia, prostate cancer, testicular atrophy and kidney failure (Kikuchi et al., 2002).

Mansour and Sidky (2002) detected higher levels of lead in wild and farmed Tilapia fish, meanwhile cadmium levels were lower than the findings of the present study. Lead mean values of 0.73 and 0.299 mg kg⁻¹ were found by Abd El-Malek and Ammar (2013) in wild and farmed tilapia (*Oreochromis niloticus*), respectively, which is lower than the current findings. However, cadmium mean value was lower (0.115 mg kg⁻¹) for farmed Tilapia, but higher (0.723 mg kg⁻¹) for wild tilapia, than the present findings. Hemmatinezhad et al. (2017) recorded lower values of lead (0.638 mg kg⁻¹ d.w.) and cadmium (0.136 mg kg⁻¹ d.w.) in Tilapia fillets from Isfahan, Iran.

Accumulation of metals like Pb and Cd is actively controlled by fish through different metabolic processes. The level of accumulation usually depends on the ambient concentration i.e the pollution status of the regions (Hamza-Chaffai et al., 1996; Raphael et al., 2011). The relatively high levels of lead and cadmium in Tilapia fish from markets of Assiut city may indicate potential pollution at least in the area where they were caught. Alne-na-ei (2003) mentioned that water bodies' contamination by metals is caused by the discharge of massive amounts of domestic sewage as well as agricultural and industrial effluents. Moreover, Dural et al. (2007) declared that pollution with metals was a result of contamination of water with fertilizers containing metals.

From the present results it was noted that concentrations of lead is generally higher than that of cadmium either in wild or farmed tilapia, which is in agreement with the results of Mansour and Sidky (2002), Eneji et al (2011) and Abd El-Malek and Ammar (2013). On contrary, Raphael (2011) found cadmium level higher than that of lead in fish collected from Okumeshi River, Nigeria.

The low levels of cadmium may be attributed to its lower concentration in water, as the accumulation of metal toxicants from the aqueous environment by the fish depends upon the availability and persistence of the contaminant in water and feed (Larsson et al., 1985).

As declared in Table (2), 94.4% of the examined wild tilapia samples showed detectable levels of lead, while all (100%) of the examined farmed tilapia samples showed detectable levels in their musculature. Lower percentages (80 and 64%, respectively) were reported by Abd El-Malek and Ammar (2013).

Comparing the obtained concentrations of lead with the permissible limit (0.3mg/kg wet basis) in fish musculature, set by the Egyptian Organization for Standardization and quality control (EOS, 2010) and by the European Community regulations (EC, 2006), it declared that most (80.6%) of the

examined wild tilapia samples had concentration exceeded the limit. Abd El-Malek and Ammar (2013) mentioned that 18% of the wild Tilapia samples had lead concentrations exceeded the limits set by the Egyptian standards (EOSQC, 2005), which was lower than findings of the current work. Lower findings were also recorded by Olusola et al. (2012) and Shaltout et al. (2015), but higher were noted by Mansour and Sidky (2002).

Following the same trend, most (90%) of the farmed Tilapia samples showed lead levels exceeded the permissible limit. Lower findings were reported by Abd El-Azeem et al. (2012) and Abd El-Malek and Ammar (2013), while higher results were found by Kaoud and El-Dahshan (2010).

All the examined samples of wild and farmed Tilapia fish showed detectable concentrations of cadmium in their musculature. Opposite results (none of the samples showed detectable level) was declared by Juniavto el al. (2017). Abd El Malek and Ammar (2013) observed lower percentages (32 and 38%, respectively).

Of the examined wild Tilapia samples, 83.3% were found to have cadmium concentrations exceeded the permissible limit (0.05 mg/kg wet basis), set by EOS (2010) and EC (2006). This was higher than findings of Mansour and Sidky (2002) (0.0%), Olusola et al. (2012) (0.0%), Abd El Malek and Ammar (2013) (26%), and Shaltout et al. (2015) (40%), but lower than the findings of Seddek et al. (1996) (100%) and Bolawa and Gbenle (2010) (100%).

Likewise, most (80%) of the farmed Tilapia samples was found to have concentrations of cadmium exceeded the limit. Mansour and Sidky (2002), and Abd El-Malek and Ammar (2013) found lower percentages "0.0 and 6.0%, respectively".

The percentage of samples exceeded the permissible limit for lead was higher in farmed (90%) than in wild (80.6%) Tilapia fish. However, it was lower in farmed (80%) than in wild (83.3%) fish in the case of cadmium. This may be attributed to the samples; and suggests consistent cadmium contamination in the wild environment.

Fish may absorb dissolved elements and trace metals from their feeding diets and surrounding water leading to their accumulation in various tissues in significant amounts (McCarthy and Shugart, 1990). The higher levels of lead and cadmium in the fish from the private farms (farmed) noticed from the current study may be attributed to the high concentrations of these metals, which sometimes exceeded the permissible levels, in the potential water used in aquaculture in Egypt. Such high concentrations were the result of the dense agricultural activities, massive usage of fertilizers and pesticides beside heavily contamination by domestic sewage and other wastes (Mansour and Sidky, 2002 and Authman et al., 2012). As well, in intensive culture systems, fish are usually fed on artificial diets that found to contain high concentrations of lead and cadmium (Mansour and Sidky, 2002), so the farmed fish, unlike those of the river, are being exposed to further (and direct) contaminating sources.

Fish is a healthy food because of its nutritional benefits which in part related to its high content of omega-3 fatty acids (Vieira et al., 2011). However, the presence of pollutants in fish tissues can counteract the positive effects of the omega-3 fatty acids and hinder its beneficial effects on heart disease risk (FAO, 1983; Domingo et al., 2007). As consumption of fish is a possible source of metal accumulation in humans, it is of great interest to estimate the daily intakes of heavy metals through fish consumption.

For the current study, and assuming a fish consumption rate of 20.8kg/person/year, i.e. 56.99g/person/day (FAO, 2011), the estimated (average) daily intake "EDI" of through consumption of wild and farmed Tilapia flesh will be 85.88 and 124.12ug/day, while that of cadmium will be 21.6 and 24.9 ug/day, respectively (Table 3). Such values of EDI were set below the maximum safe amount of lead (214.2 µg per day) and cadmium (60.0 µg per day) for an adult weighing 60kg (PTDI60) based on the data of FAO/WHO (2004) and Türkmen et al. (2009).

The dose of a toxic metal that one obtains from fish depends not only on the concentration of specific metal in fish, but also on the quantity of fish consumed (Elnabris et al., 2013). From the obtained concentrations of lead and cadmium in the current study, an Egyptian with an average body weight of 60kg will be at risk of the deleterious effects of lead if his/her daily consumption rate exceeded 142 g (4.26 kg/month) of wild Tilapia or 98 g (2.94 kg/month) of farmed Tilapia flesh. The deleterious effects of cadmium may occur if the daily consumption rate exceeded 158 g (4.74kg/month) of wild Tilapia or 137 g (4.11kg/month) of farmed Tilapia flesh.

Considering the economic conditions of the majority of Egyptians, and the relatively low price of such fish (Tilapia) in comparison to red meat, as well those who totally depends on fish as a source of animal protein (disappointed that red meat is commonly adulterated by butchers), the consumption rate of such fish may come close to or may exceed the allowed quantities to be consumed, especially those of farmed fish (98g/day) in case of lead. This may pose a potential health risk to many Egyptians (lead and/or cadmium toxicity is very likely) due to consumption of such Tilapia fish sold in the local markets of Assiut city.

CONCLUSION

The results of this survey indicated that Tilapia fish, either wild or farmed, from markets of Assiut city have high concentrations of lead and cadmium in their musculature, with the concentrations were higher in farmed Tilapia. Lead and cadmium concentrations in the majority of samples exceeded the limits proposed for fish by the Egyptian standards and European community guidelines. Within the same fish item, either wild or farmed, lead concentrations were higher than those of cadmium.

Regarding the daily intake and safety aspects, the examined fish especially farmed ones could pose a potential health risk to the consumers especially for children where, other sources of protein are hereby recommended.

Finally, it could be inferred from the results of this study that for consumers purchasing the products in large quantities on a regularly basis, a public health hazard will definitely exist especially from farmed Tilapia fish. On the other side, no hazard might exist through the consumption of average amounts of such fishes and if the consumer visits the sites once in a while.

Warning against eating such fish should be announced. It is recommended that, beside proper treatment and disposal of sewage water and sludge, government should enforce the laws that ensure standard waste treatment by industrial plants before it is being discharged into water bodies. As well, public should be educated about food pollution, their sources, health hazards and control. Besides, speciation studies and continuous monitoring of heavy metals in musculature of commercial fish should be performed acting as important warning signals for human health.

COMPETING INTERESTS

We, the authors, declare that no competing interests exist.

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