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Bioaccumulation of Heavy Metals and Potential Health Risk through Consumption of Seafoods from Selected Creeks in Rivers State, Nigeria

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ABSTRACT

Excessive oil exploration, pipeline destruction, agricultural activities, and other man-made activities including aerosol sedimentation elevate the levels of heavy metals in the surroundings that leach into the creeks. The seafoods bioaccumulates these metals often times within their body system. This work aimed at using seafood samples, Scylla serrata (crab) Clarias gariepinus (catfish), Oreochromis niloticus (tilapia fish), and Physella acuta (snail) as a bioindicator of heavy metal contamination from Ahoada, Omoku, Ndoni, and Choba creeks **in Nigeria.** The levels of Lead (Pb), Cadmium (Cd), Chromium (Cr), Copper (Cu), Arsenic (As), and Zinc (Zn) were determined in the seafood samples collected from the study creeks during September 2019. Forty-eight (48) samples comprising of *S. serrata*, *C. gariepinus*, *O. niloticus*, and *P. acuta* were digested and examined for heavy metal concentrations using Flame Atomic Absorption Spectrophotometer. The levels of Pb, Cd, Cr, Cu, As and Zn ranged between 0.310 ± 0.008 to 5.312 ± 0.009 mg/kg; 0.008 ± 0.004 to 1.310 ± 0.010 mg/kg; 2.082 ± 0.012 to 9.013 ± 0.010 mg/kg; 3.014 ± 0.010 to 13.526 ± 0.006 mg/kg; 0.007 ± 0.005 to 0.182 ± 0.005; and 2.015 ± 0.008 to 8.135 ± 0.007 mg/kg respectively. The obtained results were employed in assessing the non-carcinogenic and carcinogenic health risk in human due to the consumption of the mentioned species. The concentrations of trace elements reported in tissue samples were within the known background levels. However, alarming concentrations were found for Pb, Cd, and Cr that recorded higher values than the safe levels according to the FAO/WHO, and USEPA. The present results reaveled that the ingestion of tested species is safe and free from non-carcinogenic risks. However, there is a carcinogenic risk may be emerging due to the steady ingestion of Cr via these aqua forms by the populace.

1. INTRODUCTION

Industrialization has come with diverse impacts with a tremendous ecological and health concerns, the contamination of seafood is one of them. World ingestion of seafood has increased because of their nutritional and medicinal values. Besides its importance as a major protein source, fish in particular has an important essential minerals, vitamins and polyunsaturated fatty acids **(Lake *et al*., 2018)**.

Heavy metal discharge swiftly combines with matter and finally settles down as residues by running off the surface **(Onisokyetu *et al*., 2016)**. These thick components get access into the oceanic natural way of life and accumulated into seafood's tissues, by two major ways, direct consumption of water or food as well as non-dietary routes across permeable membranes such as muscles and gills. Hence, the metal concentration and the time of exposure to metal hazardous typically represents the heavy metal concentration observed in sediment and water **(Lake *et al*., 2018)**. In aquatic environment, sediment acts as a reservoir for heavy metals and Part of these heavy metals are then released into the water column as a potential secondary source of contaminants. These contaminantes do not have any recognized regulatory system and unfortionally bioaccumulat to aquatic organisms creating a potential threat not only to the aquatic ecosystem but also to human via ingeston of contaminated seafood. Metal hazardous are commonly poisonous with very unfavorable effects on human, such as neurotoxic and carcinogenic effects **(Morais and Pereira, 2012)**. Several works have been done on the safety of seafood consumption. In some instances, fish catches were banned because their total mercury content or other metals content (like cadmium) was above the threshold set by the World Health Organization (WHO) and Food and Agriculture Organization (FAO) **(Khoshnood and Khoshnood, 2013)**. Chemical analysis of non-living matter alone cannot directly assess the real ecotoxicological effect on human **(Enuneku *et al*., 2018)**. Therefore, the United States Environmental Protection Agency (USEPA), presented the Target Risk Quotient (THQ) to be utilized to assess the dangers presented by these toxins in a long haul. Target Hazard Quotient (THQ) is a fraction of the concentration measured and reference dosage, weighed by the exposure intensity and the ingested amount plus body mass.

In the Niger Delta area of Nigeria, creeks are utilized for multiple human activities. People living within the Niger Delta, creeks and its environs rely on seafoods in order to meet their daily nutritional needs. These seafoods are obtained from riverine communities which are often exposed to crude oil spills or discharges of dangerous effluents. To guard against this, we found it relevant to conduct the experiment in Rivers State due to the oil production, bunkering and illegal refineries activities occuering there.

This study aimed to evaluate whether the toxicity state, of most four common seafoods in River State, Nigeria (*Scylla serrata*, *Clarias gariepinus*, *Oreochromis niloticus* and *Physella acuta*) (Fig. 1), has exceeded the acceptable limits for consumption or not. As well as provide an adequate background about the heavy metal contamination levels at the study sites.

Scylla serrate (Crab) **(FAO, 2001)**

Clarias gariepinus (African catfish) **(Khater, 2018)**

Oreochromis niloticus (Tilapia) **(Martin *et al*., 2019)**.

Physella acuta (Snail) **(Yotarou, 2006)**

Figure 1: *Scylla serrata, Clarias gariepinus, Oreochromis niloticus* and *Physella acuta.*

2. MATERIALS AND METHODS

2.1. Study area

The study areas, Ahoada, Omoku, Ndoni and Choba, were illustrated in (Fig. 2). Ahoada is located in the northwest of Port Harcourt city at the Orashi region in Rivers State, Nigeria. Orashi region is notable for its river, Orashi River (5°48′35″N 7°4′23″E). It is claimed that the Orashi region contains about 35% of oil well in the Niger Delta states of Imo and Rivers **(Mmom and Aifesehi, 2013)**. Men within Orashi communities are predominantly farmers, fishermen and traders.

Omoku is a town in Rivers State Nigeria (5.342°N 6.656°E). It has a population of about 200,000 people in which fishing, hunting, trading are the primary source of livelihood. Omoku is the capital of Ogba/Egbema/Ndoni local government area which contains many oil companies such as Nigerian Agip Oil Company, Shell Petroleum Development Company, and Total Exploration & Production Nigeria.

Ndoni is a town in Ogba–Egbema–Ndoni (also spelled Ogba/Egbema/Ndoni) local government area of Rivers state, Nigeria (5 33' 0'' North, 6° 35' 0'' East). Ndoni is a very important town for oil companies and various oil pipelines. The people of Ndoni are predominantly farmers, fishermen and traders.

Choba is a town in Obio/Akpor local government area of Rivers State, Nigeria. It is located between longitude 60^0 54' 20'' east and latitude 40^0 53' 15'' north of the equator. Choba is famously known for housing the University of Port Harcourt. Choba has a river called the New Calaber River which lies between longitude 006º53 53086'E and latitude 04º53' 19.020'N. Unfortionally, the river is a black water type and within the vicinity of the rapidly oil expanding region **(Dienye and Woke, 2015)**. The people living in Choba consists of farmers, fishermen, students, and civil servants.

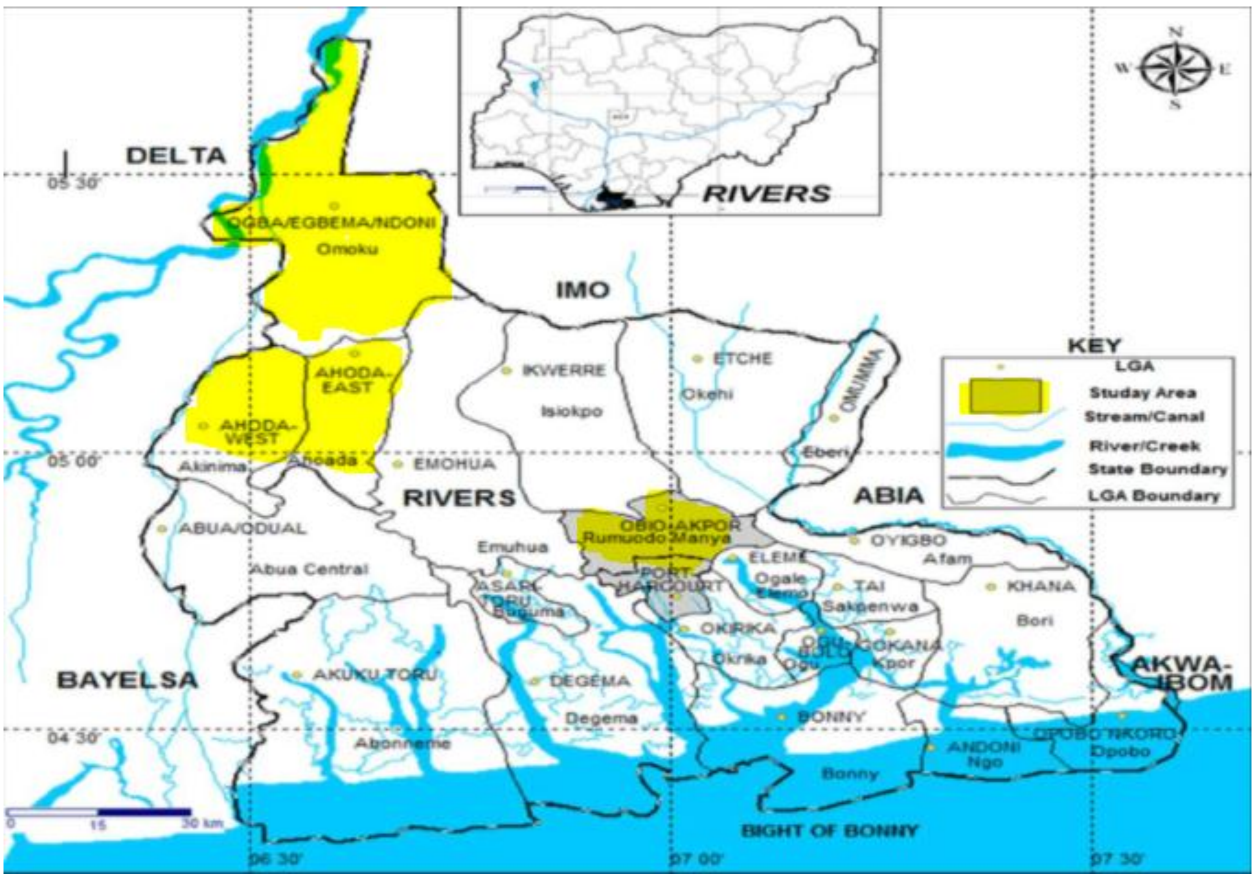

Figure 2: Map of Rivers State showing study locations **(Akukwe and Ogbodo, 2015)**.

2.2. Sample collection

By using a quasi-sampling technique, three samples of each studied seafood kind (Crab, Catfish, Tilapia, and Snail) were collected during September 2019 from the study sites at Rivers State, Nigeria.

2.3 Sample preparation for metal determination

In the laboratory, the collected samples were washed with distilled water to remove the mud, fouling substances or contaminated particles. Muscle tissue of the collected specimens (dorsal muscle), which considerd as the major target tissue for metal storage **(Rejomon *et al*., 2010),** was removed for metal analysis with a clean stainless steel knife. Tissues were cut and air-dried to a constant weight for removing the extra water and then stored at −20 °C. A wet digestion method was used and determination of metals was performed with a Solar Thermo-Elemental Flame Atomic Absorption Spectrometer (STEF-AAS) (Model S4-71096, Germany). Each sample was analyzed in triplicate and double-distilled deionised water was used throughout the study. Prior to use, the glassware and plasticware (Merck, Germany) were sanitized with 10% HNO_3 followed by washing with deionised distilled water. One gram of each sample was carefully weighed in a conical flask. Two milliliter (2mL) of the mixed acid H_2SO_4: HNO_3: $HClO_4$ in the ratio of 40: 40: 20 was added and then digested in a hot plate under a fume cupboard until white fumes appeared. It was allowed to cool down, then transferred into a 100 ml volumetric flask and filled up to the 100 ml mark of the volumetric flask with distilled water.

2.4. Health Risk Assessment of Heavy Metals

Several toxicological indices as mentioned below were used to estimate the health risk as a concequance of seafood consumption. In this work, the health hazard, due to metals ingestion via fish consumption, were based on heavy metal evaluation and records according to EPA guidelines (2004).

2.5. Estimated Daily Intake of Metals (EDI)

The Daily Intake of Metals (EDI) of each heavy metal in this work was determined through the equation:

$$EDI = \frac{C_{metal} x\, D_{food\ consumption}}{BW_{average}}$$

Where,

C_{metal} = the metal concentration in each fish samples in mg/kg,

$D_{food\ consumption}$ = the daily intake of food in kg person^{-1}

$BW_{average}$ = the average body weight in kg person^{-1} (70kg for Adult)

The daily intake of fish per person is 0.031 kg/day **(Vanguard, 2014)** was assumed in this study. Average body weight was considered to be 70 kg for adult and 24 kg for children **(USEPA, 2011)**.

2.6. Non – Carcinogenic Health Effect

2.6.1.Target Hazard Quotient

Non- carcinogenic hazard estimation of heavy metals intake was determined using THQ values. THQ is a ratio of the determined dose of a pollutant to a reference level which was taken into consideration. THQs were calculated consistent with the technique defined by the

Environmental Protection Agency (EPA) in the USA **(USEPA, 1989; Singh *et al.*, 2010; USEPA, 2011)**.

$$THQ = \frac{Efr\ x\ ED\ x\ FIR\ x\ C\ x\ 10^{-3}}{RfDo\ x\ BW\ x\ ATn}$$

Where,

Efr = Exposure frequency = 365days/year

ED = Exposure Duration = 53 years, identical to the mean life time of a Nigerian.

FIR = Average ingestion in kg per person per day

C = Concentration of metallic elements in food sample (mg/kg)

R_fDo = Oral reference dose (mg/kg)

BW = Average Body Weight of adult = 70kg

ATn = Average time of exposure in days for a non-carcinogen (19,345)

10^{-3} = unit of conversion

2.6.2. Hazard Index (HI)

Human health risks due to the intake of metal contaminated seafood was assessed by determining the Hazard Index (HI). If the value of HI is below 1, then the uncovered populace is probably not going to encounter evident antagonistic impacts. While HI value above 1 means that there is a possibility of non-carcinogenic effect, with an increasing probability as the value increases. The Supposing cumulative effects, HI was calculated as follows:

Total Hazard Index (HI) = Sum of THQ (THQ_{Pb}+ THQ_{Cd}+ THQ_{Ni}+ $THQ_{Cr\ldots\ldots}$)

Where,

R_fDo = Oral reference dose (mg/kg)

2.7. Carcinogenic Health Effect

2.7.1. Carcinogenic Risk (CR)

USEPA distinguishes between the cancer-causing agents by the load of proof characterization of the compound. The evaluated every day portion and the malignant slope factor were multiplied together to determine the lifetime cancer chance presented by the metal hazard. Malignancy slope factors are evaluations of cancer-causing intensity and are utilized to relate every day portion of a substance over a lifetime. Ingestion malignancy incline factors are communicated in units of (mg/kg/day).

Lifetime likelihood of reaching disease due to the cancer-causing synthetic substances is determined as follows:

Carcinogenic Risk = EDI x CSF_{ing}

Where,

EDI is the estimated daily intake of each heavy metal (mg/kg/day)

CSF_{ing} is the ingestion cancer slope factors $(mg/kg/days)^{-1}$

USEPA in 2011 stated that 10^{-6} (1 of every 1,000,000) to 10^{-4} (1 out of 10,000) is a range of passable anticipated lifetime dangers for cancer-causing agents. Metals for which the hazard factor falls underneath 10^{-6} might be disposed of from further thought as a compound of concern. The hazard related with the cancer-causing impact of target metal is communicated as the abundance likelihood of reaching malignant growth over a lifetime of 70years.

2.8. Statiscal Analysis

The data was analyzed using statistical package for social science version 16.0 (SPSS Inc., Chicago, IL, USA). The mean and the standard deviation error were obtained to compare the variation between groups of same samples.

3. RESULTS

3.1. Heavy metal levels in the seafoods samples

Seafood samples, comprising of *Scylla serrata, Clarias gariepinus, Oreochromis niloticus* and *Physella acuta*, were examined for Cr, Cu, Cd, Pb, As and Zn. The obtained results were presented in Table 1. The mean levels of Pb ranged from 0.310 ± 0.008 mg/kg to 5.312 ± 0.009 mg/kg. The highest Pb value (5.312± 0.009 mg/kg) was recorded in *P. acuta* from Ndoni creek, whereas the lowest concentration (0.310 ± 0.008 mg/kg) was found in *O. niloticus* obtained from Ahoada creek. Cd mean concentration in the seafood samples ranged from 0.008 ± 0.004 mg/kg in *S. serrata* obtained from Choba creek to 1.310 ± 0.010 mg/kg in *O. niloticus* from Ahoada creek. The lowest value of Cr (2.082 ± 0.012 mg/kg) was found in *O. niloticus* obtained from Ndoni creek while the highest one (9.013 ± 0.010 mg/kg) was recorded in *P. acuta* from Ahoada creek. Copper recorded the lowest concentration value (3.014 ± 0.010 mg/kg) in *C. gariepinus* obtained from Omoku creek and the highest concentration value (13.526 ± 0.006 mg/kg) in *S. serrate* from Ahoada creek. The mean concentration of As in the seafood samples was ranged from 0.007 ± 0.004 mg/kg in *P. acuta* obtained from Choba creek to 0.182 ± 0.005 mg/kg in *C. gariepinus* from Omoku creek. *C. gariepinus* from Omoku creek has the highest concentration value of Zn (8.135 ± 0.008 mg/kg), while the lowest level of Zn was observed in *S. serrata* sample obtained from Ndoni creek (2.015 ± 0.008 mg/kg).

Table 1: Concentration of Heavy Metals in Seafoods (mg/kg)

LOCATION	SAMPLE	Pb	Cd	Cr	Cu	As	Zn
AHOADA	***S. serrata***	3.113±0.011	0.130 ± 0.007	8.024 ± 0.010	13.526 ±0.006	0.023 ± 0.006	4.638 ± 0.006
	C. gariepinus	1.084 ± 0.011	0.054 ± 0.016	6.243 ± 0.010	9.754 ± 0.011	0.087 ± 0.009	6.072 ± 0.011
	O. niloticus	0.310 ± 0.008	0.018 ± 0.008	3.605 ± 0.008	6.242 ± 0.009	0.022 ± 0.009	3.641 ± 0.005
	P. acuta	4.514 ± 0.006	1.310 ± 0.010	9.013 ± 0.010	5.319 ± 0.008	0.146 ± 0.008	5.846 ± 0.012
OMOKU	***S. serrata***	1.832 ± 0.010	0.411 ± 0.012	5.011 ± 0.011	9.210 ± 0.005	0.037 ± 0.009	2.946 ± 0.007
	C. gariepinus	7.317 ± 0.009	0.943 ± 0.012	8.683 ± 0.009	3.014 ± 0.010	0.182 ± 0.005	8.135 ± 0.008
	O. niloticus	3.193 ± 0.007	0.102 ± 0.005	4.054 ± 0.009	7.335 ± 0.008	0.031 ± 0.007	3.896 ± 0.007
	P. acuta	4.027 ± 0.008	1.043 ± 0.010	7.140 ± 0.010	9.326 ± 0.009	0.021 ± 0.002	4.292 ± 0.010
NDONI	***S. serrata***	3.587 ± 0.017	0.016 ± 0.008	6.620 ± 0.010	10.856 ±0.010	0.008 ± 0.006	2.015 ± 0.008
	C. gariepinus	3.083 ± 0.012	0.513 ± 0.011	4.032 ± 0.011	5.333 ± 0.007	0.082 ± 0.012	6.521 ± 0.010
	O. niloticus	1.920 ± 0.019	0.015 ± 0.006	2.082 ± 0.012	9.037 ± 0.006	0.016 ± 0.008	7.844 ± 0.006
	P. acuta	5.312 ± 0.009	0.024 ± 0.008	3.054 ± 0.008	6.164 ± 0.006	0.024 ± 0.008	3.014 ± 0.005
CHOBA	***S. serrata***	1.016 ± 0.008	0.008 ± 0.004	2.586 ± 0.009	4.134 ± 0.008	0.021 ± 0.007	5.138 ± 0.009
	C. gariepinus	0.318 ± 0.016	0.082 ± 0.014	4.052 ± 0.011	10.134 ± 0.008	0.107 ± 0.011	3.419 ± 0.011
	O. niloticus	2.545 ± 0.016	0.204 ± 0.006	8.527 ± 0.007	4.027 ± 0.005	0.069 ± 0.006	8.006 ± 0.006
	P. acuta	2.104 ± 0.006	0.032 ± 0.011	5.012 ± 0.008	5.084 ± 0.015	0.007 ± 0.005	4.684 ± 0.005
PERMISSIBLE LIMITS							
WHO/FAO (1989)		0.5	0.5	0.6	30	-	40
FAO/WHO (1993)		0.214	0.1	-	3.0	-	60.0
USEPA (Mishra *et al.*, 2007)		4	0.2	8	120	1.2	120
WHO/FAO (Petkovšek *et al.*, 2011)		1.5	0.1	-	-	-	50

3.2. Estimated daily intake (EDI) of metals in the exposed population

The estimated daily intake of the seafoods samples were presented in Table 2. The EDI of Pb in the present study was found between 1.4 E-04 kg/person/day and 0.003 kg/person/day. *C. gariepinus* sample from Omoku creek recorded the highest value of 0.003 kg/person/day. The EDI of Cd has values between 3.5 E-06 and 5.8 E-04 kg/person/day. The highest value (5.8 E-04 kg/person/day) was obtained in *P. acuta* sample from Ahoada creek. The EDI of Cr ranged from 9.2 E-04 to 0.004 kg/person/day. The Highest value of Cr (0.004 kg/person/day) was recorded in *S. serrata* and *P. acuta* from Ahoada creek; *C. gariepinus* and *O. niloticus* from Omoku and Choba creeks respectively. Cu recorded the highest EDI value (0.006 kg/person/day) in *S. serrata* sample from Ahoada creek, while the lowest value was 8.4 E-04 kg/person/day. The lowest EDI value of As was 3.1 E-06 and the highest value which was recorded in . *C. gariepinus* sample from Omoku creek was 8.1 E-05 kg/person/day. 8.9 E-04 was the lowest EDI value of Zn while the highest value was 0.004 kg/person/day and it was recorded in *C. gariepinus* and *O. niloticus* samples from Omoku, Ndoni, and Choba creeks.

3.3. Target hazard quotient and hazard index of metals in adult population

The results obtained from target hazard quotient (THQ) and hazard index (HI) were presented in Table 3. The THQ of Pb was found in the range of 3.4 E-04 to 0.008. The highest level of Pb was found in *C. gariepinus* from Omoku creek (0.008). The THQ of Cd ranged from 3.5 E-06 to 5.8 E-04 and the highest value was obtained in *P. acuta* from Ahoada creek (5.8 E-04). The lowest THQ value of Cr was 1.8 E-04, while the higest value, which was recorded in *P. acuta* snail obtained from Ahoada creek, was 8.0 E-04. *Scylla serrate* sample obtained from Ahoada creek has the highest THQ value of Cu (1.5 E-04), while The lowest value was 3.3 E-05. The THQ of As was found in the range of 1.0 E-05 to 2.7 E-04 with the highest recorded value in *C. gariepinus* catfish from Omoku creek (2.7 E-04). The THQ of Zn in seafood samples ranged from the lowest value 3.0 E-06 and the highest value 1.2 E-05 which was recorded in *C. gariepinus* and *O. niloticus* samples from Omoku, Ndoni, and Choba creeks respectively.

The Hazard Index of metals was found in the range of 0.001 to 0.010. The highest HI value was obtained in *C. gariepinus* sample from Omoku creek.

Table 2: Estimated Daily Intake (EDI) of Metals in Seafood for Adult Population (kg/person/day)

LOCATION	SAMPLE	Pb	Cd	Cr	Cu	As	Zn
AHOADA	***S. serrata***	0.001	5.8 E-05	0.004	0.006	1.0 E-05	2.1 E-03
	C. gariepinus	4.8 E-04	2.4 E-05	0.003	0.004	3.9 E-05	0.003
	O. niloticus	1.4 E-04	8.0 E-06	0.002	0.003	9.7 E-06	0.002
	P. acuta	0.002	5.8 E-04	0.004	8.4 E-04	6.5 E-05	0.003
OMOKU	***S. serrata***	8.1 E-04	1.8 E-04	0.002	0.004	1.6 E-05	0.001
	C. gariepinus	0.003	4.2 E-04	0.004	0.001	8.1 E-05	0.004
	O. niloticus	0.001	4.5 E-05	0.002	0.003	1.4 E-05	0.002
	P. acuta	0.002	4.6 E-04	0.003	0.004	9.3 E-06	0.002
NDONI	***S. serrata***	0.002	7.1 E-06	0.003	0.005	3.5 E-06	8.9 E-04
	C. gariepinus	0.001	2.3 E-04	0.002	0.002	3.6 E-05	0.003
	O. niloticus	8.5 E-04	6.6 E-06	9.2 E-04	0.004	7.0 E-06	0.004
	P. acuta	0.002	1.1 E-05	0.001	0.003	1.1 E-05	0.001
CHOBA	***S. serrata***	4.4 E-04	3.5 E-06	0.001	0.002	9.3 E-06	0.002
	C. gariepinus	1.4 E-04	3.6 E-05	0.002	0.005	4.7 E-05	0.002
	O. niloticus	0.001	9.0 E-05	0.004	0.002	3.1 E-05	0.004
	P. acuta	9.3 E-04	1.4 E-05	0.002	0.002	3.1 E-06	0.002
Recommended tolerable daily intake (TDI)		0.00	0.000	0.1-1.2[A]	0.9	6.3×10^{-8}	8
upper tolerable daily intake (UTDI)		0.240	0.064		10.00	0.002	40

Recommended tolerable daily intake (TDI) and upper tolerable daily intake (UTDI) levels of heavy metals in food stuffs (FDA, 2001; Garcia – Rico, 2007); Tolerable Daily Intake of heavy metals by human as prescribed by JECFA (1995)

Table 3: Target Hazard Quotient (THQ) and Hazard Index (HI) of Metals in Seafood for Adult Population

LTN	SAMPLE	THQ						HI
		Pb	Cd	Cr	Cu	As	Zn	
AHOADA	***S. serrata***	0.004	5.8 E-05	7.1 E-04	1.5 E-04	3.4 E-05	6.9 E-06	0.005
	C. gariepinus	0.001	2.4 E-05	5.5 E-04	1.1 E-04	1.3 E-04	9.0 E-06	0.002
	O. niloticus	3.4 E-04	8.0 E-06	3.2 E-04	6.9 E-05	3.5 E-05	5.4 E-06	7.8 E-04
	P. acuta	0.005	5.8 E-04	8.0 E-04	5.9 E-05	2.2 E-04	8.6 E-06	0.007
OMOKU	***S. serrata***	0.002	1.8 E-04	4.4 E-04	1.0 E-04	5.5 E-05	4.4 E-06	0.003
	C. gariepinus	0.008	4.2 E-04	7.7 E-04	3.3 E-05	2.7 E-04	1.2 E-05	0.010
	O. niloticus	0.004	4.5 E-05	3.6 E-04	8.1 E-05	4.6 E-05	5.8 E-06	0.005
	P. acuta	0.005	4.6 E-04	6.3 E-04	1.0 E-04	3.1 E-05	6.3 E-06	0.006
NDONI	***S. serrata***	0.004	7.1 E-06	5.9 E-04	1.2 E-04	1.2 E-05	3.0 E-06	0.005
	C. gariepinus	0.003	2.3 E-04	3.6 E-04	5.9 E-05	1.2 E-04	9.6 E-06	0.004
	O. niloticus	0.002	6.6 E-06	1.8 E-04	1.0 E-04	2.4 E-05	1.2 E-05	0.002
	P. acuta	0.006	1.1 E-05	2.7 E-04	6.8 E-05	3.5 E-05	4.5 E-06	0.006
CHOBA	***S. serrata***	0.001	3.5 E-06	2.3 E-04	4.6 E-05	3.1 E-05	7.6 E-06	0.001
	C. gariepinus	3.5 E-04	3.6 E-05	3.6 E-04	1.1 E-04	1.6 E-04	5.1 E-06	0.002
	O. niloticus	0.003	9.0 E-05	7.6 E-04	4.5 E-05	1.0 E-04	1.2 E-05	0.004
	P. acuta	0.002	1.4 E-05	4.4 E-04	5.6 E-05	1.0 E-05	6.9 E-06	0.003
STANDARD		1	1	1	1	1	1	1

3.4. Life Cancer Risk of Heavy Metals in Adult Population via Consumption of Seafood

Life Cancer Risk (LCR) for the consumption of the seafoods were estimated and presented in table 4. The LCR of Pb was found in the range of 1.2 E-06 to 2.6 E-05. The LCR of Cd in the seafood samples was found in the range of 4.2 E-08 to 2.2 E-04. The LCR of Cr in seafood samples was found in the range of 4.6 E-04 to 0.002 while the LCR of As in the seafood samples was found in the range of 4.7 E-06 to 1.2 E-04

Table 4: Lifetime Cancer Risk (LCR) of Metals in Seafood for Adult Population

LTN	SAMPLE	Pb	Cd	Cr	As
AHOADA	***S. serrata***	8.5 E-06	2.2 E-05	0.002	1.5 E-05
	C. gariepinus	4.1 E-06	9.1 E-06	0.002	5.9 E-05
	O. niloticus	1.2 E-06	3.0 E-06	0.001	1.5 E-05
	P. acuta	1.7 E-05	2.2 E-04	0.002	9.8 E-05
OMOKU	***S. serrata***	6.9 E-06	6.8 E-05	0.001	2.4 E-05
	C. gariepinus	2.6 E-05	1.6 E-04	0.002	1.2 E-04
	O. niloticus	8.5 E-06	1.7 E-05	0.001	2.1 E-05
	P. acuta	1.7 E-05	1.8 E-04	0.002	1.4 E-05
NDONI	***S. serrata***	1.7 E-05	2.7 E-06	0.002	5.3 E-06
	C. gariepinus	8.5 E-06	8.7 E-05	0.001	5.4 E-05
	O. niloticus	7.2 E-06	2.5 E-06	4.6 E-04	1.1 E-05
	P. acuta	1.7 E-05	4.2 E-08	5.0 E-04	1.7 E-05
CHOBA	***S. serrata***	3.7 E-06	1.3 E-06	5.0 E-04	1.4 E-05
	C. gariepinus	1.2 E-06	1.4 E-05	0.001	7.1 E-05
	O. niloticus	8.5 E-06	3.4 E-05	0.002	4.7 E-05
	P. acuta	7.9 E-06	5.3 E-06	0.001	4.7 E-06
STANDARD		10^{-6} to 10^{-4}	10^{-6} to 10^{-4}	10^{-6} to 10^{-4}	10^{-6} to 10^{-4}

4. DISCUSSION

4.1. Concentration of Heavy Metals in Seafoods from Selected Creeks in Rivers State

It was observed that, in most of the analyzed seafood samples, Pb exceeded the permissible limit (0.5 mg/kg) by **WHO/FAO (1989)** as presented in Table 1. Only tilapia and catfish obtained from Ahoada and Choba creeks had Pb levels lower than the safe limit by **WHO/FAO (1989)**.

Furthermore, all the analyzed seafood samples recorded Pb levels higher than the permissible limit, 0.214 mg/kg, applied by **FAO/WHO (1999)**. Meanwhile, over 75% of the Pb contents of the analyzed seafood samples were less than the 4.0 permissible limit by USEPA **(Mishra *et al.*, 2007)** with exception of *P. acuta* and *C. gariepinus* from

Ahoada, Omoku, and Ndoni creeks respectively which exceeded the required permissible limit by USEPA. Again, over 75% of the seafood samples analyzed for Pb were higher than the 1.5 permissible limits by WHO/FAO **(Petkovšek *et al.*, 2011)**. These results showed that the examend samples have an increased Pb values in their tissues which may lead to Pb poisoning in the populace depending on the studied species as a main source of food. The high concentration of Pb in the examined samples might be because of contaminants in river bodies, ranch soil (ranch site) debased by unrefined petroleum from oil investigation and misuse or because of contamination from the interstate traffic **(Qui *et al.*, 2000; Baird, 2002)**. Furthermore, high concentration of Pb could be as a result of increase in mobile metal fraction of Pb and high level of oil exploration **(Siebe, 1995)**.

The recorded Pb values in our study were higher than values reported by **Abu and Nwokoma (2016)** on the bioaccumulation of selected heavy metal in water, sediment and bluecrab (*Callinectes amnicola*) from Bodo creek, Niger Delta, Nigeria. The present study corroborated with the study of **Farombi *et al*. (2007)** who reported that Pb, Cd, and Fe are the major heavy metals associated with Nigerian crude oils. Also, the concentrations of Pb gotten from the present study were higher than that reported by **Agwu *et al*. (2018**).

Lead is not useful for fish, and too much amounts can cause decreases in the sustenance of life, and growth rates, as well as development and metabolism, in addition to increased mucus formation in the quatic species. The bioaccumulation of Pb in human body, over long periods, above certain threshold can irreversibly harm the brain **(Bakare-Odunola, 2005; Lawrence, 2014)**. Lead is a commutative toxin and a potential human cancer-causing agent. It might likewise cause the advancement of autoimmunity where an individual's insusceptible framework attacks its own cells. This can prompt multiple illness or dysfunction of the kidneys, circulatory system and neurons **(Bakare-Odunola, 2005)**. Also, kids in areas of high Pb contents are in danger of lead toxicity since they retain lead more quickly than grown-ups. Neurologic problems in children are the principal effects of chronic Pb exposure **(Goyer and Clarkson, 2001)**. **Parkin *et al*. (2010)** indicated that there is an increase in malignant growth cases, disabled neurological issue, and lack of healthy sustenance among youngsters in Uganda.

The findings from this study showed that about 80% of the analyzed seafood had Cd levels higher than the 0.5 permissible limit by **WHO/FAO (1989)**. *P. acuta* and *C. gariepinus*, obtained from Ahoada, Omoku, and Ndoni creeks exceeded the permissible limit. Over 45% of the tested samples exceeded the 0.1 mg/kg permissible limit applied by FAO/WHO **(Petkovšek *et al.*, 2011)**. Furthermore, about 49% of the analyzed samples exceeded the 0.2 mg/kg permissible limit by USEPA **(Mishra *et al*., 2007)**.

Generally, there was an increase in the level of Cd in the analyzed seafood. The elevated value of Cd may be attributed to increased fertilizer usage in cultivation. These fertilizers were washed into the river elevating the Cd concentration in water which are further accumulated by the tissues of aquatic organisms. Comparing findings to the work of previous scientists, there were low concentrations of Cd observed which does not concur with the study by **Farombi *et al*. (2007)** who reported high concentrations of Cd in *S. serrata* sample. while, the obtained concentrations of Cd agreed with the resuts that were recorded by **Nkpaa *et al*. (2013)** which were high compared to the permissible level of 0.01 mg/kg. Exposure to Cd has been linked to kidney damage and hypertension **(Sivaperumal *et al*., 2007; Yujun *et al*., 2011; Lawrence, 2014)**. Humans are exposed to Cd through food and the average daily intake for adults has been estimated to be approximately 50 mg **(Calabrese *et al*., 1985)**. The limit for intense Cd poisoning is accounted for the ingestion of 3-15 mg. Serious dangerous manifestations are accounted for the ingestions of 10-326 mg. Lethal ingestions of Cd, causing shock and intense renal failure, occuers when the ingestion rates surpassing 350 mg **(NAS-NRC, 1974; NAS-NRC, 1975; NAS-NRC, 1982)**. Wellbeing side effects could radiate from the admission of Compact disc and side effects have been accounted for Cd esteems running from 10-326 mg g–1 **(EPA, 2004)**. Cd toxicity casue intense renal damage and can occur by consumption rate above 350 mg g^{-1} **(Obrien *et al*., 2003)**.

It was observed from the study that Cr concentration in all analyzed seafood samples exceeded the 0.6 mg/kg permissible limit by **WHO/FAO (1989)**, however, about 75% of the analyzed samples was within the 8.0 mg/kg recommended permissible limit by USEPA **(Mishra *et al*., 2007)**. Consequently, *S. serrata* and *P. acuta* obtained from Ahoada creek; and *C. gariepinus* and *O. niloticus* obtained from Omoku and Choba creeks was higher than the recommended permissible limit by USEPA **(Mishra *et al*., 2007)**. This showed that the concentrations of Cr in the analyzed seafood samples was high and may lead to health risk if frequently consumed. The high concentrations of Cr in the present study may be attributed to the increased level of crude oil exploration, exploitation and pipeline destruction. which then leached into water bodies, thereby increasing the level of Cr in the water bodies and bioaccumulated by the seafoods. Chromium is an essential trace element but has been reported as a carcinogen if ingested at a daily dose greater than 0.5 mg kg^{-1} of body weight **(Rashed, 2001)**. As an essential trace metal **(Mertz, 1969)**, the biologically usable form of chromium plays an important role in glucose metabolism. It has been estimated that the average human requires nearly 1g/day. Deficiency of chromium results in impaired growth and disturbances in glucose, lipid, and protein metabolism.

Copper is an essential trace metal. It facilitates iron uptake and serves as a constituent of respiratory enzyme complexes in the human body. The concentration of Cu in the analyzed seafood samples was found to fall within the recommended permissible limit set by **WHO/FAO (1989)** and USEPA **(Mishra *et al*., 2007)**. The mean concentration of Cu in this study was above the values reported by **Agwu *et al.* (2018)** and **Usero *et al*. (2003)** which has Cu ranged of 0.4 to 1.5 mg/kg.

The levels of As were found to be lower than those reported by **Agwu *et al*. (2018)** and **Karadede-Akin and Unlu (2004**. This suggests that the samples used in the present study does not pose a health risk since the THQ is lower than 1. Arsenic can be found in fish and other seafood products **(ASTDR, 2005)**. Some environmental protection agencies have reported that a 1.0 mg daily–1 intake of inorganic arsenic is enough after a few years to induce skin lesions **(Iwegbue *et al*., 2008)**.

Our results reported that Zn levels were lower than the 40, 60.0, 120, and 50 mg/kg permissible limit by **WHO/FAO (1989)**, **FAO/WHO (1999)**, USEPA **(Mishra *et al*., 2007)**, and WHO/FAO **(Petkovšek *et al*., 2011)** respectively. From this analysis, the concentrations of Zn was lower than those reported by **Nkpaa *et al*. (2013)**. Zinc is an important trace component in which its deficiency can result in delayed development, loss of taste, dermatitis, alopecia, hypogonadism and reduced fertility **(EPA, 2004)**. Excessive intake of Zn can lead to acute toxicity.

4.2. Estimated Daily Intake of Metals in Seafood Samples for Adult Population

The average daily intake of metals in the adult population was compared to the recommended daily intake level (DIL) of metals and their upper tolerable daily intake (UTDI) set up by the Institute of Medicine for people aged 19 to 79 years **(FDA, 2001; Garcia-Rico, 2007)**. The Pb and Cd through EDI was more than the TDI but below the UTDI, which indicates that the absorption of Pb and Cd into the body system was within the UTDI range through the intake of seafood. Considerably, there may be no health risk from ingestion of Pb and Cd through the intake of seafood from the EDI analysis of Pb and Cd. EDI value of Pb and Cd in this study was more than TDI but below UTDI, which indicated that the absorption of Pb and Cd into the body system was within the UTDI range. The EDI of Cu was below the TDI and UTDI levels of Cu that were reported by **FDA (2001), Garcia-Rico (2007)**. This showed that Cu ingestion may not pose a health risk through the use of seafood. This may be because the Cu rate ingested into the body system is still below the levels of TDI and UTDI. The EDI of As was more than the recommended TDI but was below the UTDI level of As, which indicated that there may be no health risk emanating from As ingestion via seafood consumption. The EDI of Zn were all below the TDI and UTDI level of Zn in the body system indicated that there may not be toxicity or contamination emanating from Zn ingestion via seafood consumption.

4.3. Target Hazard Quotient (THQ) and Hazard Index (HI) of Metals in Seafood Samples for Adult Population

THQ values of Pb, Cd, Cr, Cu, As, and Zn were below 1 (THQ < 1). This simply indicated that the population of the study area may not be exposed to a non-carcinogenic health risk due to the consumption of the examined seafood samples. Likewise, HI values of Pb, Cd, Cr, Cu, As, and Zn for adults were below 1 (THQ < 1), these result suggested that there may be no risk or toxicity associated with noncarcinogenic ingestion of the metals through seafood intake.

4.4. Lifetime Cancer Risk (LCR) of Heavy Metals in Adult Population

The U.S. Environmental Protection Agency reported that 10^{-6} to 10^{4} is the range of allowable lifetime risk expected for carcinogens. The LCR of Pb, Cd, and As was within the range in the adult population of the study area. This indicated that there may not be a risk of developing cancer over time due to the carcinogenic ingestion of Pb, Cd, and As. However, the LCR of Cr was very high comparing with the range of permissible lifetime risk predicted for carcinogens. Hence, there is no risk of developing cancer over time from ingestion of Cr via seafood consumption. Meanwhile, the studied tilapia, snail and crab collected from Ndoni and Choba creeks were within the limit of allowable lifetime risk for carcinogens, suggested that tilapia; snail and crab ingestion from Ndoni and Choba creeks may not lead to cancer over time.

5. CONCLUSION

The results of metal concentrations pointed out that THQ and HI of all the analyzed metals (Pb, Cd, Cr, Cu, As, and Zn) were less than 1. Hence, there is no clear adverse health effects. Furthermore, the LCR of Pb, Cd, and As was normal, but the LCR of Cr surpassed that of the permissible predicted lifetime risk of carcinogens. This indicated that carcinogenic risk might emanate from Cr via the gradual and consistent intake of the seafood by the populace. Based on the outcome of this study, it is recommended that more studies should be carried out at intervals for close monitoring of concentration of these heavy metals in seafoods from the creeks as oil exploration continues. This will help to guarantee that the consumption of seafoods from the creeks are safe and do not pose any serious health risk.

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