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Research Article

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Human Health Risk Assessment of Heavy Metals via Consumption of Selected Seafoods from Three Different Open Markets in Bayelsa State

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ABSTRACT

This study evaluated the metal levels in seafoods from three open markets in Bayelsa State, Nigeria. Five samples of seafood namely Catfish (Clarias gariepinus), Eel (Calamichthys calabaricus), Water snail (Physella acuta), Mackerel (Scombrus linnaeus), and Marine Tortoise (Caretta caretta) were purchased from Mbiama, Swali and Kpansha markets in Bayelsa State. They were pre-treated, digested and analyzed for metals using Solar Thermo Elemental Atomic Absorption Spectrophotometer (STEF-AAS). The analyzed mean concentrations ranged between 0.016 to 0.741 mg/kg, 0.044 to 0.385 mg/kg, 0.430 to 2.283 mg/kg and 1.504 to 4.943 mg/kg for Pb, Cd, Ni and Cr respectively. However, Pb and Cd were higher than the permissible limit prescribed by the European Commission and European Union; however, they fell below the permissible limit prescribed by WHO/FAO. Furthermore, Ni and Cr exceeded the limit by WHO/FAO and the EU. The Estimated Daily Intake was within the Tolerable Daily Intake and Upper Tolerable Daily Intake as recommended by the Institute of medicine. The Target Hazard Quotient and Hazard Index were less than one (<1). The Lifetime Cancer Risk of Pb and Cd fell within the range of permissible predicted lifetime risks for carcinogens. The result of this study shows that the level of metals in this seafood was high and may cause toxicity emanating from the studied metals.

Keywords: Seafood, Human health risk assessment, Heavy metals, permissible limit.

INTRODUCTION

Seafood has become one of the major consumed foods in the studied area. Seafood comprises of fish and shellfish. Shellfish describes the bivalve molluscan shellfish (oysters, cockles, clams, and mussels), the gastropods (periwinkles, sea snails) and the crustacean shellfish (crabs, lobsters, and shrimps)[1]. Most of these seafoods in the Niger Delta comes from Bayelsa State which houses most of the sea, rivers, and ocean. In recent years, the consumption of seafood has increased tremendously due to the increased knowledge of a healthy diet and the nutritional importance of seafood. Seafood is reported to be a valuable source of protein, vitamins (A, B, D, E), minerals (zinc, selenium, iodine, phosphorus, magnesium, iron, copper, potassium, low sodium levels,) as well as 2-aminoethane sulfonic acid and the n-3 polyunsaturated fatty acids (PUFAs), such as eicosapentaenoic acid and docosahexaenoic acid that are not present in terrestrial organisms [2-5].

Metals potentially bioaccumulate in aquatic environments including water, sediments, seafood, etc. These metals are later transmitted into the body system when these kinds of seafood are consumed by the populace [6,7]. Toxic metals like Pb, Cd, and Cr tend to increase due to the gradual deposition of the metals in the seafoods which constitute a safety risk when the seafood is consumed. Metal toxicity in seafoods has become a worldwide problem not only because of the threat posed to seafood but also about the carcinogenic and non-carcinogenic health danger that comes with seafood consumption, this may result in renal failure and liver damage due to the contamination emanating from Pb in food [8].

The exposure to metals over time could be harmful. For instance, the prolonged exposure to Pb may result in coma, brain damage and even loss of life [9]. Cadmium causes injuries to the kidneys and shows signs of severe contamination which comprises of impaired kidney function, infertility, hypertension, tumors and hepatic dysfunction [10]. Likewise, Cr hinders proteins and membrane lipids, which in turn interrupt the filtration ability of the cell and other functions [11,12]. This has given rise to the awareness of metals contamination worldwide. The increased industrialization and urbanization, and the high rate of population increase have added to the elevation of pollution. Since heavy metals are non-biodegradable and persistent, the release of substances and materials which may contain metals into the water body can decrease the biological variation of living organisms that exist in water [10,13]. When these polluted seafood are eaten coincidently or intentionally, the metals tend to build up in the body system which may pose serious health risks. Also, wastes generated from the leather industry and poultry are most times used to feed the fishes in Bayelsa State, which is seen as a cheap alternative. This feeding pattern elevates the gradual build-up of toxic metals such as Pb, Cd, and Cr seen in artificial breed fish which most times tend to jeopardize good health [14]

Several research studies have been done to evaluate the toxicity of metal in fish and seafood. In a recent study, in which the concentration of heavy metals (Pb, Cd, Ni, Cr, Cu, Zn, Mn and As) in some fish species were measured in two different seasons from Bansi River in Bangladesh [15]. The report of the research study indicated a possibility of health risk to the populace in relation to the rate at which they consumed seafood at the time being. In another study, Ahmed et al. [16] reported the human health risk assessment of heavy metals in tropical fish and shellfish collected from the Buriganga River, and the study also indicated a possible risk of cancer over time.

Studies have shown that seafood is among the most vital protein sources but the contamination of seafood is of great risk and possible health worries to the populace. This study therefore aimed at determining the metal levels and the possible health dangers that may emanate from Pb, Cd, Ni, and Cr in five selected seafood species sold at different markets in Bayelsa State, Nigeria.

MATERIALS AND METHODS

Study area

Bayelsa is a state in the Niger Delta region of south-south, Nigeria (Figure 1). It lies between Delta State and Rivers State and has its capital asYenagoa. Bayelsa has a riverine and estuarine setting. Many communities are almost (and in some cases) completely surrounded by water, making them inaccessible by road. Bayelsa has a total area of 10,773 km^2 (4,159 sq mi) and a population of about 1,704,515 [17]. Swali, Mbiama, and Kpansha markets are the major markets where these kinds of seafoods are sold to the populace and other people from within the country.

Sample collection

Five different selected samples of seafoods namely; Catfish (*Clarias gariepirus*), Eel (*Calamichthys calabaricus*), Water snail (*Physella acuta*), Mackerel (*Scombrus linnaeus*), and Marine Tortoise (*Caretta caretta*) were collected from Mbiama, Swali and Kpansha markets respectively in Yenagoa, Bayelsa State. The seafoods obtained from the markets (samples) were wrapped in foil papers and conveyed to a scientific laboratory for analysis.

Pre-treatment and preservation

In the laboratory, the samples were thoroughly washed with running tap water in order to remove dust particles and any other dirt that might be present. The samples were then oven-dried for about three days under proper hygienic conditions to prevent contamination from the environment. They were then pounded using sterilized pestle and mortar to obtain homogenized samples, filtered to obtain the fine powder, kept in airtight sample containers and stored at room temperature ready for analysis.

Digestion

A total volume of 100 ml of H_2SO_4, HNO_3, and $HClO_4$ were mixed together in the ratio of 40%: 40%: 20%, respectively. Five grams of each sample was weighed into a conical flask; 2 ml of the mixed acid was added to each of the samples in the conical flask. The samples were digested in the fume cupboard with a hot plate until white fumes appeared. The digest was then cooled and filtered into a 100 ml volumetric flask and made up to mark with distilled water.

Analysis of heavy metals using atomic absorption spectrophotometer (AAS)

A hollow cathode lamp of desired metal was installed and the wavelength dial set. The equipment was allowed to warm up for about 10-20 minutes for an energy source to stabilize and then the current was readjusted. A suitable burner head was installed, and the position adjusted. Air was turned on and its flow rate adjusted to give maximum sensitivity for the metal being measured. Acetylene was turned on, and its flow rate adjusted to a specified value. Blank was aspirated to zero the instrument. The standard solution was aspirated and the aspiration rate of the nebulizer was adjusted to obtain maximum sensitivity. Blank was aspirated again to re-zero the instrument. The samples were then aspirated into the flame and atomized. The machine analyzed the samples and their absorbances were recorded.

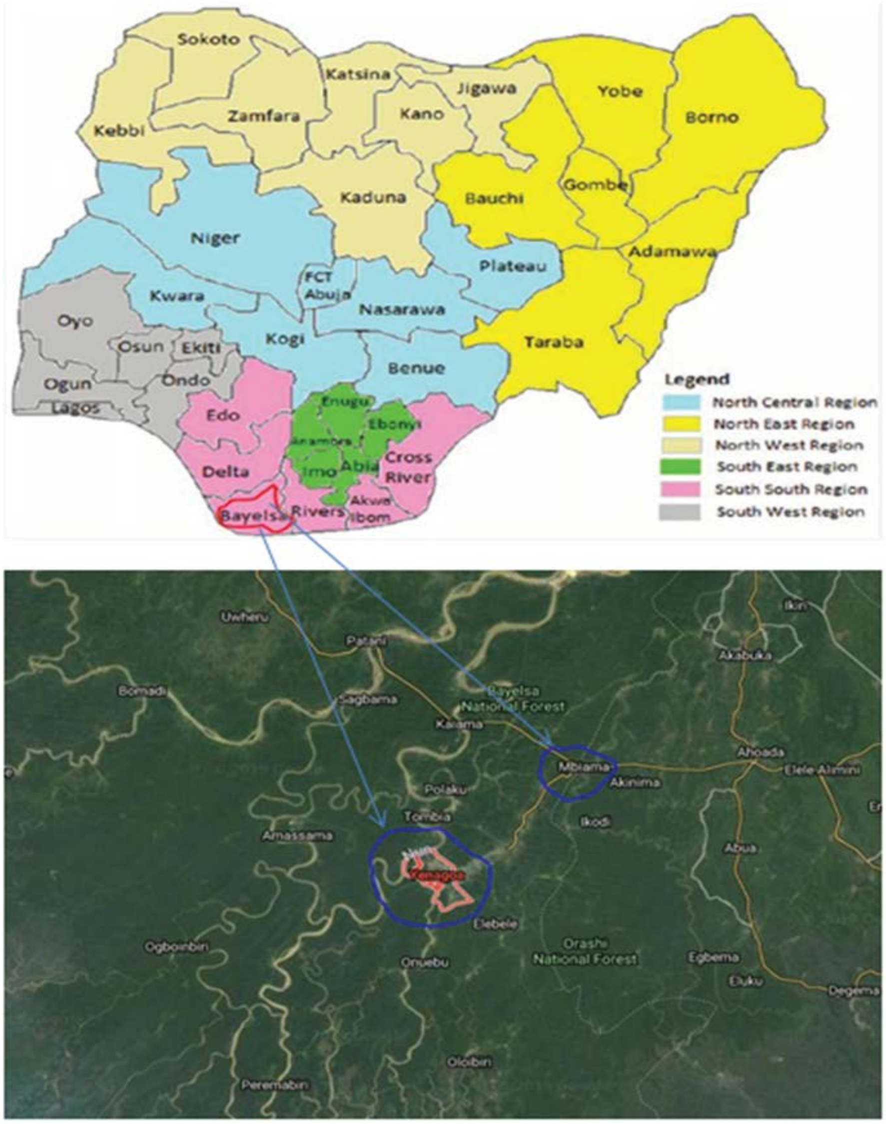

Figure 1: The geographical map of Nigeria showing Bayelsa State.

Health risk assessment

There is usually a health risk that emanates from consuming seafoods contaminated with metals. In order to estimate the extent of these health risks caused by heavy metal contamination, assessing the health dangers that may result from metals toxicity has been applied in studies related to human health. The indices used for estimating the health dangers posed to humans via metals toxicity include estimated daily intake of metals (EDI), target hazard quotient, hazard index, and carcinogenic risk [18].

Estimated daily intake of metals (EDI)

The health dangers that emanate from the ingestion of metals via the consumption of contaminated seafoods were calculated using the formula below:

Estimated Daily Intake (EDI) of heavy metals;

$$EDI = \frac{C_{metal} \times D_{food\,intake}}{BW_{average}}$$

Where:

- C_{metal} = is the metal concentration in seafood in mg/kg,
- $D_{food\ intake}$ = is the daily intake of food in kg person^{-1} and
- BWaverage= is the average body weight in kg person^{-1} (70 kg for Adult)

Average daily consumption of 0.102 kg for Adults of seafood was assumed in this study. This value was adapted based on the work of Nkpaa et al. [19] and also considering that seafood is widely consumed as a major part of the diet.

Target hazard quotient (THQ)

The assessment of the THQ of metals emanating from metals toxicity was determined using the values obtained for THQ. Target Hazard Quotient is the ratio of the measured concentration to the recommended standard dose for consumption. This study utilized the method described by the United States Environmental Protection Agency [20,21].

$$EDI = \frac{C_{metal} \times D_{food\,intake}}{BW_{average}}$$

- Where, Efr, exposure frequency in 365 days year^{-1}
- ED is exposure duration in 53 years (equivalent to an average lifetime of a Nigerian)
- FIR is average daily consumption in Kg person-1day^{-1}
- C is the concentration of metal in food sample in mg/kg
- RfDo is reference dose in mg/Kg day^{-1}
- ATn is the average exposure time for non-carcinogens in days (19,345)

The following reference doses were used (Pb=4.0 × 10^{-3}, Cd=0.001, Ni=0.02, Cr=1.5). Doses were calculated using the standard assumption for integrated risk analysis and an average adult body weight of 70 kg [18,20]. In addition, based on EPA guidelines, it was assumed that ingested doses were equal to absorbed contaminant doses [20,22].

Hazard index (HI)

Hazard Index is the total summation of the THQ. Since various metals have similar adverse effects, it is necessary to determine the Hazard Index.

The Hazard index was calculated using the formula below;

$$Total\ Hazard\ Index\ (HI) = \sum THQ\ (THQ_{Pb} + THQ_{Cd} + THQ_{Cr} + THQ_{n} \ldots \ldots \ldots . .)$$

Carcinogenic health effect

The United States Environmental Protection Agency [23] recommended that 10^{-6} (1 in 1,000,000) to 10^{-4} (1 in 10,000) is the range of permissible predicted lifetime risks for carcinogens. Chemicals that are less than the 10^{-6} may not be considered to cause cancer over time. The risk that comes with developing cancer is shown as the excess probability of developing cancer over a lifetime of 70 years.

The Lifetime Cancer Risk is calculated using the formula below:

$$Carcinogenic\ Risk = EDI \times CFS_{ing}$$

Where:

- EDI is the Estimated Daily Intake of each heavy metal (mg/kg/day)
- CSF_{ing} is Ingestion Cancer Slope Factor (mg/kg/day)$^{-1}$

The United States Environmental Protection Agency [24] states that 10^{-6} (1 in 1,000,000) to 10^{-4} (1 in 10,000) represent a range of permissible predicted lifetime risks for carcinogens. Chemical for which the risk factor falls below 10^{-6} may be eliminated from further consideration as a chemical of concern. The risk associated with the carcinogenic effect of target metal is expressed as the excess probability of contracting cancer over a lifetime of 70 years.

RESULTS

The mean concentrations of the metals in the analyzed seafoods were presented in Table 1. The concentration of Pb ranged between 0.016 to 0.741 mg/kg. The highest concentration was recorded in *C. carabaricus* (0.741 mg/kg) from the Swali market; meanwhile, the lowest concentration was recorded in *S. linnaeus* (0.016 mg/kg) from the Mbiama market. However, *P. acuta* and *C. caretta* from the Kpansha market were below the detectable limit (BDL).

Meanwhile, the mean concentration of Cd ranged between 0.044 mg/kg to 0.385 mg/kg. The highest concentration was recorded in *C. carabaricus* (0.385 mg/kg) from the Kpansha market whereas the lowest concentration was observed in *P. acuta* (0.042 mg/kg) from the Swali market. However, *S. linnaeus* from the Swali market and *C. caretta* from the Mbiama market were Below Detectable Limits (BDL).

The concentration of Ni ranged between 0.430 to 2.283 mg/kg which recorded the highest concentration in *P. acuta* (2.283 mg/kg) from the Mbiama market while the lowest concentration was seen in *C. gariepinus* (0.429 mg/kg) from Swali market.

Furthermore, the concentration of Cr ranged from 1.504 to 4.943 mg/kg. The highest concentration was recorded in *C. gariepinus* (4.943 mg/kg) from the Mbiama market while the lowest concentration was recorded in *S. linnaeus* (1.504 mg/kg) from Kpansha market

Table 1: Concentration of heavy metals (mg/kg) in selected seafoods.

Locations	Samples	Pb	Cd	Ni	Cr
Swali Market	*C. gariepirus*	0.564 ± 0.006	0.097 ± 0.002	0.430 ± 0.001	2.852 ± 0.001
	C. carabaricus	0.741 ± 0.002	0.265 ± 0.002	1.470 ± 0.002	2.521 ± 0.002
	P. acuta	0.089 ± 0.001	0.044 ± 0.001	2.151 ± 0.002	3.284 ± 0.001
	S. linnaeus	0.039 ± 0.001	BDL	1.691 ± 0.002	1.736 ± 0.003
	C. caretta	0.030 ± 0.002	0.052 ± 0.001	0.851 ± 0.001	1.544 ± 0.001
Mbiama Market	*C. gariepirus*	0.398 ± 0.001	0.061 ± 0.001	1.344 ± 0.001	4.943 ± 0.002
	C. carabaricus	0.528 ± 0.002	0.169 ± 0.001	1.892 ± 0.002	3.169 ± 0.001
	P. acuta	0.052 ± 0.004	0.077 ± 0.001	2.283 ± 0.002	2.514 ± 0.001
	S. linnaeus	0.016 ± 0.002	0.062 ± 0.002	1.743 ± 0.002	2.176 ± 0.001
	C. caretta	0.130 ± 0.001	BDL	1.403 ± 0.001	2.283 ± 0.002
Kpansha Market	*C. gariepirus*	0.683 ± 0.007	0.160 ± 0.001	0.869 ± 0.001	3.086 ± 0.001
	C. carabaricus	0.656 ± 0.001	0.385 ± 0.001	1.202 ± 0.002	3.276 ± 0.002
	P. acuta	BDL	0.083 ± 0.002	1.623 ± 0.003	1.816 ± 0.001
	S. linnaeus	0.437 ± 0.003	0.174 ± 0.001	0.725 ± 0.002	1.504 ± 0.002
	C. caretta	BDL	0.088 ± 0.002	1.273 ± 0.003	± 0.001
Permissible Limits					
JECFA		0.025	0.001		0.1–1.2
EU		0.30	0.5	0.02	0.005
WHO/FAO		2.00	1.00	3.70	2.00
NAFDAC		2.00	20.00		
EC/CODEX		0.300	0.200	2.30	
EU		0.300	0.200		0.300

Estimated daily intake (EDI) of heavy metals (mg/kg/day/Bw) for adults (70 kg)

The EDI of the metals was presented in Table 2 From the EDI result, Pb ranged between 0.00008 to 0.001 with *C. Carabaricus* and *C. gariepinus* from both Swali and Kpansha markets recording the highest concentration (0.001) while *P. acuta* from Mbiama market recorded the lowest value (0.00008). The EDI of Cd ranged between 0.00009 to 0.0004 with *C. caretta* from the Swali market recording the highest value (0.0004); however, *C. gariepinus* recorded the lowest value (0.00009). The EDI of Nickel ranged between 0.0006 to 0.003, with *P. acuta, S. linnaeus* from Swali market**,** *C. caretta, P. acuta, S. linnaeus* from Mbiama market recording the highest value (0.003), while *C. gariepinus* from Swali market recorded the lowest value (0.0006). Furthermore, the EDI of Cr ranged between 0.002 to 0.007, with *C. gariepinus* from the Mbiama market recording the highest value (0.007) while *C. Caretta* and *S. linnaeus* from Swali and Kpansha markets respectively recorded the lowest value (0.002).

Table 2: Estimated Daily Intake for the adult population.

Locations	Samples	Pb	Cd	Ni	Cr
Swali Market	*C. gariepirus*	0.0008	0.0001	0.0006	0.004
	C. carabaricus	0.001	0.0004	0.002	0.004
	P. acuta	0.0001	0.00006	0.003	0.005
	S. linnaeus	0.00006	0	0.003	0.003
	C. caretta	0.00004	0.001	0.001	0.002
Mbiama Market	*C. gariepirus*	0.0006	0.00009	0.002	0.007
	C. carabaricus	0.0008	0.0003	0.003	0.005
	P. acuta	0.00008	0.0001	0.003	0.004
	S. linnaeus	0.00002	0.00009	0.003	0.003
	C. caretta	0.0002	0	0.002	0.003
Kpansha Market	*C. gariepirus*	0.001	0.0002	0.001	0.005
	C. carabaricus	0.001	0.0006	0.002	0.005
	P. acuta	0	0.0001	0.002	0.003
	S. linnaeus	0.0007	0.0003	0.001	0.002
	C. caretta	0	0.0001	0.002	0.003
TDI		0.00	0.000	0.50	-
UTDI		0.240	0.064	1.00	-

TDI: Tolerable Daily Intake of heavy metals in (mg/kg); UTDI: Upper Tolerable Daily Intake of heavy metals in (mg/kg)

Target hazard quotient (THQ) and hazard index (HI) for adult in seafoods

The THQ and HI were presented in Table 3. The THQ of Pb ranged between 0.007 to 0.318 having the highest value (0.318) in *C. calabaricus* from the Swali market while *S. linnaeus* from the Mbiama market recorded the lowest value (0.007). However, THQ of Cd ranged between 0.063 to 0.578 with *C. calabaricus* from the Kpansha market recording the highest value (0.578) whereas *P. acuta* from Swali market showed the lowest value (0.063). The THQ values of Ni ranged between 0.032 to 0.171 with *P. acuta* from Mbiama market recording the highest value (0.171) while *C. gariepinus* recorded the lowest value (0.032). Furthermore, the THQ of Cr in the ranged between 0.002 to 0.005 with *C. gariepinus* from Mbiama market recording the highest value (0.005) whereas the lowest value was recorded at *S. linnaeus, C. caretta* from Swali and Mbiama markets, *P. acuta, S. linnaeus* and *C. caretta* from Kpansha market (0.002) for Cr. The HI for adults exposed to seafood contaminated with metals ranged between 0.145 to 0.952 having the highest value recorded at *C. carabaricus* from Kpansha market, however, the lowest value was observed in *S. linnaeus* from Swali market.

Table 3: Target Hazard Quotient (THQ) and Hazard Index (HI) of adults in seafoods.

Locations	Samples	Pb	Cd	Ni	Cr	Hazard Index
Swali Market	***C. gariepirus***	0.242	0.146	0.032	0.003	0.422
	C. carabaricus	0.318	0.398	0.11	0.003	0.828
	P. acuta	0.038	0.063	0.161	0.003	0.266
	S. linnaeus	0.017	0.000	0.127	0.002	0.145
	C. caretta	0.012	0.080	0.064	0.002	0.157
Mbiama Market	***C. gariepirus***	0.171	0.089	0.101	0.005	0.365
	C. carabaricus	0.226	0.254	0.142	0.003	0.624
	P. acuta	0.022	0.114	0.171	0.003	0.310
	S. linnaeus	0.007	0.093	0.131	0.002	0.233
	C. caretta	0.055	0.000	0.105	0.002	0.162
Kpansha Market	***C. gariepirus***	0.293	0.243	0.065	0.003	0.604
	C. carabaricus	0.578	0.578	0.090	0.003	0.952
	P. acuta	0.125	0.125	0.122	0.002	0.248
	S. linnaeus	0.261	0.261	0.054	0.002	0.504
	C. caretta	0.129	0.129	0.096	0.002	0.227

Lifetime cancer risk (LCR) for adult population

The result of the LCR of metals via the ingestion of metals over time in the adult population was presented in Table 4. The LCR value for Pb, Cd, Ni, and Cr ranged from 8.5E-07 to 1.7 E-06 mg/kg/day, 7.6E-05 to 1.14 E-04 mg/kg/day, 9.1 E-04 to 1.82E-03 mg/kg/day, and 8.2E-04 to 1.23E-03 mg/kg/day respectively. The highest values were observed in *C. caretta* (1.7 E-06 mg/kg day) from Mbiama market for Pb, *C. carabaricus and S. linnaeus* (1.14E-04 mg/kg/day) from Mbiama and Kpansha markets respectively for Cd, *C. carabaricus, C. gariepinus, C. caretta, C. carabaricus, P. acuta, and C. caretta* (1.82 E-03 mg/kg/day) from Swali, Mbiama and Kpansha markets respectively for Ni, and *S. linnaeus* from Swali market, *S. linnaeus, C. caretta* from Mbiama market, *P. acuta and C. caretta f*rom Kpansha market respectively for Cr.

Table 4: Lifetime cancer risk for the adult population.

Locations	Samples	Pb	Cd	Ni	Cr
Swali Market	***C. gariepinus***	6.8 E-06	3.8 E–05	5.46 E-04	1.64 E-03
	C. carabaricus	8.5 E-06	1.52 E-04	1.82 E-03	1.64 E-03
	P. acuta	8.5 E-07	2.28 E-05	2.73 E-03	2.05 E-03
	S. linnaeus	5.1 E-07	0	2.73 E-03	1.23 E-03
	C. caretta	3.4 E-07	3.04 E-05	9.1 E-04	8.2 E-04
Mbiama Market	***C. gariepinus***	5.1 E-06	3.42 E-05	1.82 E-03	2.87 E-03
	C. carabaricus	6.8 E-06	1.14 E-04	2.73 E-03	2.05 E-03
	P. acuta	6.8 E-07	3.8 E-05	2.73 E-03	1.64 E-03
	S. linnaeus	1.7 E-07	3.8 E-05	2.73 E-03	1.23 E-03
	C. caretta	1.7 E-06	0	1.82 E-03	1.23 E-03
Kpansha Market	***C. gariepinus***	8.5 E-06	7.6 E-05	9.1 E-04	2.05 E-03
	C. carabaricus	8.5 E-06	2.28 E-04	1.82 E-03	2.05 E-03
	P. acuta	0	3.8 E-05	1.82 E-03	1.23 E-03
	S. linnaeus	5.95 E-06	1.14 E-04	9.1 E-04	8.2 E-04
	C. caretta	0	3.8 E-05	1.82 E-03	1.23 E-03

DISCUSSION

Consumption of foods made toxic by metals may lead to acute or chronic toxicity. Usually, the major means by which these toxic metals get into the body system is when these foods that have metals embedded in them are consumed. Seafoods consumed in Bayelsa State is perceived to be a major producer of metals toxicity among the inhabitants [25].

In this study, the contamination profile of seafoods commonly sold and consumed in Bayelsa state and the possible health implications were reviewed. The concentrations of Pb were lower than the permissible limit of 2.00 mg/kg as prescribed by WHO/FAO [26] about 50% of the samples were more than the permissible limit of 0.300 mg/kg prescribed by CODEX ALIMENTARIUS [27]. The findings in this study indicate that the populace residing in this study area may likely be faced with the danger of Pb toxicity. The result agreed with the findings of Mansour and Sidky [28] who reported a high concentration of Pb in seafood. Lead exposure is estimated to account for 9.8% of the global burden of idiopathic intellectual disability, 4% of the global burden of ischemic heart disease, and 5% of the global burden of stroke [29].

Meanwhile, the concentrations of Cd were lower than the permissible limit of 1.00 mg/kg and 20.00 mg/kg prescribed by WHO/FAO and CODEX [26,27] respectively, however *C. carabaricus* from Swali and Kpansha markets with the mean concentrations of 0.265 and 0.385 mg/kg respectively, were more than the permissible limit of 0.200 mg/kg prescribed by both EC/CODEX and EU. The result obtained from this study, therefore shows that the consumption of *C. carabaricus* may impose a potential risk to the population concerned. Compounds containing Cd are carcinogenic and ingestion of any significant amount of Cd can cause immediate poisoning and damage to the liver and kidney [30].

Furthermore, the concentration of Ni exceeded the permissible limit of 0.02 mg/kg prescribed by WHO/FAO [26]. The exposed populace may be faced with the danger of Ni toxicity because of the frequent consumption of seafoods. Furthermore, Ni concentration was lower than the permissible limit of 2.70 mg/kg and 2.300 mg/kg prescribed by CODEX [27]. The result is similar to the work done by Chien et al. [31] who reported a high level of Nickel in seafood.

The result obtained for Cr showed that about 70% of the analyzed samples from the three markets were more than the permissible limit of 2.00 mg/kg prescribed by WHO/FAO [26] except for *S. linnaeus, C. caretta* from Swali market with the mean concentrations of 1.736 and 1.544 mg/kg, *P. acuta* and *S. linnaeus* from Kpansha market with the mean concentrations of 1.816 and 1.504 mg/kg, also all the analyzed samples from the three markets exceeded the permissible limit of 0.300 mg/kg as recommended by CODEX [27].

The result obtained in this study suggests that the populace of the study area may be faced with the danger of toxicity as a result of Cr via the consumption of contaminated seafoods. The level of Cr obtained in this study was far above the permissible limit of 0.3 mg/kg prescribed by CODEX [27]. The implication of this high level of Cr suggests health dangers to the exposed populace. Arita and Costa [32] reported a high level of Cr on work carried out on seafoods, which also was similar to the work carried out by Dayan and Paine [33] who reported a high concentration of Cr among the selected seafoods. The lack of Cr is implicated in impaired growth and disturbances in lipid and protein metabolism. This is in tandem with the findings of Arita and Costa [32].

The EDI results were compared with the recommended tolerable daily intake (TDI) and upper tolerable daily intake (UTDI) of metals level established by the Institute of Medicine [34]. The EDI of Pb and Cd were more than the TDI of 0.00 and 0.000 mg/kg for Pb and Cd respectively prescribed by the Institute of Medicine [34] but fall below the UTDI of 0.240 and 0.064. The EDI of Ni was below the TDI and UTDI of 0.50 and 1.00 mg/kg respectively. The results obtained for the EDI of Ni, therefore indicate that the intake of metals contaminated seafoods is still within the safe limit. The result obtained in this study suggest that the populace of the study area may currently be safe from Pb, Cd, and Ni toxicity via the consumption of these heavy metals contaminated seafoods presently but may be faced with health danger if with continuous ingestion of these seafoods over time. The EDI of Cr was below the TDI of 0.30 mg/kg as suggested by the Institute of Medicine [34]. The THQ of Pb, Cd, Ni, and Cr were less than 1, this may suggest that the populace of the study area may not be currently faced with metals toxicity but may face health dangers emanating from metals toxicity with continuous ingestion of seafoods over time.

The HI obtained from this study were less than 1, this may suggest that the populace of the study area may not be currently faced with metals toxicity but may face health dangers emanating from metals toxicity with continuous ingestion of seafoods over time.

The LCR of Pb and Cd fall within the safe limit suggested by USEPA [35]. This result suggests that the populace may not be faced with the risk of developing cancer as a result of exposure to Pb and Cd via seafood consumption. Furthermore, the LCR of Ni shows that most of the samples were more than the safe limit prescribed by USEPA, which suggests that the populace may be faced with the danger of developing cancer from the daily ingestion of Ni contaminated seafood overtime except for *C. gariepinus, C. caretta* from Swali market, *C. Gariepinus* and *S. linnaeus* from Kpansha market which fall within the safe limit prescribed by USEPA indicating that there may be potential risk of developing cancer from the daily consumption of these seafood contaminated with Ni over time.

The LCR of Cr exceeded the safe limit suggested by USEPA, this suggests that there may be potential carcinogenic risk from consuming seafood contaminated with Cr except for *C. caretta* from Swali market and *S. linnaeus* from Swali and Kpansha which fall within the safe limit suggested by USEPA, this suggests that there may not be any potential carcinogenic risk from consuming *C. caretta* from Swali market and *S. linnaeus* from Swali and Kpansha which were within the safe limit suggested by USEPA.

CONCLUSION

The result obtained in this present suggested that the consumption of the seafoods in Bayelsa State by the populace could be the major source of metals toxicity among the inhabitants, following the frequent consumption of seafoods.

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