Potential Hazard Levels of Lead and Cadmium in Muscles of the River Nile Catfish (*Clarias gariepinus*) Available in Markets in Assiut City, Egypt

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ABSTRACT

The objective of current study was to determine the levels of lead (Pb) and cadmium (Cd) in the muscular tissue of the River Nile catfish "*Clarias gariepinus"*, collected randomly from fish-sellers in Assiut city, Egypt. A total of 50 samples were purchased, inspected and prepared for metal analysis. Inductively Coupled Plasma Emission Spectrometer was used for quantitative determination of lead and cadmium in the samples. The obtained concentrations for Pb ranged from 0.02 to 4.0 with a mean value of 1.29±0.17 mg Kg^{-1}, while that of cadmium ranged from 0.03 to 1.05 with a mean value of 0.19±0.04 mg Kg^{-1}. Most of the samples "66% and 76%" had residues of lead and cadmium exceeded the permissible limit (0.3 and 0.03 mg Kg^{-1}) set for fish by Egyptian Organization for Standardization and Quality, respectively. In conclusion, the flesh of *Clarias gariepinus* fish sold in markets of Assiut city, constitute a potential public health hazard considering lead toxicity and to a less degree for cadmium.

Key words: Heavy metals, lead, cadmium, catfish, Clarias gariepinus.

1. INTRODUCTION

Fish is a vital source of food for hundreds of millions of people worldwide. It accounted for about 16% of the global population's intake of animal protein (FAO, 2010). It is a healthy food occupies one of the foremost places among the food products of animal origin because of its nutritional benefits attributed to its content of high biological valuable proteins, desirable lipids, valuable mineral compounds and vitamins (Darwish et al., 2003 and Vieira et al., 2011).

Despite its nutritional value, fish is a commodity of potential health concern because of its ability to accumulate large amounts of toxic contaminants from its living environment. One group of contaminants accumulated by fish is heavy metals (Suhaimi et al. 2006).

Heavy metals are high density natural components of the Earth's crust being indeed an intrinsic natural constituent of our environment, used widely in the artifacts of everyday life. They are produced from a variety of natural (volcanic activities and erosion) and anthropogenic (industrial wastes) sources being introduced into the environment via a wide range of pathways, including air, water, and soil (Jarup, 2003). Increase in population, urbanization and agriculture practices have raised the natural concentrations causing serious environmental problems. As well, the raised industrial and mechanical activities have further aggravated the situation (Gupta et al, 2009).

The environmental pollution by heavy metals is currently a major concern worldwide in both developed and developing countries because of their toxicity even at low concentrations, persistence in nature, bioaccumulation, and biomagnifications in the food chain (Karadede-Akin and Ünlü, 2007 and Dimari et al, 2008). Lead and cadmium are among the main toxic metals that accumulate in the aquatic food chains including fish and have a cumulative public health hazard effect (Cunningham and Saigo, 1997).

Lead is applied in the manufacturing, construction and chemical industries. It is used in batteries, alloys, pigments, cable sheathing, ammunition and as petrol additives (Gavaghan, 2002). Exposure to lead can occur via drinking water, food, air, soil and dust. Lead is recognized as the number one environmental poison amongst the toxic heavy metals all over the world. It accumulates in the body causing serious health hazards to humans, especially to young children. The classic symptoms of lead poisoning are colic and abdominal pain, anemia and encephalopathy. As well, it causes renal tubular dysfunction, liver damage and is considered as one of immunosuppressive agents in human. Over exposure to lead causes damage to foetal nervous system, increasing the risk of premature birth or low birth weight. Circulatory disorder, madness and death are some other effects associated with consumption of foods containing high lead level (Cunningham and Saigo, 1997).

Cadmium derives its toxicological properties from its chemical similarity to zinc, an essential micronutrient. It is produced as an inevitable by-product of zinc refining (Patricia and Boma, 2013). It is also present as an impurity in several products, including phosphate fertilizers, detergents and refined petroleum. Once absorbed by an organism, cadmium can be there for a long time. In the general non-smoking population, the major exposure is through food via the addition of cadmium to agricultural soil/rivers from effluents or fertilizer application (WHO, 1985). Cadmium is classified as a probable human carcinogen. Chronic exposure to cadmium is associated with a wide range of diseases, including heart diseases, anemia, skeletal weakening, poor reproductive capacity, depressed immune system response and liver diseases. Cadmium had a significant role in the incidence of chronic renal failure (Codex Alimentarius, 2001).

Aquatic environment is one of the receiving ends for such pollutants which are then accumulated in fishes and finally biomagnified in man causing serious health problems.

River Nile is the principal freshwater resource for Egypt. It passes through agricultural and industrial fields, where most human activities are around the Nile, subjecting it to contamination with different pollutants including heavy metals such as lead and cadmium. Agriculture through impurities in fertilizers, pesticides and sewage sludge which drain finally into the River Nile; constitutes one of the very important non-point sources of metals pollutants. Other anthropogenic activities including industrial practices and discharge of massive amount of wastewater into the River were further deteriorating the water quality (Malhat, 2011)

Fish are often used as indicators of heavy metals pollution in the aquatic ecosystem as they have the ability to bioaccumulate such pollutants from their surroundings (Abd El Azeem et al., 2012). *Clarias gariepinus* (Burchell, 1822), the principal clarid catfish in Africa, is an abundant and widely distributed fish in the River Nile and its tributaries (Ibrahem, 2012). It is ecologically and commercially appreciated because of its resistance to diseases, ability to tolerate a wide range of environmental parameters and its relative fast growth rate (Goos and Richter, 1996). *Clarias. gariepinus*, referred to as mudfish, is a benthopelagic, omnivorous feeder (Teugels, 1986). It is of great commercial value and is a popular and tasty consumed fish in Africa and Egypt **(**Ibrahim and Omar, 2013). However it has been shown to adapt to polluted aquatic environment (Akwiri et al., 2016).

For that, heavy metal residues in fish flesh and its hazard effects on the health of people are a matter of great concern to food hygienists. Several studies have been carried out in fish pollution by heavy metals in Egypt (Mansour and Sidky, 2002; Kaoud and El-Dahshan, 2010; Malhat, 2011; Authman et al., 2012 ; Abd El-Malek and Ammar, 2013; Hamed et al., 2013; El-Shafei, 2015; Emara et al., 2015 and Ibrahim et al., 2016). Yet, few studies were about *Clarias gariepinus* (Osman and Kloas, 2010; Habib and Samah, 2013; Ibrahim et al., 2013; Bayomy et al., 2015 and Shaltout et al., 2015).

For that, the goal of this study was to determine the concentrations of two of highly toxic heavy metals namely lead and cadmium in the muscular tissues of Nile fresh water fish *Clarias gariepinus* in Assiut city, Egypt. The obtained concentrations were then compared against the recommended maximum levels in fish set by the Egyptian Organization for Standardization and Quality (EOS, 2010). In addition, the quality of the fish for human consumption was assessed.

2. MATERIAL AND METHODS

2.1 Study area

Assiut city is located in Assiut Governorate, Egypt, on latitude 27º 10′ 58″ N and longitude 31º 10′ 58″ E, and 56 meters above sea level with a population of 745,544 (Figure 1).

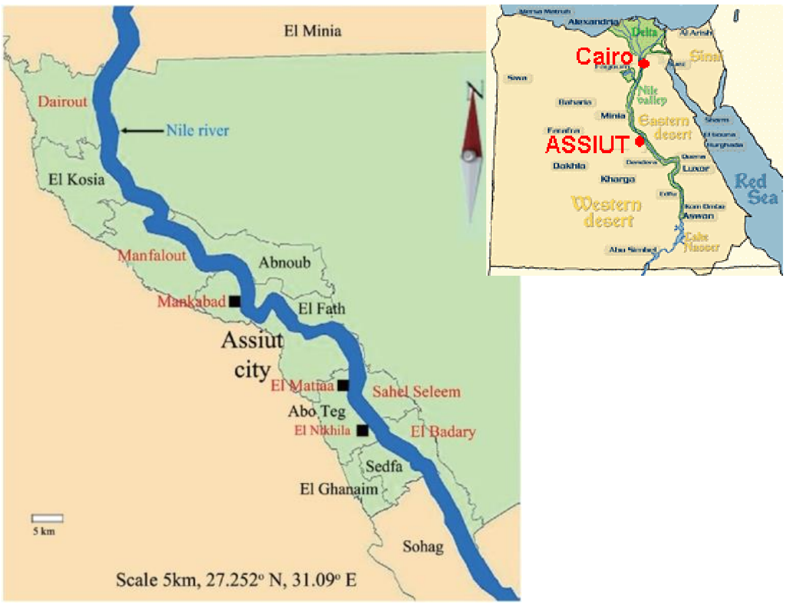

Figure 1. Map shows study area.

2.2. Collection of samples

Fifty samples of River Nile catfish (*Clarias gariepinus*) were randomly purchased from fish-sellers in markets of Assiut city, Egypt. Samples were immediately transported to the Laboratory of Meat Hygiene, Faculty of Veterinary Medicine, Assiut University, being stored at 4°C till being soon prepared with a minimum of delay. The type of fish selected for research was based on its marked acceptance to be consumed by local people (Figure 2 a and b).

Figure 2a. Picture of the studied River Nile catfish (*Clarias gariepinus*).

Figure 2b. Picture of the studied River Nile catfish (*Clarias gariepinus*) "Head removed"

2.3. Preparation of samples

In the laboratory, samples were washed off to remove external dirties and slime and before dissection, each fish specimen was sensory assessed (inspected for any external abnormalities, skin erosions or scratches, ragged or torn fins and for the signs of freshness) according to FAO (1995). The head and fins were then removed, the fish gutted, filleted and the muscular tissues were collected, cut and homogenized thoroughly and being kept frozen at -20°C until time of analysis.

2.4. Digestion of samples

The procedure entitled by Finerty et al. (1990) was used for digestion of samples with slight modification. Briefly, of the prepared sample 1 g was accurately weighted into a previously washed (using deionized water) and dried capped glassware, and then 5 ml of analytical grade conc. nitric acid were added. The samples were subjected to an overnight cold digestion in the acid, followed by heating at 70°C on hot plate for about 6hrs (all vapors "NO_2" ceased and the sample became clear). After digestion the samples were allowed to cool to room temperature, and then diluted with 10 ml deionized water. The diluted samples were filtered and made up to 50 ml volume with de-ionized water. Acid blank was prepared in the same manner using deionized water instead of the sample.

2.5. Quantitative determination of lead and cadmium

Inductively Coupled Plasma Emission Spectrometer, iCAP 6200 (Thermo Scientific, USA); [Central laboratory for chemical analysis, Faculty of Agriculture, Assiut University, Assiut, Egypt], was used for the quantitative determination of lead and cadmium concentrations in the digested catfish samples. Each sample was measured as triplicate. The apparatus was adjusted to specific wavelength corresponding to each of the metals to be measured (220.353 nm for lead and 214.438 nm for cadmium). The minimum detection limit for lead was 1.06 µg/L while, for cadmium was 0.07 µg/L. Results were calculated automatically as the necessary sample details were computed in the software. Concentrations were calculated as mg/kg on wet weight basis.

2.6. Health-risk assessment of fish consumption

The average per capita consumption of fish in Egypt is 20.8 kg/year (FAO, 2011), i.e 56.99 g/person/day. Multiplying this value by the average concentration of each metal in analyzed fish, the average daily intake of the metal per person through consumption of such fish can be estimated. Based on the data of FAO/WHO (2004) and Türkmen et al. (2009) and assuming average body weight of 60kg for Egyptians, the permissible tolerable daily intake "$PTDI_{60}$" for each metal (µg/person/day) and the amount required to be consumed of the fish to attain the $PTDI_{60}$ was calculated.

2.7 Statistics

The obtained concentrations of lead and cadmium were analyzed statistically using Microsoft Excel 2010 version to calculate the mean and standard deviation. The data were shown as means± standard errors (S.E.).

3. RESULTS

Table1. Statistical values of lead and cadmium concentrations (mg/kg wet weight) in the examined Catfish (*Clarias gariepinus*) samples

	Lead*	Cadmium**
Min	0.02	0.03
Max	4.00	1.05
Mean ± SE	1.29 ± 0.17	0.19 ± 0.04

*n= 45 **n= 50

Table2. Acceptability (%) of the examined Catfish (*Clarias gariepinus*) samples based on their lead or cadmium content

	Lead	Cadmium
Samples tested	50	50
Samples positive (%)	45 (90%)	50 (100%)
Samples (%) within the permissible limits	17 (34%)	12 (24%)
Samples (%) exceed the permissible limits	33 (66%)	38 (76%)
Permissible limits	0.3 mg/kg	0.05 mg/kg

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

Table3. The estimated daily intake (EDI) of lead/cadmium (µg/day/person) through consumption of the River Nile catfish (*Clarias gariepinus*) by adult people (assuming 60 kg person) in Egypt

	EDI	PTDI[a]	$PTDI^{b}_{60}$
Lead	73.52 (166.05)[c]	3.57	214.2
Cadmium	10.82 (315.79)	1	60.0

[a] PTDI: provisional permissible tolerable daily intake (µg/kg body weight/day) (FAO/WHO, 2004)
[b] $PTDI_{60}$: permissible tolerable daily intake for 60 kg person (µg/day)=PTDI x 60.
[c] Values between brackets are the daily intake (in grams) of *Clarias gariepinus* fish that should be consumed in order to attain the permissible tolerable daily intake of metal for 60 kg person (=$PTDI_{60}$ (µg/day) /metal concentration "the mean value" (µg/g) according to FAO/WHO (2004).

The Lead concentrations (mg/kg wet basis) in the flesh of examined *Clarias gariepinus* samples as declared in Table 1 ranged from 0.02 to 4.0 with a mean value of 1.29±0.17mg/kg, while that of cadmium ranged from 0.03 to 1.05 with a mean value of 0.19±0.04mg/kg. The concentrations of lead were generally higher than that of cadmium.

Of the examined samples, 5 (10%) showed undetectable level of lead and the other 45 (90%) samples showed concentrations above the detection limit. All of the measured samples had detectable levels of cadmium. Lead concentration in 33 (66%) of the samples were above the permissible limit (0.3mg/kg) of the Egyptian Standards, while only 17 (34%) samples had concentrations below the limits. As for cadmium concentrations, 38 (76%) of the samples exceeded the limit (0.05 mg/kg), and only 12 (24%) samples were below the limit (Table 2).

The average daily intake of lead and cadmium through consumption of such *Clarias gariepinus* flesh was estimated to be 73.52 and 10.82 µg/ day/person as presented in Table 3. The provisional permissible tolerable daily intake "PTDI" (µg/kg body weight/day) was 3.57 and 1 for lead and cadmium, respectively. For a 60 kg body weight person the provisional permissible tolerable daily intake "$PTDI_{60}$" (µg/person/day) were 142.2 and 60.0 for lead and cadmium, respectively. The quantity of *Clarias gariepinus* flesh required to be consumed to attain the $PTDI_{60}$ was estimated to be about 166g in case of lead and 316g in case of cadmium.

4. DISCUSSION

Fish constitutes an important part of human diet so its quality and safety aspects are of particular interest. As they pose a serious threat for human health and because diet is the main route of human exposure (Castro-Gonzeza and Méndez-Armentab, 2008) heavy metals pollution in fish is a matter of concern worldwide. The major interest was in the edible commercial species (Kaoud and El-Dahshan, 2010; Malhat, 2011; Elnabris et al., 2013; Olusoula et al., 2012; Tabinda et al., 2013; Basyigit and Tekin-Ozan, 2013; Jinadasa and Edirisinghe, 2013; Raeisi et al., 2014; Bayomy et al., 2015; Bensalem and Ayadi, 2016; Sim et al., 2016 and Juniato et al., 2017).

The present work was aimed to evaluate the lead and cadmium residues content in the muscular tissue of the River Nile catfish "*Clarias gariepinus*", in Assiut city, Egypt.

Sensory evaluation declared that all samples were accepted. Of the samples 42 (94%) were of excellent quality, 6 (12%) were of good quality and only 2 (4%) were of fair quality (data not shown).

In the recent times, the River Nile in Egypt has been subjected to a lot of anthropogenic pollutants, including heavy metals. This is directly reflected on the inhabitant biota including fish, which has the ability to bio-accumulate large concentrations of such pollutant (e.g. lead and cadmium) in their musculature, that pose serious threat to human health (Kaoud and El-Dhshan, 2010; Ibrahim and Omar, 2013; Bayomy et al., 2015 and Shaltout et al., 2015).

Lead and cadmium are taken up passively from the water and deposited in the organisms and hence the organisms may contain more quantity of these metals than water (Markert et al., 1997). This increases the actual dose of metal to which the local population is exposed (Chakraborty et al., 2003 and Chandrasekhar et al., 2003).

Generally, lead and cadmium concentrations in the tissue of freshwater fish "*Clarias gariepinus"* were observed to vary considerably among different studies (show Table 4).

For the current work, the lead and cadmium concentrations (mg/kg wet basis) in the flesh of examined *Clarias gariepinus* samples were declared in Table1. The obtained mean values for lead and cadmium residues were 1.29±0.17 and 0.19±0.04 mg/kg, respectively. Nearly similar values were found in the muscles of *Clarias gariepinus* in Nigeria by Eneji et al. (2011) for lead and cadmium; and by Edward et al. (2013) and Ijeoma et al. (2015) for cadmium only.

On the other hand, the finding of this study was higher when compared with that of Bayomi et al. (2015) for lead and cadmium, and of Habib and Samah (2013) for cadmium only. Aderinola et al. (2012), Olusola et al. (2012), Bob-Manuel et al. (2015), Orosun et al. (2016) and Nhiwatiwa et al. (2017) also, recorded lower concentrations. However, higher levels of lead and cadmium was observed by Ibrahim et al., (2013) and Ibrahim and Omar (2013); of lead only by Osman and Kloas (2010), Habib and Samah (2013) and Titilayo and Olufemi (2014); and of cadmium only by Tiimub and Afua (2013) and Omozokpia et al. (2015). Variable concentrations for lead and/or cadmium were detected by Elijah et al. (2016), Nzeve et al. (2014) and Udiba et al. (2014).

In the River, fish are often at the top of the food chain and have the tendency to concentrate heavy metals from water. The variation in lead and cadmium concentrations among different studies may possibly due to differences in metal concentrations of water and sediments from which fish were caught, ecological needs, metabolism and feeding patterns of fish, and also the season in which studies were carried out (Mansour and Sidky, 2002).

Generally lower concentrations of cadmium were recorded than that of lead in the examined samples of the current study. This was in agreement with many authors such as Osman and Kloas (2010), Habib and Samah (2013), Ibrahim et al., (2013), Titilayo and Olufemi (2014) and Bob-

Manuel et al. (2015). However, some other authors such as Tiimub and Afua (2013), Omozokpia et al. (2015) and Orosun et al. (2016) observed higher concentrations of cadmium than that of lead in the flesh of catfish in some African countries. Aderinola et al. (2012), Shaltout et al. (2015) and Nhiwatiwa et al. (2017) recorded nearly similar concentrations of lead and cadmium in the flesh of *Clarias gariepinus*. The lower concentrations of cadmium may be attributed to that it is bioaccumulated poorly in fish (Ibrahim, 2007 and Ololade et al., 2007).

Of the 50 examined samples, only 5 (10%) showed undetectable level of lead, which disagree with the findings of Tiimub and Afua (2013) and Omozokpia et al. (2015) who found lead residues below the detection limit (undetectable level) in all samples.

On the other side, detectable levels of cadmium were found in all samples of the current study. This totally disagrees with findings of Titilayo and Olufemi (2014) that cadmium level in all samples was below the detection limit.

Lead and cadmium are a threat to public health, even at low concentrations. Chelating of foods for such metals is important from a toxicological point of view (Jinadasa and Edirisinghe, 2013). Maximum levels of lead and cadmium for fish have been enforced by the Egyptian government.

Of the examined *Clarias gariepinus* samples, 66% were unaccepted based on their lead content, as compared with the permissible limit (0.3 mg/kg) set for fish by the Egyptian Organization for Standardization (EOS, 2010). On the other hand and based on their cadmium content, 76% of the samples were unaccepted when comparing them with the maximum safe limit (0.05mg/kg) stipulated by the Egyptian Organization for Standardization (EOS, 2010).

lead and cadmium are toxic elements which have no significant biological functions. Their serious health hazards effects to humans may not manifest immediately but show up after several years (Olusola et al., 2012). Chronic lead exposure is known to cause musculo-skeletal, renal, ocular, neurological, immunological, reproductive and developmental disorders (ATSDR, 1999). On the other hand, chronic cadmium toxicity cause impaired kidney function, poor reproductive capacity, hypertension, tumors and hepatic dysfunction (Mansour and Sidky, 2002).

As consumption of fish*" Clarias gariepinus* " is a possible source of metal accumulation in humans, the estimation of the daily intakes (EDI) of lead and cadmium through such fish consumption will be of great interest (Table 3).

Comparing the EDI of the each metal with the respective permissible tolerable daily intake for a 60 kg person "$PTDI_{60}$" (µg/day), declared that the values of estimated daily intakes (EDI) of cadmium and lead from fish flesh in the current study set well below their corresponding permissible tolerable daily intake for 60 kg person ($PTDI_{60}$) values. As the dose of a toxic metal that one obtains from fish however, not only depends on the concentration of specific metal in fish, but also on the quantity of fish consumed. For that the daily amount (in grams) of fish flesh that should be consumed in order to attain the permissible tolerable daily intake of metal for 60 kg person "$PTDI_{60}$" were also calculated (Table 3).

Accordingly, Egyptian person will be at risk of the deleterious effects of a metal only if his/her daily intake exceeded their respective $PTDI_{60}$, i.e when his daily consumption of such fish exceeded 166g in case of lead, and 316g in case of cadmium. Considering normal consuming habits in Egypt, it can be stated that the calculated daily intake of fish to be consumed to cause health hazard is generally somewhat far from the actual daily amount consumed by most Egyptian people in case of cadmium, but to a less degree in case of lead. Therefore, care must be taken especially for those regularly consume large quantities of fish.

Continuous monitoring for such metals concentration in muscular tissue of commercial fish in markets of Assiut city to ensure their suitability for human consumption is recommended.

Table4. Lead and cadmium concentrations (mg/kg wet basis) in Catfish (*Clarias gariepinus*) muscles in comparison to some other studies

Location/Country	Fish species	Lead	Cadmium	Ref.
Assiut, Egypt	*Clarias gariepinus*	0.02 – 4.0 (1.29)	0.03 – 1.05 (0.19)	Current study
Menofia, Egypt	*Clarias gariepinus*	0.03 – 0.35 (0.14)	0.02 – 0.3 (0.14)	Shaltout et al., 2015
Behira, Egypt	*Clarias gariepinus*	0.0130 – 0.0199 (0.0167)	0.00019 – 0.00029 (0.00026)	Bayomy et al., 2015
El-Kanater El-Khayria city, Egypt	*Clarias gariepinus*	7.25 – 45.45	1.18 – 16.09	Ibrahim et al.,, 2013
Assiut, Egypt	*Clarias gariepinus*	0.432 – 2.54	0.344 – 1.41	Ibrahim and Omar, 2013
Damietta and Dakahlia, Egypt	Catfish	1.22 – 11.90	0.07 – 0.17	Habib and Samah, 2013
Aswan, Kena, Assiut, Beni-Suef, Damietta and Rosetta, Egypt	*Clarias gariepinus*	5.895 – 14.51	0.20 – 0.78	Osman and Kloas, 2010
Zimbabwe	*Clarias gariepinus*	Trace – 0.08	0.03 – 0.06	Nhiwatiwa et al., 2017
Northeastern Nigeria	Catfish	0.0085 – 0.0156	0.0258 – 0.0275	Orosun et al., 2016
Nigeria	*Clarias gariepinus*	0.062	0.001	Bob-Manuel et al., 2015
Kenya	*Clarias gariepinus*	0.28 – 1.92 (0.921)	NM*	Nzeve et al., 2014
South Western Nigeria	*Clarias gariepinus*	3.41 - 53.01	BDL** (below 0.004)	Titilayo and Olufemi, 2014
Ghana	Catfish	BDL**	0.808	Tiimub and Afua, 2013
Ekiti State, Nigeria	*Clarias gariepinus*	0.5	0.1	Edward et al., 2013
North Central Nigeria	*Clarias gariepinus*	0.801	0.269	Eneji et al., 2011
Lagos Nigeria	*Clarias gariepinus*	0.145	NM*	Doherty et al., 2010
Niger State, Nigeria	*Clarias gariepinus*	BDL**	0.17 – 2.83	Omozokpia et al., 2015
Delta State, Nigeria	*Clarias gariepinus*	ND#	0.219	Ijeoma et al., 2015
Lagos Nigeria	*Clarias gariepinus*	0.006	0.007	Aderinola et al., 2012
Bayelsa State, Nigeria	*Clarias gariepinus*	0.36 – 2.33 (1.16)	0.04 – 1.44 (0.54)	Elijah et al., 2016
Zaria, Nigeria	*Clarias gariepinus*	NM*	0.06 – 0.50 (0.32)	Udiba et al., 2014
Oyo State, Nigeria	*Clarias gariepinus*	0.029	0.014	Olusola et al., 2012
Permissible limit (ppm wet weight)				
EOS		0.3	0.05	EOS (2010)
WHO		0.3	0.03	WHO (2008)
EC		0.3	0.05	EC (2006)
FAO/WHO		0.5	0.5	FAO/WHO (1989)
Saudi Arabia		2.0	0.5	SASO (1997)

*NM: Not Measured, **BDL: Below Detection Limit, #ND: Not Detected

5. CONCLUSION

The results of present study declared that the River Nile catfish "*Clarias gariepinus*" available in Assiut city contained detectable residue levels of lead and cadmium in their muscular tissue. Such residue levels exceeded the permissible limit set by the Egyptian Organization for Standardization and Quality in most of the examined samples which pose public health hazard from consumption of such fish. The percentage of samples exceeded the permissible limit was higher in case of cadmium than that in case of lead. However, the concentrations of cadmium in the flesh were generally lower than that of lead. As well, the quantity of fish flesh needed to be consumed to cause health hazard are much more in case of cadmium than in case of lead. In conclusion, consumption of such fish flesh on regular basis could pose public health hazard concerning lead toxicity, and to a less degree cadmium toxicity.

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