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Assessment of heavy metal concentrations in the muscles of ten commercial fish species from Lagos lagoon, Nigeria

[1]Taiwo, I. O., [2]Olopade, O. A. and [1]Adeniyi, B. T.
[1]*IFSERAR, Federal University of Agriculture, Abeokuta*
[2]*Dept. of Fisheries, University of Port-Harcourt, Port-Harcourt*
Corresponding email: iomtai@yahoo.com

Abstract

The study was undertaken to assess the concentration of five heavy metals (zinc (Zn), lead (Pb), copper (Cu), iron (Fe) and manganese (Mn)) in the muscles of Tilapia zilli, Hydrocynus fiscalis, Parapristipoma humile, Caranx hippo, Cynoglossusa caudatus, Chrysichthys nigrodigitatus, Letjanus sp, Portunus validus, Sardinella maderensis, and Sphyreana sp. from Lagos Lagoon. The concentrations of heavy metals were measured by atomic absorption spectrophotometry after digestion of the samples. There were significant differences (P<0.05) in the concentration of heavy metals in fish muscles. There was no specific pattern in the levels of heavy metals among the fish species. P. validus had the highest concentration of Zinc in the fish sampled with a mean value of 14.45mg/g while T. zilli had the lowest concentrations of Zn and Mn. Sphyreana sp had the highest concentrations of Lead and Copper and Manganese in the muscles. Iron concentration was highest in the muscle of S. maderensis. In this study, the overall average concentrations of metals in fish muscles were in the order of Zn> Fe > Pb> Cu> Mn. The values of Zn and Cu were within or lower than the acceptable limits by FAO/WHO (Food and Agriculture Organization of the United Nations/World Health Organization) for concentrations of heavy metals in fish while levels of Pb, Fe and Mn in the muscles of the various fishes were beyond the safe limit in foods. Close monitoring of heavy metal pollution of Lagos Lagoon is strongly advocated, in view of possible risks to the health of consumers.

Keywords: Lagos Lagoon, pollution, heavy metal, fish muscle, shell fish

Introduction

The potential for heavy metal contamination to negatively affect human health has resulted in many studies into heavy metal levels in fish and shellfish species, particularly in regions heavily impacted by anthropogenic inputs (Ratkowsky *et al*., 1975; Walker, 1982; Fabris *et al*., 1992). Levels of contaminants in fish are of interest not only because of the potential effects on the fish themselves, but also because of the effects on organisms that consume them, such as higher order predators and humans (Hylland *et al*., 2006). Guidelines on the maximum permitted levels of metals in seafood have been introduced in many parts of the world for the safe consumption of fish species (Adams and McMichael, 1999). Studies and monitoring programs examining heavy metal levels in fish are becoming more and more important, especially in less developed parts of the world where fish provides the major source of protein (Toth and Brown, 1997; Burger *et al*., 1999a; Burger *et al*., 1999b). Even in more affluent areas, fish are being consumed increasingly as an essential health food (Gislason *et al*., 2000; Carvalho *et al*., 2005). Fish is promoted as a healthy and nutritious component of a balanced diet and an important source of proteins and lipids, including long chain polyunsaturated fatty acids, and also of lipo-soluble vitamins. Studies indicated that people who included fish in their diets have lower risk of coronary heart disease, hypertension, and cancer. However, in contrast fish can be a source of contamination and in some circumstances can contain amounts of heavy metals which are highly toxic (Egeland and Middaugh, 1997; Carvalho *et al*., 2005).

According to Carvalho *et al*. (2005), the concentration of heavy metals in fish is influenced by several factors, most importantly biological differences (e.g. species, size, age, gender, sexual maturity, diet) and environmental differences (e.g. water chemistry, salinity, temperature, and levels of contamination) Numerous studies (Blevins and Pancorbo, 1986; Calta and Canpolat, 2006) have shown that heavy metal accumulation in fish is strongly influenced by environmental concentrations such as the levels in the water and sediments. However, metal accumulation has been found to vary markedly between species in the same area, as a result of differences in feeding habits (Calta and Canpolat, 2006) and position in the food chain (Asuquo *et al*., 2004).

Heavy metal contamination in sediment could affect the water quality and bioaccumulation of metals in aquatic organisms, resulting in potential long-term implication on human health and ecosystem. In most circumstances, the major part of the anthropogenic metal load in the sea and seabed sediments has a terrestrial source, from mining and industrial development along major rivers and estuaries (Qu *et al.,* 2012). The spatial distribution of heavy metals in marine sediments is of major importance in determining the pollution history of aquatic systems, and is basic information for identifying the possible sources of contamination and to delineate the areas where its concentration exceeds the threshold values and the strategies of site remediation. Therefore, understanding the mechanisms of heavy metals in fish, water and sediments is crucial for the management of coastal environment (Miller *et al.,* 2008).

The pollution of the aquatic environment with heavy metals has become a worldwide problem because they have indestructible, potential toxic effects on organisms (Malik *et al.,* 2010). These heavy metals in the aquatic ecosystems are usually monitored by measuring their concentrations in water, sediments and biota (Camusso *et al.,* 1995). Studies on heavy metals in rivers, fish and sediments (Ozturk *et al*., 2008), have been a major environmental focus especially during the last decade. As a consequence, fish are often used as indicators of heavy metals contamination in the aquatic ecosystem because they occupy high trophic levels and are important food source (Agah *et al*., 2009).

Assessment of heavy metal residues in fish and its effects on the health of consumers has attracted a lot of interest and generated many research in different countries. Essential metals such as copper, zinc and iron have normal physiological regulatory functions, but with continuous consumption may bio-accumulate and reach toxic levels. Non-essential metals are usually potent toxins and their bioaccumulation in organisms lead to intoxication, decreased fertility, tissue damage and dysfunction of a variety of organs (Fernandes *et al.,* 2008).

Since fish is an important component of human diet in Nigeria, therefore information on levels of metal concentrations in the fish species of Lagos Lagoon could help monitor the environmental impact and health of populace that are dependent on the water body. This study was carried out to assess the levels of five heavy metals (zinc, lead, copper, iron and manganese) in the muscles of ten fish species harvested from Lagos Lagoon for human consumption

Materials and methods

Sample collection

Nine finfish species and one shellfish, *T. zillii* (Red belly), *H. fiscalis, P. humile, C. hippo, C. acaudatus* (sole), *Letjanus* sp. *(Red Snapper), C. nigrodigitatus* (West African catfish), *Sphyraena* sp. (Barracuda), *S. maderensis* (Herring) and *P. validus* (Crab) were fished from Lagos Lagoon and transported to Makoko landing site, Lagos State, Nigeria where they are sold. The organisms were packed in ice and transported to the University laboratory for analysis.

Heavy metal analysis in fish muscle

The fish muscles analysed were collected in triplicates from different parts of the fish body. The fish samples were oven dried at 105°C for about 12hours. The sediment samples were air dried. Dried fish samples were homogenized using a ceramic mortar and pestle. All glass wares used were washed and rinsed severally with distilled water; then washed in 10% HCl before use to avoid contamination.

The fish and sediment samples were digested using the wet digestion procedure according to Asegbeloyin *et al*. (2010). Muscle tissues were taken from various parts of each fish and homogenized. Four grams of the homogenized muscles (without skin) were taken from each specimen and placed in 300 ml Kjldahl digestion tubes. 10g of each of the dried samples were digested in 60 ml of freshly prepared 1:1 HNO_3/ H_2O_2 solution at 160°C on a hot plate for about one hour until the contents were reduced to 5ml each. The residues were then filtered separately with Whatman filter paper (No. 42) and the filtrates transferred to a standard flask and distilled, de-ionized water was added to make 25 ml. The Atomic absorption spectrometer (AAS) (Analyst 200, Perkin Elmer) was then used to determine the concentrations of Lead, Manganese, Copper, Iron and Zinc in the fish samples.

Laboratory blanks were prepared in order to ensure that the samples and chemicals used were not contaminated. They were analysed by atomic absorption spectrophotometry before the samples and their values were subtracted to ensure that the equipment read only the exact values of heavy metals. Each set of digestion has its own acid blank and was corrected by using its blank.

Statistical analysis

Data were subjected to Analysis of Variance (ANOVA) using IBM SPSS version 20 after the logarithmic transformation was done on the data to improve normality. The data was subjected to Duncan multiple range test to assess whether the means of metal concentrations varied significantly among the ten fish species. The mean differences were separated at $P<0.05$ levels of significance.

Results

The Concentrations of Zn, Pb, Cu, Fe and Mn in the muscles of nine finfish species and one shellfish species analysed from Lagos Lagoon are shown in Table 1. The concentration of zinc was the highest. The lowest metal concentration was for manganese in the muscles of the nine finfish and one shellfish species sampled.

Table 1: Heavy metal concentration of sediment and fish species sampled from Lagos Lagoon at Makoko Fish Landing site

Fish Species	Heavy Metals				
	Zinc	Lead	Copper	Iron	Manganese
Tilapia zillii	9.31±0.08 [d]	4.82±0.02 [c]	3.07±0.03 [cd]	7.10±0.02 [c]	1.02±0.00 [f]
Hydrocynus fiscalis	9.50±0.03 [d]	4.41±0.01 [d]	3.20±0.01 [bc]	7.14±0.01 [c]	1.13±0.01 [e]
Parapristipoma humile	9.77±0.06 [c]	5.15±0.04 [b]	2.80±0.09 [e]	6.87±0.05 [d]	1.36±0.02 [b]
Caranx hippo	10.21±0.05 [b]	4.75±0.12 [c]	3.33±0.11 [b]	8.22±0.05 [a]	1.18±0.01 [d]
Cynoglossus acaudatus	12.05±0.07 [a]	5.96±0.03 [a]	4.08±0.06 [a]	7.58±0.02 [b]	1.71±0.01 [a]
Letjanus sp.	12.79±0.07 [c]	6.56±0.08 [a]	4.04±0.05 [b]	8.05±0.07 [a]	1.80±0.02 [b]
Chrysichthys nigrodigitatus	14.03±0.07 [b]	4.60±0.01 [b]	3.43±0.01 [c]	8.10±0.05 [a]	1.41±0.01 [d]
Sphyraena sp.	11.08±0.07 [d]	6.52±0.03 [a]	4.33±0.02 [a]	7.69±0.12 [b]	1.93±0.03 [a]
Sardinella maderensis	14.11±0.08 [b]	6.39±0.01 [a]	4.22±0.06 [a]	7.99±0.06 [a]	1.69±0.01 [c]
Portunus validus	14.45±0.08 [a]	6.40±0.01 [a]	3.98±0.04 [b]	7.28±0.02 [c]	1.13±0.03 [c]

*Means with different superscript along same column are significantly different ($P<0.05$)

There were slight differences among the heavy metal concentrations of the organisms sampled. None of the fish species sampled had a consistently high or low level for all the five metals analysed. *P. validus* had the highest levels of zinc; *Letjanus* sp. had the highest levels of lead and *Sphyraena* sp. had the highest levels of copper and manganese while *C. hippo* had the highest levels of iron.

The overall average concentrations of Zn, Pb, Cu, Fe, and Mn in the muscles of the nine finfish species was 11.427; 5.462; 3.61; 7.637 and 1.469 respectively while the mean concentration of Zn, Pb, Cu, Fe, and Mn in the muscles of the shellfish was 14.445; 6.399; 3.981; 7.284 and 1.134. This gave a ranking of: Zn > Fe > Pb > Cu > Mn. The metal levels in the muscles of each organism gave a similar ranking.

P. validus had a significantly higher ($P < 0.05$) mean concentration of Zn (14.45 ± 0.08) than in all other species, followed by *S. maderensis* with an average concentration of 14.11 ± 0.08. The average concentration of Zn in the fish muscles was in the order *C. nigrodigitatus*>*Letjanus* sp. >*C. acaudatus* > *Sphyraena* sp. >*C. hippo* >*P. humile*>*H. fiscalis*>*T. zilli* with values of 14.03 ± 0.07, 12.79 ± 0.07, 12.05 ± 0.07, 11.08 ± 0.07, 10.21± 0.05, 9.77 ± 0.06, 9.50 ± 0.03, 9.31 ± 0.08 respectively (Figure 1).

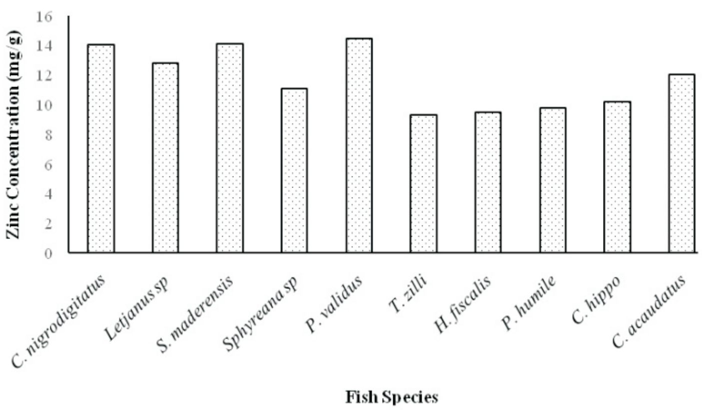

Figure 1: Concentration of Zinc in the muscles of Fish Species

Lead was detected in fish species and the concentration of Pb was not significantly (P > 0.05) different from each other in five of the organisms as shown in the Table. The mean concentration of Pb was in the following order *Letjanus* sp.> *Sphyraena* sp. >*P. validus*>*S. maderensis*>*C. acaudatus* >*P. humile* >*T. zilli*>*C. hippo* >*C. nigrodigitatus*>*H. fiscalis*with values of 6.56 ± 0.08, 6.52 ± 0.03, 6.40 ± 0.01, 6.39 ± 0.03, 5.96 ± 0.03, 5.15 ± 0.04, 4.82 ± 0.02, 4.75 ± 0.12, 4.60 ± 0.01, 4.41 ± 0.01 respectively (Figure 2).

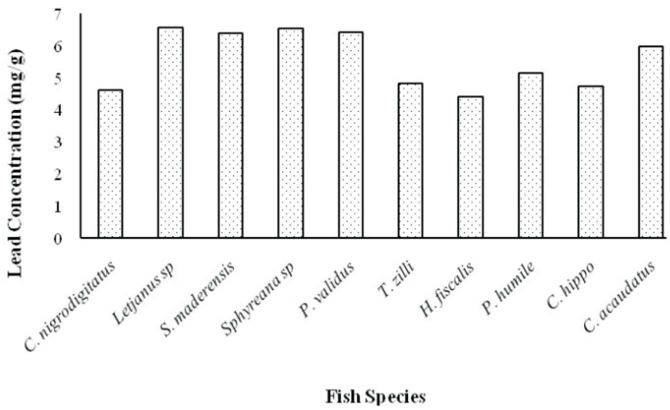

Figure 2: Concentration of Lead in the muscles of Fish Species

Cu concentration was not significantly (P > 0.05) different among three of the organisms. The mean concentration of Cu in the muscles of the organisms was *Sphyraena* sp. >*S. maderensis*>*C. acaudatus* >*Letjanus* sp >*P. validus* >*C. nigrodigitatus*>*C. hippo* >*H. fiscalis*>*T. zilli*>*P. humile* with values of 4.33 ± 0.02, 4.22 ± 0.02, 4.08 ±0.06, 4.04 ± 0.05, 3.98 ± 0.04, 3.43 ± 0.01, 3.33 ± 0.11, 3.20 ± 0.01, 3.07 ± 0.03 and 2.80 ± 09 respectively (Figure 3).

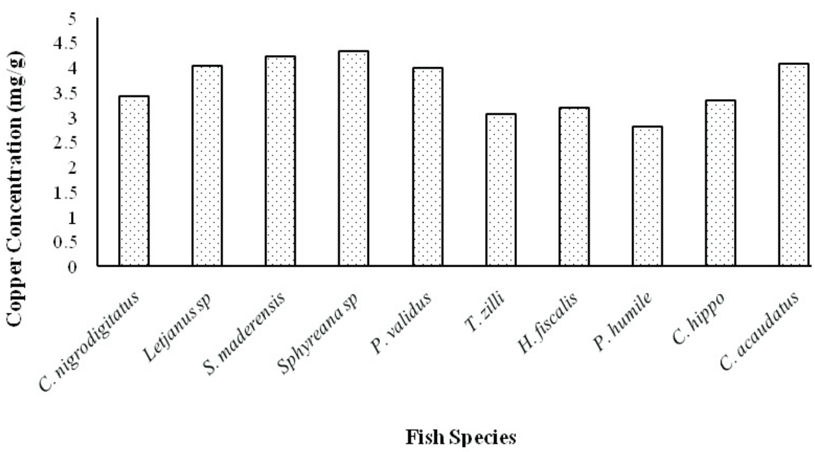

Figure 3: Concentration of Copper in the muscles of Fish Species

The mean concentration of Fe was in the following order: *C. hippo* >*C. nigrodigitatus*>*Letjanus* sp >*S. maderensis*>*Sphyraena* sp. >*C. acaudatus*

>*P. validus*>*H. fiscalis*>*T. zilli*>*P. humile* with mean values of 8.22 ± 0.05, 8.10 ± 0.05, 8.05 ±0.07, 7.99 ± 0.06, 7.69 ± 0.12, 7.58± 0.02, 7.28± 0.02, 7.14 ± 0.01, 7.10 ± 0.02 and 6.87 ± 0.05 respectively. The mean concentration of Fe in four of the organisms was not significantly (P > 0.05) different from each other (Figure 4).

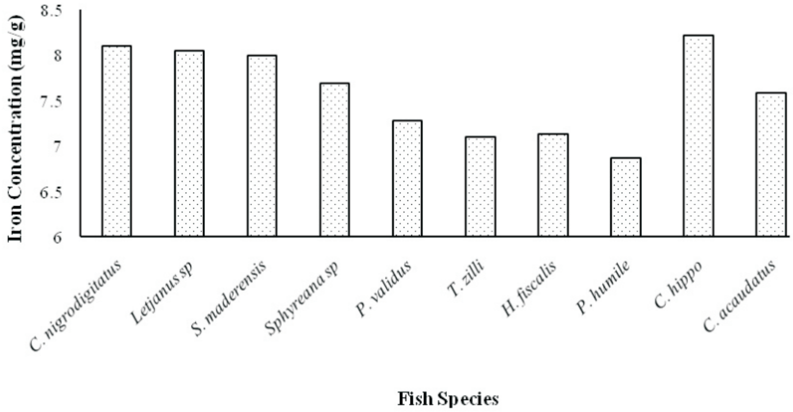

Figure 4: Concentration of Iron in the muscles of Fish Species

Mean concentration of Mn was in the following order: *Sphyraena* sp. >*Letjanus* sp >*C. acaudatus* >*S. maderensis*>*C. nigrodigitatus*>*P. humile* >*P. validus*= *H. fiscalis*>*T. zilli*>*C. hippo* with the following values: 1.93 ± 0.03, 1.80 ± 0.02, 1.71 ±0.01, 1.69± 0.01, 1.41± 0.01, 1.36 ± 0.02, 1.13 ± 0.03, 1.13 ± 0.01 and 1.02 ± 0.00 respectively (Figure 5). There were significant (P < 0.05) differences in manganese concentrations among fish species. This was similar to Epe Lagoon findings.

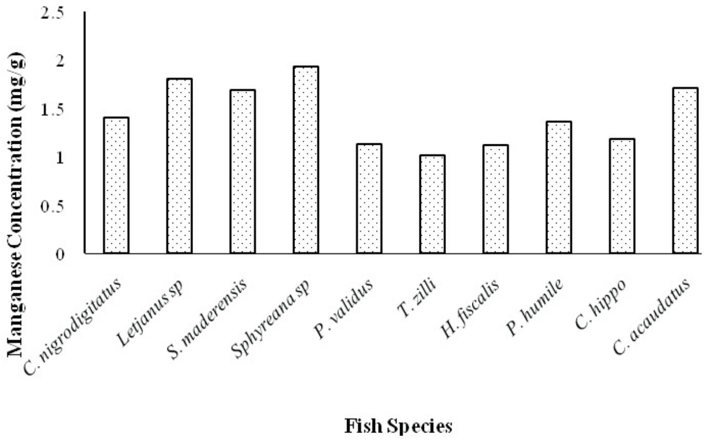

Figure 5: Concentration of Manganese in the muscles of Fish Species

Discussion

Heavy metal concentration in aquatic organisms

Fish is an important source of food and represents a major part of many natural food chains. Therefore, the levels of contamination in ?sh are of particular interest because of the potential effects of these polluting substances on ?sh themselves and on the organisms that consume them, including humans (Burger and Gochfeld, 2005).

The most important sources of heavy metal pollution are industrial emissions and effluents. Heavy metals bio-accumulate and bio-magnify in the food chain, which causes serious concern in relation to human health. Scheren and Ibe (2002) investigated heavy metal concentrations in the coastal environment in the West African region, and found concentrations below the level of detection in several localities. This was attributed to the limited industrial development, with the exception of the oil-rich states.

Heavy metal accumulation in the tissues of organisms from the Lagos lagoon has been widely studied and documented. Metal concentrations of lead, iron and manganese exceeded the maximum permissible levels for human consumption by USEPA (1994) and WHO (2004) while concentrations of Zinc and copper were within the acceptable limits (WPCL 2004). The maximum lead level permitted is 0.5 mg/kg for FAO Nauen (1983), 0.3 mg/kg for WHO (Czarnezki, 1985), 0.110 mg/kg for USEPA (1998) and0.05mg/kg for WPCL (2004). Lead contents in the muscle of the organisms were much higher than 0.68 and 0.66 mg/kg reported by Alhas *et al*. (2009) in *Barbus xanthopterus* and *Barbus rajanorum respectively in Turkey;* 1.23 mg/kg in *Tor grypus* from the same Dam Lake in Turkey (Oymak *et al*., 2009), 0.39 mg/kg in *Labeo rohita* and 1.32 mg/kg in *Ctenopharyngodon idella* from lake Bhopal, India (Malik *et al*., 2010); 0.02 mg/kg in *Elops lacerta* and 0.01mg/kg in *Psettiasse bae* from Calabar River, Nigeria (Ekpo and Ibok, 1999). Other studies carried out on in Calabar on *Sphyraena* sp. also revealed lead concentrations above acceptable limits (Edem *et al*., 2008).

Demersal species are expected to contain higher concentration of metals than pelagic species, which could be related to their greater exposure to metal enriched bottom sediments (Campbell *et al*. 1988). This could be seen in *P. validus* which is a demersal specie with the highest level of zinc. The zinc concentration is higher (14.45 mg/g) than that recorded for *P. validus* (9.93 mg/kg) from Takwa bay, Lagos Lagoon, Nigeria. Elnabris *et al*. (2013) noted that due to interspecific differences, assessment of levels of heavy metals in fish, should be compared to results of the same species caught within the same water body.

This study revealed that the organisms had different mean concentrations of heavy metals in their muscles and there was not much variation in heavy metal concentration within their muscles. Heavy metal bioaccumulation in fish is species-dependent because it moves along the food chain. Fishery organisms at the top of the food chain tend to accumulate more metals in their organs and tissues. Feeding habits and habitats where the species dwell are also linked to heavy metal accumulation in fish muscles (Al-Majed and Preston, 2000; Yilmaz, 2005). The organisms from the Lagoon contained lead, Iron and Manganese above the acceptable limits recommended for human consumption as shown in the Table 1. Zn concentrations ranged from 9.31 mg/g to 14.45 mg/g among the fish species with a mean concentration of 11.43 mg/g. This concentrations were much higher than that recorded by Hossam *et al.* (2012), from Gaza fishing harbour in the Mediterranean Sea along Gaza coast, Palestine, in which the concentrations of zinc ranged from 13.56 µg/g to 40.43 µg/g with mean concentration of 26.9 µg/g (0.0269mg/g).These levels of Zn concentration are much higher than the tolerable weekly intake (PTWI) of 7mg/kg body weight equivalent to 490mg/week for a 70kg adult (FAO/WHO, 2004). The provisional tolerable weekly intake (PTWI) for lead is 0.3mg/kg body weight (FAO/WHO, 2004). Result from this study revealed that fishes in Lagos lagoon contained lead above the FAO/WHO safe standard level for consumption. This however, was contrary to reports of Stancheva *et al.* (2013) on heavy metal and proximate composition of Black sea sprat and Goby with Black sea sprat and Goby having lead concentrations of 0.08 mg/kg w.w and 0.03 mg/kg w.w respectively which were lower than the concentration of Pb found in organisms from Lagos Lagoon.

The proposed acceptable limits of Cu concentrations in fish species as recorded by FAO/WHO (2017), EU (2001) and Turkish guidelines (TFC) is about 30 µg/g (0.03mg/g). It was observed that the concentrations of Cu found in tissues of all the fish species in the present study were above the recommended value. This finding was in agreement with previous observations by Adedeji and Okocha (2011) on Bio concentration of Heavy Metals in Prawns and Water from Epe Lagoon and Asejire River in Southwest Nigeria that Lagos Lagoon contains copper above the acceptable limit similar to Epe Lagoon.

Iron levels in *C. hippo* were the highest (8.22mg/g) while *P. humile* had the lowest concentration of 6.87mg/g. However, the maximum limit recommended by the IAEA-407 (2003) is 146mg/kg indicating that the concentrations of iron in the muscle of the fish species were far above the acceptable limits. The high level of Fe in the muscle of the fishes analysed were similar to the previous findings by Taiwo *et al.* (2016) who assessed heavy metals concentration in muscles and bones of organisms from Epe lagoon and reported Fe concentration above the maximum recommended level by WHO.

The concentrations of Mn ranged from 0.87mg/g to 1.24mg/g in the fish species from Epe Lagoon. However, the permissible limit of manganese concentrations in fish species by the Turkish Food Codes (TFC) is about 20µg/g (TFC, 2002; Dural *et al.,* 2007; Turkmen *et al.,* 2009; Yilmaz, 2009). The concentration of Mn found in the tissues of the fish species was least in ***T. zillii***, though this was still higher than the acceptable TFC limit. The results of this study differ from that obtained by Taiwo *et al.* (2016) on the concentration of Mn in tissues of fishes from Epe Lagoon. However, Taoheed and Said (2014) observed very low levels of Manganese in *T. zillii*, below the tolerable acceptable limits of metal consumption in River Challawa in Kano State, Nigeria. The metal concentrations levels of Fe, Pb, Cu and Zn in *C. nigrodigitatus* from Afikpo, Ebonyi State, Nigeria (Oti Wilberforce *et al*., 2016) were comparable to the present study.

Demirezen and Uruc (2006) observed that copper, manganese, iron and zinc are essential elements, required by a wide variety of enzymes and other cell components in all living organisms, but very high intakes could cause health problems. In this study, the overall average concentrations of metals were in the order of Zn>Fe> Pb> Cu> Mn. This was at variance with the study of Elnabris *et al*. (2013) where the concentrations of essential elements were higher than the non-essential elements.

Heavy metal concentrations vs. international dietary standards and guidelines

There are Nigerian food safety standards but none is currently available regarding heavy metal concentration in fish. Therefore, the results obtained in this study for muscle samples of fish were compared with limit values and guidelines found in literature. The levels of Zn and Cu were lower than the maximum levels and guidelines values described in literature. The levels of Pb, Fe and Mn tested in the muscles of the eight fish species were higher than the limit values for fish proposed by the European Community (EC, 2005).

Heavy metals in excess of the body needs of fish or man may constitute a major pollution source and pose a serious health risk (Onyia *et al*., 2007). The toxicity of Fe may lead to heamochromatosis and, in severe cases, to thalassaemia (Hovinga *et al*., 1993) while excessive intake of Zn may lead to diarrhoea and vomiting in humans. Also, in man, the toxicity of Mn leads to a syndrome called manganism which involves both psychiatric symptoms and features of Parkinson disease (Dobson *et al*., 2004). It is therefore, necessary for Nigeria to develop a Nigeria Food Code (NFC) which would state the maximum acceptable limits of heavy metals that could be contained in fish and other foods.

Conclusions

Heavy metals are toxic to both humans and fish, therefore, these compounds should be monitored regularly in the Lagoons. The overall average concentrations of Zn, Pb, Cu, Fe, and Mn in the muscles of the fish species studied gave a ranking of: Zn > Fe > Pb > Cu > Mn. These metals are essential in human diets in minute quantities; their consumption should not exceed the limits set by FEPA, WHO and FAO. The high concentration of these metals in the fish species studied calls for caution in their consumption. However, if eaten in moderation, the fish are safe for consumption. The concentration of heavy metals in the fish species is an indication of the level of pollution in the Lagos Lagoon. This level of pollution could be due to industrialisation and inadequate monitoring of dumping into the lagoon. It is essential to monitor disposal of industrial effluents and dumping of domestic sewage.

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Appendix 1: Heavy Metal MPL in Fish

Metal	USEPA	WHO
Copper	2.25	2.25
Lead	0.110	0.010
Zinc	0.010	5.00
Manganese	0.002	0.500
Iron	0.50	0.30

*USEPA 1998, WHO2004;MPL (Maximum Permissible Limit)

Appendix 2: The World Health Organization (WHO) established a safety metal quantity limits from eating fish, a weekly maximum dosage, Provisional Table Weekly Intake (PTWI), per kg of body weight. It used an average human body weight of approximately 70kg, to obtain the following limits in mg/person/week:

Heavy Metal	WHO (mg/person/week)	EUmg/kg
Zn	490	
Pb	1.75	0.30
Cu	245	
Fe	392	
Mn	68.6	

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https://www.researchgate.net/post/Standard_of_the_permissible_limits_of_toxic_heavy_metals_and_arsenic_in_fish_and_sea_water_and_sediment [accessed Apr 12, 2017]

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