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Health Risk Assessment of Trace Metals in Fish Species from Westernmost Region of Barrier Lagoon Coast, Badagry, Nigeria

[1]Balogun K. J. and [2]Ajani E. K.
[1]Department of Biological Oceanography, Nigerian Institute for Oceanography and Marine Research, Victoria Island, P.M.B. 12729, Lagos, Nigeria
[2]Department of Aquaculture and Fisheries Management, Faculty of Renewable and Natural Resources, University of Ibadan, Nigeria

Abstract

Assessment of trace metal concentration (Cu, Zn, Pb, Cr, and Cd) and associated human health risk in two selected fish species (*Chrysichthys nigrodigitatus* and *Tilapia guineensis*) from Westernmost region of Barrier Lagoon Coast, Badagry, Nigeria was carried out between November 2011 and September 2012. Trace metal levels were determined using atomic absorption spectrophotometry. The data obtained were analysed using Paired samples t - test and significant differences accepted at $p < 0.05$. Target hazard quotient (THQ) was calculated to estimate the non-carcinogenic health risks. Results showed there were no significant differences in metal levels between the two fish species ($p > 0.05$). The Pb and Cr were present in higher concentrations than the globally acceptable guidelines. The THQ for lead and chromium were above one suggesting potential health risk. Furthermore, the combined impact, estimated by hazard index (HI), suggested health risk for both fish (*Chrysichthys nigrodigitatus* and *Tilapia guineensis*) consumption over a lifetime.

Keywords:
Trace metal; Target hazard quotient; Hazard Index; Fish; Atomic absorption spectrophotometry

Introduction

The craving for fish is on the increase in Nigeria given its implication for individual and national health. Fish contains Omega III fatty acids that are known to reduce cardiovascular diseases, hypertension and arteriosclerosis, thus becoming a preferred source of animal protein for those nearing 50 years of age and above (Ovie and Raji, 2006). In spite of the significant role of fish in the diet of Nigerians, trace metals pollution in aquatic environment and their uptake in the food chain by aquatic organisms and humans put public health at risk. Toxic metals can be present in industrial, municipal and urban runoff, and are harmful to humans and aquatic biota. Increased urbanization and industrialization have increased the levels of trace metals in water ways. The heavy metal intakes by fish in a polluted aquatic environment vary depending on ecological requirements, metabolisms, and other factors, such as salinity, water pollution level, food, and sediments. Fish accumulates metals in its tissues through absorption, and humans can be exposed to these metals via the food web. The consumption of contaminated fish can lead to acute and chronic effects to humans (Nord *et al.,* 2004).

The Barrier Lagoon Coast is one of the four broad regions of Nigeria coastal zone. Other regions are the Transgressive Mud Coast, Niger Delta and the Strand Coast. The Westernmost region of Barrier Lagoon coast (Badagry creeks and adjoining waters) is an ecologically important lagoon system in Nigeria with fisheries of economical values (Solarin and Kusemiju, 1991). However, the water bodies are affected by increasing anthropogenic influences and industrial effluents in their catchments, making it an ideal study location. *Chrysichthys nigrodigitatus* (Lacepède, 1803) and *Tilapia guineensis* (Bleeker, 1862) are among the notable and highly demanded fish species for consumption in Badagry, Nigeria. These fishes are frequently caught and largely eaten in Badagry and its environs, so their toxic metal content should be of concern to human health.

Many studies have been carried out in Nigeria on heavy metal contamination in water, sediment and aquatic organisms (Okoye, 1989; Oyewo, 1998; Asuquo *et al.,* 2004; Don-Pedro *et al.,* 2004; Adeniyi and Yusuf, 2007; Ajani and Balogun, 2015). However, there is limited information on health risk associated with heavy metals in edible fish. The purpose of this study is to determine the concentration of trace metals (Cu, Zn, Pb, Cr and Cd) in fish species and evaluate the health risk associated with these metals in fish using the target hazard quotient.

Materials and Methods

Fish collection

Chrysichthys nigrodigitatus and *Tilapia guineensis* samples were collected between November 2011 and September 2012, from fishermen catches in the selected landing points of westernmost region of Barrier Lagoon coast waters, Badagry, Nigeria (Figure 1).

Samples obtained were immediately kept in pre-cleaned polythene bags, sealed, labelled and kept in ice boxes and transported to the laboratory of Biological Oceanography Department of Nigerian Institute for Oceanography and Marine Research (NIOMR), Victoria Island, Lagos. In the laboratory, total length (cm) and weight (grams) were recorded using measuring board (measuring to the nearest 0.1cm) and weighing scale (to nearest 0.1g). The fish samples were then kept in a deep freezer until muscle tissues were extracted for analysis.

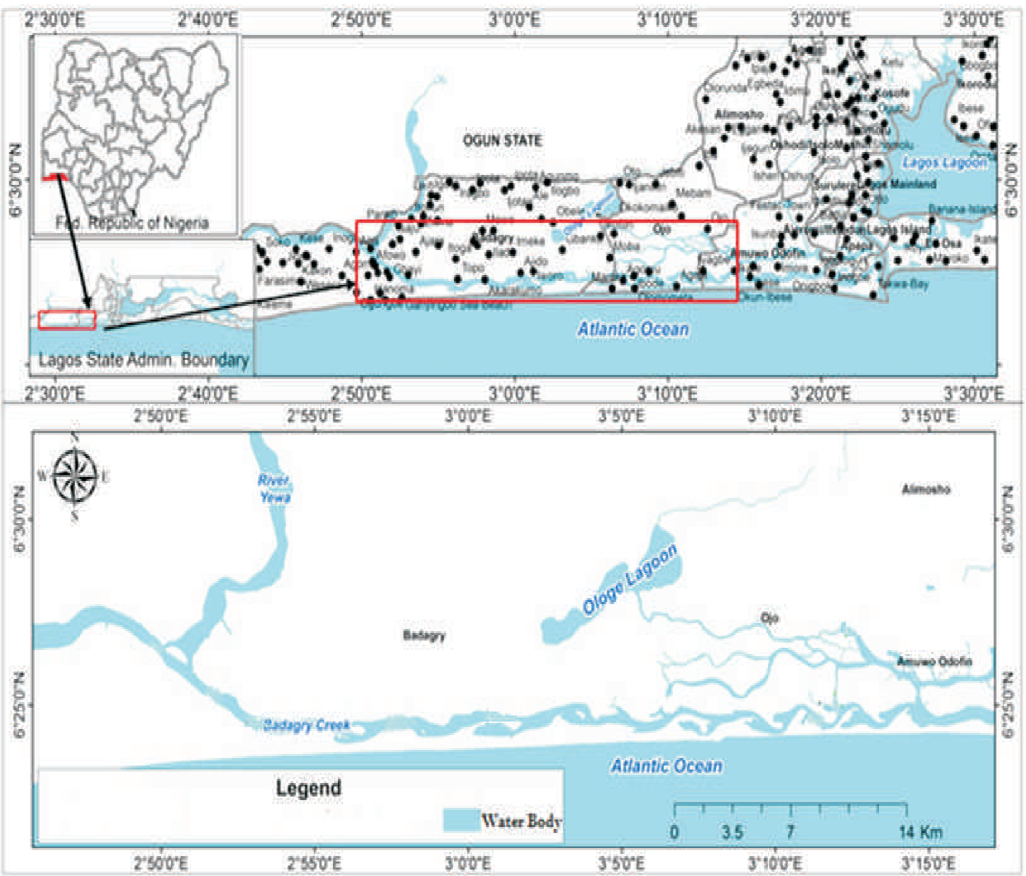

Figure 1: Map of Westernmost region of Barrier Lagoon Coast Waters, Badagry, Nigeria

Fish muscle tissue preparation

Muscle tissue of fish (dorsal muscle) was used in this study because it is the most edible part of the fish. The skin of each fish sample was removed using plastic knives to avoid metal contamination and this was followed by extraction of fish muscles. Fish muscles were put in a pre-acid washed and oven-dried crucibles. The samples were then dried to a constant weight in an oven at 50^0C. The dried fish samples were allowed to cool in a desiccator at room temperature. Prior to use, all glassware were soaked in diluted nitric acid for 24 hour and then rinsed with distilled deionized water.

After cooling, 2 g of fish dorsal muscle samples were placed into digestion flasks and ultrapure Conc. HNO_3 and H_2O_2 (2:1 v/v) was added. The samples were digested in triplicates according to AOAC (1998).

Sample analysis

Concentrations of trace metals (Cu, Zn, Pb, Cr and Cd) in the digested fish species muscles (filtrate) for each set of samples were measured using Atomic Absorption Spectrophotometer (Spectra AA-240, Agilent Technologies) with air-acetylene flame by comparing their absorbance's with those of standards (solutions of known metal concentration). All the instrumental adjustments had been as recommended in the manual by the manufacturer. For Quality Assurance / Quality Control (QA/QC) purposes, AAS standard solutions (factory prepared) were run as samples for accuracy check after every five samples measurements (William and Latimer, 2005). The results were expressed in milligrams of metal per dry weight kilogram of fish muscle tissues (mg/kg).

Health Risk Estimation

The health risk estimation was done using the following indices:

Target hazard quotient

To estimate the human health risk from consuming metal-contaminated fish, the Target Hazard Quotient (THQ) was calculated as per USEPA Region III Risk-Based Concentration Table (USEPA, 2011).

The target hazard quotient (THQ) values were estimated from the following formula:

$$THQ = \frac{EF \times ED \times FIR \times CM}{ABW \times ATn \times RfD} \times 10^{-3}$$

Where,
EF is the exposure frequency (365 days/year),
ED is the exposure duration (30 years for non-cancer risk as used by USEPA, 2011),
FIR is the fish ingestion rate (36 g/person/day in Nigeria; FAO, 2017),
CM is the heavy metal concentration in fish (mg/kg d.w.),
ABW is the average body weight (b.w) (60.7kg; in Africa; BMC Public Health 2012),
ATn is the average exposure time for non-carcinogens (EF×ED) (365 days/year for 30 years (i.e., ATn = 10,950 days) as used in characterizing non-cancer risk (USEPA 2011),
RfD is the reference dose of the metal; which is an estimate of the daily exposure to which the human population may be continuously exposed over a lifetime without an appreciable risk of deleterious effects.

Hazard Index

The hazard index (HI) is expressed as the arithmetic sum of the individual metal target hazard quotient values (USEPA 2011).

$$HI = THQ(Cu) + THQ(Zn) + THQ(Pb) + THQ(Cr) + THQ(Cd)$$

Where,
HI is the hazard index,
THQ is the target hazard quotient for metal intake.

Statistical Analysis

The data were statistically analyzed using the statistical package, SPSS 16.0 for windows evaluation version. The means and standard deviations of the metal concentrations in fish species were calculated. Paired samples t - test was employed to examine the differences in mean metal concentrations between fish species for each metal and significant differences accepted at $p < 0.05$.

Results and Discussion

Trace metals concentration

Trace metal mean concentrations in the dorsal muscles of edible fish species (*Chrysichthys nigrodigitatus* and *Tilapia guineensis*) from westernmost region of Barrier Lagoon Coast waters Badagry, Nigeria is presented in Table 1.

The length and weight of *Chrysichthys nigrodigitatus* sampled ranged from 18.5 cm to 32 cm and from 72.5 g to 315 g, respectively. *Tilapia guineensis* sampled length and weight varied from 16.5 cm to 24.5 cm and from 62.5 g to 222.5 g, respectively. All the metals investigated in the dorsal muscles of fish species samples were found within the detection limit of Atomic Absorption Spectrophotometer (Spectra AA-240, Agilent Technologies) with air-acetylene flame except cadmium.

Table 1: Mean ± standard deviation for trace metal concentrations in dorsal muscles of *Chrysichthys nigrodigitatus* and *Tilapia guineensis* during the study period

Metals (mg/kg)	*Chrysichthys nigrodigitatus*	*Tilapia guineensis*	P.value
Copper	0.49 ±0.47	0.32 ± 0.16	.43
Zinc	16.08 ± 4.56	17.15 ± 3.68	.44
Lead	14.20 ± 4.52	13.87 ± 6.70	.23
Chromium	96.68 ± 60.62	94.60 ± 78.11	.98
Cadmium	BDL	BDL	

BDL: Below detectable limit

With an exception of zinc, metals mean concentrations were higher in *Chrysichthys nigrodigitatus* than *Tilapia guineensis.* Variations were observed in the concentration of trace metals between different species.

Copper (Cu) mean concentrations in the dorsal muscle were 0.49 ±0.47mg/kg in *Chrysichthys nigrodigitatus* and 0.32 ± 0.16 mg/kg in *Tilapia guineensis* (Table 1). These concentrations are however below the Maximum Acceptable Levels (MAL) of 30 mg/kg prescribed by FAO (1983) and WHO (1989). Copper is an essential element found in a natural environment and required by all living organisms. However, it poses potential hazards that endanger both animal and human health at high concentration. Copper is essential for the normal growth and metabolism of all living organisms (Eisler 1998). In humans, Cu concentration can increase by consuming contaminated fishes. Chronic toxic effects may induce poor growth, decrease immune response, shorten life span, cause reproductive problems, low fertility and changes in appearance and behaviour (Yacoub and Gad, 2012).

Zinc (Zn) mean concentration of 16.08 mg/kg in the dorsal muscle of *Chrysichthys nigrodigitatus* was lower than 17.15 mg/kg obtained for *Tilapia guineensis* (Table 1). Zinc mean levels in the muscles of fish species investigated were below the Maximum Acceptable Levels (MAL) of 30 mg/kg prescribed by FAO, (1983) and WHO, (1989). Zinc is the second most abundant trace element after iron and is an essential trace element in living organisms. Zn is critical for aquatic organisms, including fishes. However, Zn becomes poisonous when it exceeds its maximum tolerance value. The common sources of zinc are galvanized ironwork, paints containing zinc components and zinc chloride used in plumbing (Clarke, *et al.,* 1981).

In the present study, Lead (Pb) was found in dorsal muscles of fishes in high content. Mean concentration of Pb (14.20 mg/kg) in the dorsal muscle tissues of *Chrysichthys nigrodigitatus* was higher than 13.87 mg/kg obtained for *Tilapia guineensis* (Table 1). The concentrations of Pb in the present study are higher than the guideline values. Therefore, the metal poses threat through consumption of these aquatic organisms. The Pb values in the various fish tissues investigated were high and exceeded the Maximum Acceptable Levels (MAL) of 0.5 mg/kg dry weight prescribed by FAO (1983) and WHO (1989). Lead is a persistent heavy metal which has been characterized by USEPA as high priority hazardous substance. Lead found in the environment is as a result of human activities, natural and anthropogenic sources. The possible increase in anthropogenic activities which includes automobile traffic emissions from leaded petroleum, emissions from heavy duty generator, Pb based paints and battery manufacturing around the water body catchment could have contributed to the elevated Pb concentration. The Pb exposure may weaken the immune system, resulting in increased susceptibility to infections (Shah and Altindag, 2005).

The mean concentration of Chromium (Cr) in the dorsal muscle of *Chrysichthys nigrodigitatus* and *Tilapia guineensis* were 96.68 mg/kg and 94.60 mg/kg respectively (Table 1). The Cr mean concentration in the dorsal muscles of fish species investigated exceeded the Maximum Acceptable Levels (MAL) of 1.0 mg/kg prescribed by FAO (1983) and WHO (1989). This study indicated higher concentration of Cr than the levels reported by other authors in fish species (Asuquo *et al.,* 2004; Adeniyi and Yusuf, 2007).

These results suggest high Cr contamination that might have resulted from the unregulated human activities in the westernmost region of Barrier Lagoon coast catchment, arising from discharges of effluents from electro-painting, dyeing and printing industries, textiles and metal finishing industries.

Some of the toxic effects of Cr exposure in human are skin irritation, ulcer, liver, kidney, circulatory and nerve tissue damage.

Cadmium was below the detectable limit in the dorsal muscle of the investigated fish species in this study. Cd is non-essential element known to have a toxic potential. Cadmium even in low concentration is quite toxic to human health (Mohan *et al.,* 1998).

Health Risk Estimation

The target hazard quotient (THQ) estimated for individual trace metals through consumption of different fish species is presented in Table 2. The Target Hazard Quotient (THQ) is an estimate of the risk level (non-carcinogenic) due to pollutant exposure. The acceptable guideline value for THQ is 1 (USEPA, 2011).

Table 2: Target hazard quotient (THQ) for trace metals and hazard index (HI) from consumption of two fish species collected from Westernmost region of Barrier Lagoon Coast waters, Badagry, Nigeria

Trace metals (mg/kg)	**RfD (mg/kg) (FAO/WHO, 2013)**	**Target hazard quotient (THQ)**	
		Chrysichthys nigrodigitatus	***Tilapia guineensis***
Copper	0.040	7.27E-03	4.74E-03
Zinc	0.300	3.18E-02	3.30E-02
Lead	0.004	2.11E+00	2.06E+00
Chromium	0.003	19.11E+00	18.70E+00
Cadmium	0.001	-	-
Hazard index (HI)	0.348	21.26E+00	20.80E+00

RfD: Reference dose of the metal

The THQ value of less than one signifies non-obvious risk while an exposed population of concern will experience health risk if the dose (value) is equal to or greater than the metal reference dose (RfD). The THQ less than one implies that the level of exposure is smaller than the reference dose; a daily exposure at this level is believed not to cause adverse effects during a person's lifetime.

With an exception of lead and chromium, the target hazard quotient (THQ) values were less than one for Cu, Zn and Cd in the two fish species (Table 2), indicating no non-carcinogenic health risk from ingestion of these trace metals through consumption of these fishes. However, THQ values of lead and chromium in the fish species dorsal muscles were more than one and greater than the metal reference dose, suggesting potential health risks in consumption of these fishes. THQ highest value was estimated for Cr followed by Pb contamination in the two fish species (Table 2).

The Hazard Index (HI) for *Chrysichthys nigrodigitatus* and *Tilapia guineensis* were 21.26 and 20.80, respectively (Table 2). This indicates that continuous and excessive intake of these fish species from the westernmost region of Barrier Lagoon Coast waters could result in chronic non-carcinogenic health hazard.

Conclusion

Fish is an important food resource for human consumption and a major component of the marine/ brackish ecosystem, thus assessment of the trace metal adverse effects is particularly important. The present study revealed that *Chrysichthys nigrodigitatus* and *Tilapia guineensis* from the western most region of Barrier Lagoon Coast waters, accumulates various trace metals at varying concentration. Lead (Pb) and chromium (Cr) concentration in fish species investigated were found to pose potential non-carcinogenic health risk. Further studies should be done on these fish and other fish species available in the region for metal contamination screening. As remedial measures in controlling trace metals risks in fish in this aquatic ecosystem, it is recommended that Environmental Regulatory Authorities such as DPR, NIMASA, NPA, NESREA and NOSDRA should enforce proper treatment of wastewaters, sewage and agricultural wastes to eliminate pollutants (including trace metals) from them before discharge into the aquatic systems. The unregulated uses of westernmost region of Barrier Lagoon Coast waters should be controlled through the enforcement of various regulations and laws by the various implementing agencies involved.

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