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Research Article

Assessment of Heavy Metals and Public Health Concern in Selected Fish Species in Lagos Lagoon, Nigeria

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ABSTRACT

The possibility of public health risk from the uptake of heavy metals such as Cadmium, Lead, Nickel, Manganese, Iron, and Zinc in eight selected resident fish species of Lagos Lagoon, Nigeria, was investigated in 2021. The fishes were *Hemichromis fasciatus, Polydactylus quadrifilis, Monodactylus sebae, Citharichthys stampfili, Cynoglossus senegalensis, Scomberomorus tritor, Eucinostomus melanopterus, and Lutjanus goreensis*. The sizes and weight of specimens were measured; concentrations of heavy metals were determined by Atomic Absorption Spectrometry; consumer hazard risk assessment, carcinogenic and non-carcinogenic risks estimation were calculated using equations. Total length of specimens ranged from 5.5 – 48.5 cm (mean, 19.9 ± 13.03 cm); total weight ranged from 5.0 – 376.00 g (mean, 228.88 ± 139.73 g). Mean concentrations of essential metals, Fe and Mn in *C. senegalensis* (58.39 mg/kg and 14.04 mg/kg), *C. stampfili* (45.47 mg/kg and 13.30 mg/kg), *L. goreensis* (58.61 mg/kg and 10.71 mg/kg) respectively were higher than the FAO/WHO permissible limits; concentration of Zn was exceeded in *H. fasciatus* (61.18 mg/kg). FAO/WHO limits were exceeded for Pb in *C. senegalensis* (5.01 mg/kg) and *L. goreensis* (5.17 mg/kg); Cd in *L. goreensis* (0.29 mg /kg) *C. senegalensis* (0.07 mg/kg), *C. stampfili* (0.07 mg/kg), *P. quadrifilis* (0.07 mg/kg) and *H. fasciatus* and Ni in *H. fasciatus* (0.83 mg/kg) and *P. quadrifilis* (0.61 mg/kg), which are potentially carcinogenic metals. However, the non-carcinogenic risk (THQ and HI) and target cancer risk (TR) assessment were less than 1, the critical limit. This indicated no adverse health risk from the consumption of any of the selected fishes.

Keywords: bio-indicator, Concentration, Fish, Heavy metal, Lagos Lagoon, Risk
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INTRODUCTION

Fish are found in fresh, brackish and marine waters (Yadav, 2002), and have direct economic worth, apart from being an important aspect of biodiversity, and they are a significant source of animal protein for humans (Ward *et al.*, 2005; Rasmussen *et al.*, 2009; Bingpeng *et al.*, 2018). In most African countries, including Nigeria, fish is an essential source of animal protein in the common diet, and with the abundant expanse of aquatic resources such as the Lagos Lagoon with its interconnectivity, several fish species of fresh, brackish and marine water origin inhabit the ecosystem. Many fish species are permanent residents in Lagos Lagoon and they include species from family Mugilidae, Clupeidae, Sciaenidae, Polynemidae, Cichlidae, Haemulidae, Ariidae, Elopidae, and Cynoglossidae among others (Fagade & Olaniyan, 1974; Amadi, 1990; Soyinka, *et al.*, 2020). However, the Lagos Lagoon, although has supported several fisheries till date, yet has been under intensified introduction of pollutants for decades. These pollutants include untreated sewage, detergents and industrial effluents, petroleum products and sawdust (Akpata & Ekundayo, 1978; Akpata, 1987; Amund, 2000; Akpata, 2002). These pollutants are sources for the release of heavy metals (metals with densities greater than 5 gcm^3 and atomic number greater than that of calcium – Shaid and Omar (2020) into the aquatic food web.

Fishes ingest heavy metals discharged into the lagoon (Velez *et al.*, 1998; Stephen, 2003) through the food intake, and due to their indestructible nature, the metals bioaccumulate (Censi *et al.*, 2006) in fish tissues. The transfer of this accumulated metals from plankton to fish, and then from fish to scavenger birds and man, has resulted in a progressive increase in the concentration of the substance in a food chain, which has resulted in biomagnification of that substance (Croteau *et al.,* 2005) with the attendant toxic effects (Hilton *et al.,* 2003) in man at the top of the food web. The public health implications of ingesting heavy metals are influenced by the duration of exposure, age of exposed individual, the heavy metal involved, route of exposure and the dosage during exposure (Oguguah & Ikegwu, 2017). It could lead to nausea, diarrhea, cancer, negative effect on haemoglobin synthesis among others (Sures, 2003). According to Lushenko (2010) cited in Bassey and Chukwu (2019), health risk assessment grouped elements into non-carcinogenic and carcinogenic chemicals, with the non-carcinogenic being those assumed to have a threshold limit and as such regarded as having no adverse health effect at doses below the threshold point; whereas the carcinogenic are those assumed to have no effective threshold limits and thus with high risk of cancer to exposed living organisms.

Few reports on the health risk assessment of heavy metals in fish from lagoons in south-west Nigeria include Bassey and Chukwu (2019), who worked on *C. nigrodigitatus* from Ologe and Badagry lagoons; Oguguah and Ikegwu (2017) who highlighted the health implication of trace metals in 12 fishes of economic importance from Lagos Lagoon. However, there were some other resident species in the Lagos Lagoon not reported by Oguguah and Ikegwu (2017), and the present study sought to examine them.

Moreover, there is need for continuous surveys on heavy metals content in fishes and an assessment of their risk to the coastal communities in Nigeria. The present study was aimed at examining the heavy metal content in the flesh of selected fish species as well as the carcinogenic and non-carcinogenic risk connected with the ingestion of the selected fish species.

MATERIALS AND METHODS

Description of Study Area

The Lagos lagoon (Fig. 1) is located within longitudes 3° 23″ and 3° 53″ E and latitudes 6° 26″ and 6° 37″ N. It is an open tidal estuary located at the heart of the Lagos metropolis that connects to the Atlantic Ocean through the Lagos harbor. It is bounded to the North by the Ogun River and to the east by the Atlantic Ocean. It is fed by several rivers like Ona, Ogun, Osun, Shasha, and Oni. It is approximately more than 3 km to 13 km wide and 50km long. The open and tidal lagoon is slightly hollow, with an average depth of 1.5 meters and an expanse of 6,354.7 square kilometers. The lagoon serves many purposes such as means transportation, serves as recreation spot, a natural buffer to the wave actions from the sea, but also adversely used as a dumpsite for residential and industrial discharges.

Collection of Fish Samples

A total of 637 fish specimen from several families were obtained from fishermen who deploy cast nets in fishing from the Lagos Lagoon between March and June 2021. The collections were done randomly throughout the sampling period to obtain the samples. The fish procured were kept in ice box and moved to the Marine Research Facility of the Department of Marine Sciences, University of Lagos, where they were sorted, cleaned with distilled water and preserved in deep freezer at temperature -20°C until further analysis.

Laboratory Procedures

Length and Weight Measurements

The fish samples were thawed and water was allowed to drain out. Morphometric and meristic measurements were taken; total length to the nearest 0.1 cm; total weight to the nearest 0.1 g. Three samples of each species were selected and 5 g of the muscle or flesh was cut off from the side of each specimen. These extracted samples were stored separately and taken to the Central Research Laboratory of the Nigerian Institute of Oceanography and Marine Research (NIOMR) in Lagos, Nigeria for analysis of the heavy metals contents of the tissues.

Heavy Metal Analysis

The fish tissues were digested in analytical grade ratio, 15ml HCl: 5ml HNO_3. The solution was filtered using Whatman filter paper after digestion, and the sample volume was increased to 50ml with distilled water. The prepared sample solution was then transferred for Atomic Absorption Spectrometric analysis.

The Aqua-regia method for heavy metal was adopted for the digestion processes. This method was partially modified from that of ISO 11466 (Quevauviller *et al.,* 1998). 50mL of each of representative water samples were treated with 15ml HCl and 5ml HNO_3 in Pyrex beakers. The samples were boiled slowly at increasing temperature and then evanesced on a hot plate to the minimum possible volume of about 5ml. Heating continued until digestion was finalized. The samples were vaporized again to dryness (but not simmered) and the beakers were chilled. The solutions were then filtered and transferred to a 50ml volumetric flask, which was filled up to the mark with distill water and filtered before being transferred to a pre-cleaned sample bottle for further examination.

All digested samples were tested for Pb, Fe, Cd, Ni, Zn and Mn using Atomic Absorption Spectrophotometer. All of the chemicals used were analytical grade, and deionized water was used throughout the experiment. The glassware was first immersed in nitric acid for 72 hours before being cleaned with ultrapure water. In order to avoid batch-specific errors, certified reference materials used as an internal standard were examined along with the samples in five replicates for each analysis blank run (Azemard *et al*., 2006).

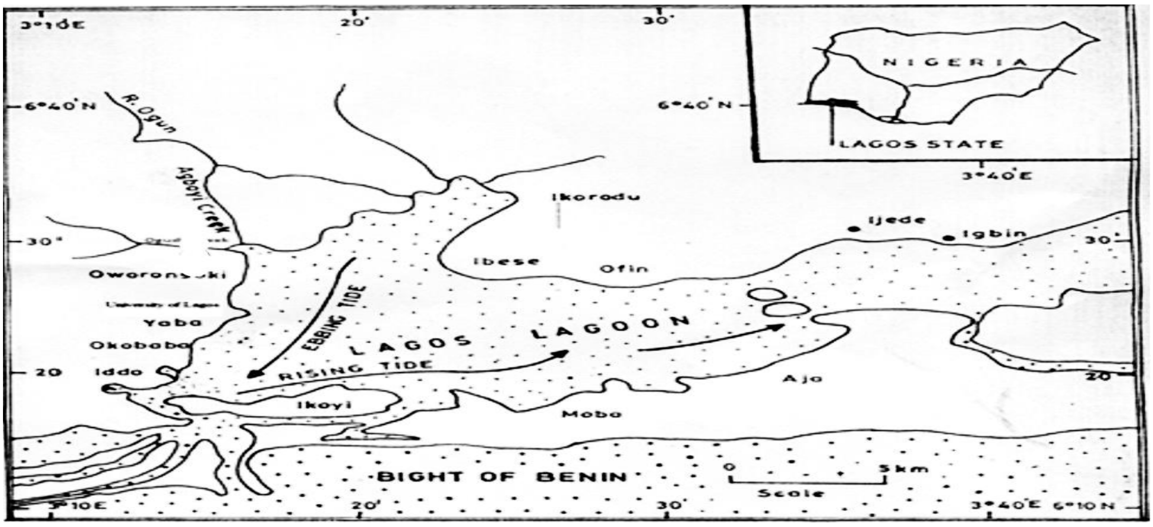

Figure 1: Lagos Lagoon with surrounding land masses (Source: Emmanuel & Ross, 2019)

Consumer Health Hazard Assessment

The per diem or estimated daily intake and target hazard quotient of each individual metal were calculated. Estimated Daily intake was calculated using Equation 1, while the THQ (Total Hazard Quotient) was estimated using Equation 2 according to United State Environmental Protection Agency, USEPA (2000). Total Hazard Quotient is an estimate of the non-carcinogenic risk level due to exposure to the metal. If the THQ value is higher than one (THQ>1), the exposed community is likely to experience deleterious consequences as a result of fish consumption. The greater the THQ value, the larger the possibility of hazard to the consumer's body.

$$Daily\ Intake\ (mgkg^{-1}day^{-1}) = \frac{(EF\ x\ ED\ x\ FIR\ x\ C)}{(WAB\ x\ AT_n)}$$

………. Equation 1

$$\text{THQ} = \frac{(EF\ x\ EDx\ FIR\ x\ C)}{(\text{RfD x WAB x AT})} X10^{-3}$$

……… Equation 2

Where;

EF = exposure frequency (365 days $year^{-1}$)

ED = exposure duration (55.12 years for adults) which equals the average lifetime (life expectancy for a Nigerian adult according to USEPA, 2000)

WAB = average body weight (kg), (60.7 kg for adults)

FIR = fish ingestion rate (kg $person^{-1}day^{-1}$), (0.036 kg $person^{-1}day^{-1}$ for adults)

C = metal concentration in fish (mg kg^{-1})

AT_n = average exposure time for non-carcinogens (365 days $year^{-1}$×ED).

RfD = oral reference dose (mg kg^{-1} day^{-1}) (Ni = 0.02, Zn = 0.3, Cd = 0.001, Pb = 0.0035, Mn = 0.14, Fe = 0.7 mg kg^{-1} day^{-1}) (USEPA, 2011)

Individual exposure assessment was estimated using the equation below according to USEPA (2000):

$$E_m = C_m\ X \frac{CR}{BW}$$

……………Equation 3

Where;

E_m = individual exposure to chemical contaminants in the form of ingesting fish (mg/kg-d)

BW = body weight of an individual consumer (kg).

C_m = concentration of chemicals in the edible portion of fish (mg/kg)

CR = average diurnal consumption rate of fish (kg/d)

Non-Carcinogenic Risk Estimation

The estimation of the heavy metal's non-carcinogenic hazard present in fish samples was carried out by analyzing total hazard index, THQ (target hazard quotient) and MAFCR (maximum allowable fish consumption rate) with regards to non-carcinogenic effects of contaminants.

For the risk assessment of multiple heavy metals contained in fish, a total hazard index (HI) was estimated using

$$HI = THQ(Fe) + THQ\ (Pb) + THQ\ (Mn) + THQ\ (Zn) + THQ\ (Cd)$$

..…Equation 4

Where:

THQ is the target hazard quotient of a specific element of heavy metals and HI (USEPA, 2000) is the total hazard index of the six metals examined in this study.

For non-carcinogenic effects, based on the reference dose for each of the potential pollutants, the following equation according to USEPA (2000) was used:

$$CR_{lim} = \frac{(\text{RfD x BW})}{\text{Cm}}$$

………. Equation 5

Where,

CR_{lim} = highest allowable fish consumption rate (kg/d)

RfD = oral reference dose (mg kg^{-1} day^{-1}) BW = consumer body weight (kg) (70kg)

C_m = metal concentration in fish ($mgkg^{-1}$)

BW = consumer body weight (kg) (70kg)

Carcinogenic Risk Estimation

The acceptable diurnal consumption (CR_{lim}) of contaminated fish, based on a contaminant's carcinogenic health effects was expressed in kilograms per day (USEPA, 2016).

$$CR_{lim} = \frac{(\text{ARL x BW})}{(\text{ARL x BW})}$$

………… Equation 6

Where

ARL = highest acceptable individual life time risk level (10^{-6}, dimensionless)

BW = consumer body weight (kg) (70kg)

C_m = metal concentration in fish ($mgkg^{-1}$)

CSF = cancer slope factor (Ingested nickel = 1.7, Pb = 0.009 and Cd = 0.6) (USEPA, 2011)

Target Cancer Risk (TR)

This is used in the estimation of carcinogenic risk. According to New York State Department of Health, NYSDOH (2007), the TR categories are:

TR ≤ 10^{-6} = Low; 10^{-4} to 10^{-3} = moderate; 10^{-3} to 10^{-1} = high; ≥10^{-1} = very high. The model according to

USEPA (2000) is shown below:

$$TR = \frac{\text{EF x ED x FIR x CR x C(metal)x CFS}}{\text{WAB x ATc}} \text{ x } 0.001$$

……………… Equation 7

Where:

EF = exposure frequency (350 days $year^{-1}$)

ED = exposure duration (55.12 years for adults) which equals the average lifetime (life expectancy for a Nigerian adult)

FIR = fish ingestion rate (kg $person^{-1}day^{-1}$), (0.036 kg $person^{-1}day^{-1}$ for adults)

CR= average diurnal consumption rate of fish (kg/d)

C (metal) = metal concentration in fish (mg kg^{-1})

CSF = cancer slope factor

WAB = average body weight (kg), (60.7 kg for adults)

AT_C = average exposure time for carcinogens (365 days $year^{-1}$×ED).

RESULTS

Heavy metal Contents in Fish Species

The level of heavy metals varied widely across different species, as shown in Table 1. The ranges of those metals were Pb (0.59 to 5.17µg/g ww); Fe (8.18 to 58.6096 µg/g ww); Mn (0.88 to 107.14 µg/g ww); Cd (0.00 to 0.29 µg/g ww) and Ni (0.02 to 4.82 µg/g ww), with *L. goreensis* having the highest value in all these heavy metals. The sequences of heavy metals accumulation in the species examined were: *H. fasciatus* (Zn>Fe>Mn>Pb>Ni>Cd); *Lutjanus goreensis* (Fe>Mn>Zn>Ni>Pb>Cd); *Eucinostomous melanopterus* (Zn>Fe>Mg>Pb>Ni>Cd); *Scomberomorus tritor* (Fe>Pb>Mn>Zn>Ni>Cd); *C. stampfili* (Fe>Mn>Pb>Ni>Cd); and in *Polydactylus quadrifilis*, *Cynoglossus senegalensis* and *Monodactylus sebae* (Fe> Zn > Mn> Pb> Ni> Cd)

Non-Carcinogenic Health Hazard

The target hazard quotient (THQ) for species of fish (Table 2) decreased in the following order Cd>Fe>Pb>Mn>Ni>Zn. Cd had the highest total THQ of 0.26, while the least value of 1.37 x 10^{-4} occurred in Zn. The Hazard Index (HI) value of the metals in the species was 0.0455. It was observed that the THQ for all the metals was less than 1. The hazard index (HI) which is the combination of the THQ of individual metals was also less than 1. Since the values are less than 1, the community is relatively safe and should not experience any deleterious effect from consumption of fish from the lagoon in respect of non-carcinogenic risk. However, more attention should be placed on Cd, Pb and Ni which are potential carcinogens in the study area.

The estimated daily intake of metals is shown in Table 3, while Table 4 showed values for the maximum allowable fish consumption rate (CR_{lim}) of the selected fish species. The average EDI values obtained were Cd (0.0655 x 10^{-3}); Pb (1.6075 x 10^{-3}); Ni (0.96 x 10^{-3}); Fe (23.18 x 10^{-3}); Zn (15.75 x 10^{-3}) and Mn (19.25 x 10^{-3}).

Carcinogenic Risk Assessment

The assessment of the carcinogenic risk of the heavy metals present in the fish species was carried out by analyzing Target cancer risk (TR) and maximum allowable fish consumption rate with regards to carcinogenic effects of contaminants. Table 5 showed the CR_{lim} of each individual metal with consideration of the carcinogenic effect of the contaminant as well as their target cancer risk. And since Mn, Fe, and Zn do not cause high toxicity because their Cancer gradient factors have still not been ascertained, only the CR_{lim} and TR values for Ni, Cd, and Pb intake were determined to demonstrate the carcinogenic risk. The TR values were below the 10^{-6} limit except for Cd in *C. stampfili* and *L. goreensis;* Pb in *L. goreensis* and *C. senegalensis*; and Ni in *E. melanopterus, C. stampfili, L. goreensis*, and *C. senegalensis*, which had values higher than the 10^{-6} limit. The highest value for Cd (0.100 x 10^{-3}) was found in *L. goreensis;* Pb (0.0661 x 10^{-3}) in *C. senegalensis*, and Ni (4.66 x 10^{-3}) in *L. goreensis.*

Table 1: Mean Heavy Metal Concentrations in selected fish species Collected from Lagos Lagoon, Nigeria

Species	**Pb (**mg/kg)	**Zn (**mg/kg)	**Fe (**mg/kg)	**Mn (**mg/kg)	**Cd** (mg/kg)	**Ni (**mg/kg)
Hemichromis fasciatus	1.523	61.184	35.111	5.095	0.072	0.825
Polydactylus quadrifilis	1.34±1.13	10.54±2.02	23.565±392.05	4.10±4.56	0.07±0.01	0.61±0.52
Scomberomorus tritor	1.09±0.30	0.37±0.30	16.26±12.01	0.88±0.12	N.D.	0.02±0.03
Eucinostomus melanopterus	0.59±0.54	14.06±8.31	8.18±1.95	2.72±1.29	0.028±0.026	0.56±0.083
Citharicthys stampfili	1.21±0.29	26.87±6.83	45.47±0.26	13.30±20.79	0.07±0.04	0.78±15.61
Lutjanus goreensis	5.17±7.12	34.31±31.66	58.61±10.11	10.71±18.27	0.29±0.45	4.82±7.53
Cynoglossus senegalensis	5.01±5.24	40.91±7.34	58.39±35.35	14.04±3.73	0.07±0.04	0.79±0.30
Monodactylus sebae	1.10±0.49	10.31±7.48	34.71±31.24	3.91±1.33	N.D	0.43±0.09
Permissible limit in fish						
WHO (1985, 1989, 2011)	2.0	100	43	5.5	0.2	0.5-0.6
FAO (1989, 2003, 2011)	0.20	40	43	5.5	0.05	---
EC (2006)	0.30 – 2.0	-----	-----	-----	0.05 – 0.50	----

EC = European Commission; WHO = World Health Organization; FAO = Food and Agriculture Organization

Table 2: Target hazard quotient (thq) for different heavy metals and hazard Index (HI) from consumption of selected fish species collected from Lagos Lagoon, Nigeria

Species	**Pb THQ**	**Zn THQ**	**Fe THQ**	**Mn THQ**	**Cd THQ**	**Ni THQ**	**HI**
Hemichromis fasciatus	0.00025	0.00012	0.000029	0.000021	0.000041	0.0000240	0.00048
Polydactylus quadrifilis	0.00022	0.000020	0.000190	0.000017	0.000037	0.0000180	0.00051
Scomberomorus tritor	0.00018	0.00000028	0.000710	0.300000	0	0.0000036	0.00084
Eucinostomus melanopterus	0.00230	0.0000019	0.0000022	0.0000023	0.004700	0.0000170	0.00700
Citharicthys stampfili	0.00044	0.0000019	0.000011	0.0000032	0.260000	0.0000034	0.03000
Lutjanus goreensis	0.00084	0.0000065	0.004800	0.00044	0.000170	0.0001400	0.00640
Cynoglossus senegalensis	0.00071	0.000067	0.000041	0.000049	0.000035	0.0000190	0.00092
Monodactylus sebae	0.00054	0.000060	0.00006	0.00005	0	0.0003600	0.00120

Table 3: Estimated daily intake for individual metals from consumption of selected fish species collected from the Lagos Lagoon, Nigeria

Species	**Estimated Daily Intake, EDI (mg/kg/day)**					
	Pb	**Zn**	**Fe**	**Mn**	**Cd**	**Ni**
Hemichromis fasciatus	0.00087	0.03500	0.02000	0.00290	0.000041	0.00049
Polydactylus quadrifilis	0.00077	0.00610	0.14000	0.00240	0.000037	0.00035
Scomberomorus tritor	0.00081	0.00043	0.01700	0.00054	0.000000	0.00019
Eucinostomus melanopterus	0.00034	0.00800	0.00470	0.00150	0.000016	0.00032
Citharicthys stampfili	0.00069	0.01500	0.02600	0.00760	0.000041	0.00044
Lutjanus goreensis	0.00290	0.02000	0.03300	0.06100	0.000170	0.00270
Cynoglossus senegalensis	0.00250	0.02000	0.02900	0.00690	0.000035	0.00039

Table 4: Maximum Allowable fish consumption rate (CR_{lim}) of selected fish species collected from the Lagos Lagoon, Nigeria.

Species	Highest Allowable Consumption Rate, CR_{lim} (kg/day)					
	Pb	**Zn**	**Fe**	**Mn**	**Cd**	**Ni**
Hemichromis fasciatus	0.1400	0.3000	1.2100	1.6700	0.8400	1.4200
Polydactylus quadrifilis	0.1600	1.7300	0.1800	2.0800	0.9300	1.9900
Eucinostomus melanopterus	0.3600	1.3000	5.2000	3.1200	2.1900	2.1800
Lutjanus goreensis	0.0410	0.5300	0.0070	0.0790	0.2100	0.2500
Cynoglossus senegalensis	0.0490	0.5100	0.8400	0.7000	1.0000	1.7800
Scomberomorus tritor	0.3100	18.3100	7.9600	8.5000	0.0000	0.2300

Table 5: Maximum allowable fish consumption rate (CR_{lim}) with regards to carcinogenic effect for different heavy metals and target cancer risk (TR) from consumption of selected fish species collected from Lagos Lagoon, Nigeria

Species	Cd		Pb		Ni	
	CR_{lim} (kg/day)	**TR**	**CR_{lim}(kg/day)**	**TR**	**CR_{lim}(kg/day)**	**TR**
Hemichromis fasciatus	1.41×10^{3}	2.46×10^{-8}	4.43×10^{3}	7.80×10^{-9}	4.17×10^{1}	8.28×10^{-7}
Polydactylus quadrifilis	1.48×10^{-4}	9.59×10^{-13}	5.33×10^{-3}	3.36×10^{-12}	1.18×10^{-4}	1.92×10^{-11}
Eucinostomus melanopterus	1.78×10^{8}	9.44×10^{-6}	5.53×10^{8}	3.04×10^{-6}	3.12×10^{6}	5.37×10^{-4}
Citharicthys stampfili	1.67×10^{7}	2.48×10^{-5}	2.72×10^{8}	6.17×10^{-6}	2.22×10^{6}	7.55×10^{-4}
Lutjanus goreensis	1.67×10^{7}	1.00×10^{-4}	6.34×10^{7}	2.65×10^{-5}	3.60×10^{5}	4.66×10^{-3}
Cynoglossus senegalensis	1.67×10^{-3}	2.07×10^{-8}	5.22×10^{-1}	6.61×10^{-5}	1.55×10^{-3}	2.22×10^{-8}

DISCUSSION

Heavy metal concentration in the flesh of marine organism has been established as a nonlinear indicator of metal richness and presence in the marine ecosystem (Kucuksegin *et al.,* 2006). As a result, observance of contamination in fish tissue is crucial as an early indicator of sediment pollution or other water quality issues (Babatunde, 2012). The heavy metals were observed in various quantities in the fishes examined, although some were not detected in some samples. Differences observed could be due to a number of factors including the bioaccumulation factors of each metal, the species trophic level and degree of trophic transfer according to Oguguah and Ikegwu (2017). It is important to note that the bioaccumulation of heavy metals beyond the threshold levels can have negative effects on fish populations and physiology, such as the interruption of communication of fish with their aquatic environment, deformities in survival, growth rates, phenotypic appearance and general well-being (Ali *et al.,* 2019).

In the present study, Fe, Zn and Mn were detected in all the fish species examined. These metals are classified as nutritionally essential metals, and are thus required in living organisms but excess or deficiency have deleterious consequences (Hovinga *et al*., 1993; Goyer *et al.,* 2004). The mean concentrations of Fe in *C. senegalensis* (58.39 mg/kg)*, C. stampfili* (45.47 mg/kg)*, L. goreensis* (58.61 mg/kg) were higher than the permissible limits of 43.0 mg/kg set by FAO/WHO (Food and Agriculture Organization / World Health Organization); the FAO/WHO permissible level for Mn (5.5 mg/kg) was exceeded in those fishes above with values 14.04 mg/kg, 13.30 mg/kg and 10.71 mg/kg respectively.; while the FAO safe limit of 40 mg/kg for Zn was only exceeded in *H. fasciatus* (61.18 mg/kg) although was still safe with WHO permissible However, Ni is classified as a metal with possible beneficial effect (Goyer *et al.,* 2004); Pb and Cd are classified as metals with no beneficial effects (Goyer *et al.,* 2004; Turkmen *et al.,* 2006).

In the present study, the concentrations of these non-essential or potentially toxic metals were lower than FAO/WHO permissible limits, except in *C. senegalensis* and *L. goreensis* where Pb exceeded the limit of 2.0 mg/kg (World Health Organization [WHO], 1989), and Cd mean concentration critical limit of 0.50 mg/kg (FAO, 2011; EC, 2006) was exceeded in *C. senegalensis, C. stampfili, P. quadrifilis* and *H. fasciatus.* In contrast, Ayoola *et al. (*2014) reported a non-detectable concentration of Pb in *H. fasciatus* collected at the Bariga refuse dump site, Lagos Lagoon; while Aderinola *et al.* (2012), pointed that excessive Pb levels could be linked to the refuse dumping activities prevalent in the lagoon and constant inflow of industrial wastes. Cadmium is noted as one of the carcinogens in humans (Goyer, 2004), and known to affect kidney functions, cause poor reproductive capacity, hypertension, tumours and hepatic dysfunction (Waalkes, 2000; Rohasliney *et al.,* 2014).

The concentration of Ni, another human carcinogen (Goyer, 2004), in this present study was higher than the permissible limit of 0.5 – 0.6 mg/kg recommended by WHO (1985), in *H. fasciatus* and *P. quadrifilis.* These concentrations of carcinogens exceeding the permissible limits in some fishes from the Lagos Lagoon is of serious public health concern and the sources of these contaminants must be arrested and adequate measures to curtail the harm to public health from consumption of these fishes taken by government authorities and coastal communities. High values of these essential metals have been reported by Kawsher *et al.* (2016) and Oguguah and Ikegwu (2017). However, there is need to checkmate the over enrichment of the natural habitat of those species with mean concentrations above the FAO/WHO threshold so that toxicity from the excessive consumption of these essential metals do not occur.

Sources or pathway of Pb, Cd and Ni into the lagoon include the uncontrolled and untreated waste water, industrial effluents (lead mining, cement production, electroplating, nickel-cadmium batteries, coal utilization and tobacco smoking) and leachate from landfills and dumpsite. Some of these companies discharge their waste, either directly or indirectly into the lagoon. Of note is that cigarette tobacco, which is commonly smoked in recent times in some of these coastal communities, contain about 0.5 – 2.0 µg of cadmium and about 10% of the Cd content is inhaled and some are retained in the ash (WHO, 1992) that dropped on the soil, which are later washed into the lagoon as run-offs during flooding. Cadmium contamination of fish was the main cause of the endemic bone disease "itai-itai" reported from Japan, during which several people were affected (Ajagbe *et al.*, 2012; Singh, 2016). Nickel is known to cause asthma, cardiovascular disease, lung fibrosis and respiratory tract cancer (Chen *et al.*, 2017)

The metals in the muscle of the species had target hazard quotient (THQ) of less than 1, indicating a low risk of non-carcinogenic repercussions per metal. This suggested that the species do not presently constitute health risks upon ingestion by final consumers. On the other hand, fish consumers are frequently exposed to many pollutants and may have combined or interacting effects, thus the need to calculate the HI (hazard index), which was however also less than 1. The carcinogenic risk for the metals investigated in this study was found to be negligible when the TR was examined. As a result, consumption of any of these species from the Lagos Lagoon is safe with no health risks at present. However, there is probability of contracting cancer due to the exposure to Cd, Pb and Ni from the consumption of the studied fishes from Lagos Lagoon over a lifetime of 55 years or more.

In conclusion, the concentration of the studied heavy metals varied in the different fish species examined with values above the WHO/FAO/EC permissible levels exceeded in three principal species namely *C. stampfili, C. senegalensis* and *L. goreensis.* The estimation of the non-carcinogenic risk (THQ and HI) in this present investigation showed no adverse health risk from the consumption of any of those fishes selected. However, from the target cancer risk (TR) assessment, the presence of Cd, Pb and Ni in those fishes studied may increase the chances of fish consumers to cancer in the future. These findings underscores the urgent need for regular biomonitoring of the coastal communities and the regulatory bodies conduct their oversight duties in the analyses of treated effluents, examining of industrial storage facilities to ensure standard methodologies are strictly followed. Public awareness especially in coastal environments, on the health implications of the discharge of pollutants into the aquatic environment becomes imperative. The data obtained from this study project the fish species as good bio-indicators for the monitoring of aquatic pollution.

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