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HEALTH RISK EVALUATION OF CHILDREN AND ADULTS VIA THE CONSUMPTION OF FRESH AND SALT WATER FISH AND SHELLFISH CONTAMINATED WITH HEAVY METALS FROM THE NUN RIVER, BAYELSA STATE, NIGERIA

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ABSTRACT

This study investigated the levels of As, Pb, Cd, Cr and Ni in fresh and salt water fish and shellfish species and evaluated the health risk of children and adults via the consumption of these species from the Nun River. The mean metal levels were determined by AAS. Cr levels were above the threshold limits of FAO/WHO and IAEA, while Pb, As, Cd and Ni were within or below their threshold values in both fresh and salt water species. The health risk evaluation results revealed that children are at greater risk of exposure to these contaminants compared to adults in all the species. The CDI (mg/kg-bw/day) values for both children and adults were either below or within the provisional tolerable daily intake (PTDI) set by regulatory bodies. The non-carcinogenic risk results were all < 1, indicating that the exposed populations are unlikely to experience non-carcinogenic health hazard at the moment. The carcinogen risk evaluation revealed that Pb, Cd and Cr will posed a risk of 3-5 persons in a thousand rather than threshold value of $1.00E^{-04}$ for both children and adults. Ni values were within the limits of $1.00E^{-06}$ but lower than $1.00E^{-04}$ while, TRc values of As were all below the threshold values of $1.00E^{-06}$ – $1.00E^{-04}$ set by USEPA. Therefore, in view of the potential risk pose by these contaminants to children and adults from this study, there is need for continuous monitoring of contaminants in the Nun River, Bayelsa State.

KEYWORDS: Fish and Shellfish, Heavy Metal, Nun River, Carcinogenic and Non-carcinogenic Risk.

INTRODUCTION

The vulnerability of biota (including man) to contaminants in the Niger Delta region via oil and gas activities, as well as illegal artisanal oil activities by local residents along the Nun River is alarming. Examples of such biota are; fresh and salt water fish and shellfish species like *synodontis budgetti* (fish), *Microbrochium felicinum* (prawn), *Galatea paradoxa* (clam), *Ethmalosa fimbriata* (bonga shad fish), *Penaeus monodon* (shrimp) and *Tegillarca Granosa* (blood clam). These species constitute a major nutrient in the average diet of most household in Bayelsa State, Nigeria. These species are in abundance in many coastal communities in Nigeria especially the Niger Delta Region, Bayelsa State in particular. They serve as common and cheap important animal protein for many because they can be easily harvested and processed either for commercial or subsistence purposes.

Globally, these fish and shellfish species are considered as healthy diet because they contained essential nutrients such as vitamins and proteins.[1, 2] Recent studies had shown that, fish and shellfish species contains long-chain polyunsaturated omega^{-3} and omega^{-6} fatty acid which may improve lipid profile, lower cholesterol levels and the risk of heart related diseases as well as stroke.[3, 4] In spite of the healthy benefits of fish and shellfish to humans, the increased levels of contaminants and toxic metals in these organisms had become a global concern because of their potential adverse health effects on biological organisms including man. As such, major human organs (especially, liver, kidney, central nervous system, mucus tissue, intestinal tract and reproductive system) are severely damaged due to the consumption of these contaminated organisms, especially when these contaminants (heavy metals in particular) are present in higher concentrations that can cause toxicity.[5]

The evaluation of heavy metal in fish and shellfish are of great importance because, in the aquatic environment, these metals are present in freely dissolved forms and are easily taken up by fish, shellfish and other aquatic organisms especially the filter feeding organisms.[6, 7, 8] Thus the aquatic environment has been impaired by continuous entrance of heavy metals from both natural and anthropogenic sources. Once released, these metals persists, bio-accumulate and bio-magnify within the food chain and cause toxicity to the organism themselves as well as the consumers.[9] Most of these metals are nutritionally essential to maintain and regulate physiological metabolism in living system but, higher levels are known to cause hazardous effects and in extreme cases death.[10] Examples metals like Cu, Fe, Zn, Mn are essentially needed for normal body functions yet, higher levels would cause toxicity. While metals such as Cd, Hg, Pb and As have no biological roles in the body but are toxic even at low levels and are omnipresent in nature, so exposure to these metals are not easily, preventable to a large extent.[10] One major receptor of these heavy metals in Bayelsa State is the Nun River.

The Nun Rivers lies within the coastal communities in the Niger Delta region of Nigeria. In Bayelsa State, the Nun River is made up of long fresh water river system as well as salt water river system with an outlet linked to the Atlantic Ocean. The fresh water system of the Nun River also stretches into the Gulf of Guinea with an inlet from the Atlantic Ocean at Akassa, Bayelsa State. As such, the Nun River has become major debris for natural and anthropogenic activities. Therefore, it drains and receives effluents from oil and gas related activities (include illegal artisanal oil activities by local resident), commercial boat drivers, and sometimes these oil discharge accidentally and flows into the Nun River. Also the Nun River serves as a dump site for industrial and domestic sewage, waste water and solid wastes.[11, 12, 13] To this end, there is no gain saying that the Nun River has been contaminated by heavy metals and other contaminants due to these numerous activities. Hence, it is eminent to investigate the health risk of children and adults via the consumption of fresh and salt water fish, and shellfish species from the Nun River, Bayelsa State. Therefore, the objective of this study was to evaluate the carcinogenic and non-carcinogenic health risk of Ab, As, Pb, Cd, Ni and Cr in some selected fresh and salt water fish, and shellfish for children and adults from Bayelsa State, via the consumption of these organisms.

MATERIALS AND METHODS

Sample Collection

Salt water fish bonga shad (*Ethmalosa fimbriata*) and shell fish shrimp (*Penaeus monodon*) and blood clam (*Tegillarca Granosa*) were purchase from local farmers in the River Nun, Sangana axis, Akassa, Bayelsa State. While the fresh water fish (*synodontis budgetti*) and shellfish species Prawn (*microbrochium felicinum* and clam (*Gralatea paradoxa*) were purchase from local farmers in the River Nun, Igbomatoru axis, Southern Ijaw, Bayelsa State. They were placed in separate plastic containers and transported to the Central Research Laboratory, Department of Chemical Sciences, Niger Delta University, Wilberforce Island, Bayelsa State for analysis.

Sample Preparation and Heavy Metal Analysis

The edible tissues of the salt and fresh water fish and shellfish species were thoroughly washed with distilled water, placed in an oven and dried at 105 ^{0}C to constant weight. Then each sample was crushed with manual laboratory mortar and pestle, and sieved to obtain uniform particle size. Thereafter, 1 gram (g) of each sample was digested with 20 mL solution of H_2SO_4/HNO_3 containing 3:1 V/V, and 5 mL of $HClO_4$. At the end of the digestion, approximately 5 mL solution was left. The digest were cooled and diluted with 20 mL of distilled water, stirred and filtered into 100 mL flasks. Then distilled water was added to makeup the mark [14]. The concentrations of As, Pb, Cd, Ni and Cr were determined using Thermo-Elemental Atomic Absorption Spectrophotometer (FAAS-471096 model).

Health Risk Evaluation Methods

In Nigeria, there is no agreed value for tolerable maximum limits for carcinogenic and non-carcinogenic risk, therefore, the United State Environment Protection Agency (USEPA) models were employed to evaluate the risk of children and adults from Bayelsa State via the consumption of fish and shellfish contaminated with Pb, Cd, As, Ni and Cr from the Nun River. These models include chronic daily intake (CDI), target hazard quotient (THQ), Hazard Index (HI) and Target Cancer risk (TRc).[15, 16] These models have been successfully employed by many researchers to investigate the health risk of heavy metals exposure to human via contaminated water, soil and air, fish and shellfish species which were proven valid and useful.[9, 17, 18, 19, 20,] The mathematical expressions for each risk model are expressed as follows;

Chronic Daily Intake (CDI)

$$\text{CDI (mg/kg-bw/day} = \frac{C_{metal} \times IR}{BW} \quad \ldots\ldots 1$$

Target Hazard Quotient (THQ)

$$\text{THQ} = \frac{EF \times ED \times C_m \times IR}{RfD \times BW \times AT_n} \times 10^{-3} \quad \ldots\ldots 2$$

Hazard Index (HI)

$$HI = THQ_{AS} + THQ_{Pb} + THQ_{Cd} + THQ_{Cr} + THQ_{Ni} \quad \ldots\ldots 3$$

Target Cancer Risk (TRc)

$$TRC = \frac{EF \times ED \times IR \times CPSF_O \times CM}{BW \times AT} \quad \ldots\ldots 4$$

Table 1. Some Toxicological Parameters of the Metals and Risk Input Parameters used for Evaluation of Fish and Shellfish from the River Nun, Bayelsa State.

Index	Characteristics	Unit	Value	Reference
CM	Concentration of metals	mg/kg	Presented in table 2	This study
IR	Injection rate	Kg/person/day	0.3 kg/person/day (adults) and 0.15 kg/person/day(children)	USEPA [15] Manuel *et al.;* [21]
EF	Exposure frequency	Days/year	365 days	
ED	Exposure duration	Years	70 years (adults)and 10 years (children)	
RfD	Reference dose (oral)	mg/kg-bw/day	As (0.003), Pb (0.004), Cd (0.001), Cr (0.002) and Ni (0.02)	USEPA [22]
BW	Body weight	kg/	60 kg (adults) and 25 kg (children)	
AT	Average time	Days	EF X ED: 365 X 70 = 25550 (adults) and 365 X 10 = 3650 (children)	
$CPSF_O$	Carcinogenic potency slope factor (oral)	mg/kg-bw/day	As (1.5), Pb (0.009), Cd (0.38), Cr(0.5) and Ni (1.7)	USEPA [16]
10^{-3}	Conversion factor unit			

RESULT AND DISCUSSION

The concentrations of As, Pb, Cd, and Ni in fish and shellfish species from the River Nun, in comparison with international standard values are presented in table 2. Usually, the concentration of metals varies amongst different species which depends solely on the bio-availability of the metal to the organism and its environment as well as the subsequence capacity of the organisms to accumulate these metals within its systems. As shown in table 2, the mean values of the metals (As, Pb, Cd, Cr, and Ni) in the fish and shellfish were sun-drily distributed. This depends on the availability of the metal to the fish species and subsequence uptake of the metal by the fish. Collectively, it was observed that Cr accumulated higher concentrations in all the fish and shellfish species and these values are higher than the recommended standard limits of FAO/WHO[23] and IAEA.[24] This could be attributed to the bioavailability of Cr in the fresh and salt water river system and further up of the Cr metal by these organisms. Cr occurs commonly as Cr^{+3} (trivalent) and Cr^{+6} (hexavalent). The trivalent – Cr is the most rife form of Cr in food and is an essential metal which form complex with vitamin B_{12}, and is needed in small amounts for glucose metabolism in the human body but higher concentrations are toxic. The hexavalent Cr^{-6} is the most toxic form of chromium, and is easily absorbed into the kidneys, spleen, liver, lung and bone when taken in excess.[25] However, higher concentrations of both Cr^{+3} and Cr^{+6} have been reported to reduce fertility and fetal weight, impaired respiratory system, skin swelling, ulcer, and likely carcinogenic in animal studies.[26] The concentration of Cr in this study is higher than the values reported by Nwabueze and Emefe[27] in clam and Ebenezer[28] in prawn.

While the concentrations of As, Pb, Cd and Ni in both the fresh and salt water species were either below or within the standard limits of FAO/WHO (2010) and IAEA, (2003). The metals concentrations in this study are lower than the values reported by Manuel *et al.*,[21] These values were similar to the values obtained by Baki *et al.*,[7] in marine fish but lower than the values they obtained in crustacean (shrimp, lobster and crabs). Generally, the mean concentrations of all the five heavy metals in this study were in the hierarchical order of Cr > Pb > Ni > Cd > As respectively. Pb, Cd and As have no biological roles in the human body rather they bio-accumulate and elicit various toxic effects such as reduced growth and development in children, major organs damage (e.g kidney, liver, lung), they also damage the central nervous system etc.[9] Therefore, considering the bio-accumulative properties of these metals and their potential for causing problems even at low level of exposure, moderate intake of these organisms is recommended.

Table 2. Comparison of Heavy Metals (As, Pb, Cd, Cr and Ni) Concentrations (mg/kg dry weight) in Edible Fresh and Salt Water Fish and Shellfish from River Nun, Bayelsa State with International Standard Limits.

Heavy metals (mg/kg)	Fresh water species			Salt water species			International Standard Unit	
	S. budgetti	M. felicinum	G. paradox	E. fimbriata	P. monodon	T. garanosa	FAO/WHO[23]	IAEA[24]
As	0.02 ± 0.00	0.20 ± 0.01	0.13 ± 0.03	0.02±0.01	0.04±0.01	0.10 ± 0.01	0.05	-
Pb	0.45 ± 0.07	0.54 ± 0.09	0.65 ± 0.35	0.35±0.07	0.20±0.00	0.38 ± 0.04	2.00	0.12
Cd	0.33 ± 0.03	0.35 ± 0.00	0.20 ± 0.06	0.13±0.04	0.30±0.04	0.29 ± 0.04	2.00	0.18
Cr	2.13 ± 0.13	1.88 ± 0.31	1.35 ± 0.29	1.26±0.33	2.52±0.08	1.69 ± 0.00	0.3	0.73
Ni	0.43 ± 0.03	0.39 ± 0.01	0.39 ± 0.05	0.24±0.01	0.34±0.06	0.34 ± 0.07	0.05	0.6

Health Risk Evaluation of As, Pb, Cd, Cr and Ni in Fish and Shellfish from the Nun River

The carcinogenic and non-carcinogenic risk of As, Pb, Cd and Ni were evaluated in order to assess the potential adverse health effects these toxicant pose to children and adults residing in Bayelsa State via the consumption of fish and shellfish from the Nun River. The models for the non-carcinogenic risk evaluation were Chronic Daily Intake (CDI), Target Hazard Quotient (THQ) and the Hazard Index (HI), and the Target Cancer Risk (TRc) was used for the evaluation of the carcinogenic risk. The result obtained were presented in table 3, 4 and 5 respectively. The USEPA[15, 16, 22, 29] has set standard limits for carcinogenic and non-carcinogenic risk. The acceptable risk distribution for a 95th percentile of the exposed population, that are unlikely to exist without an appreciable risk of deleterious effects are 10E^{-06} – 10E^{-04} for carcinogenic risk, and $\sum THQ = HI < 1$ for non-carcinogenic risk. The interpretation of these risk values are binary, for carcinogenic risk the value is either one in a million (10E^{-06}), or one in a thousand (10E^{-04}) of the exposed population. This is considered safe, but exposures to higher levels than these values are considered unsafe during a life time. While for non-carcinogenic risk, HI is either ≤ 1. When HI is > 1, it implies that the exposed population is at risk but when HI is equal to 1 or < 1 it implies that the exposed population is at safe limits.

Table 3. Chronic Daily Intake (mg/kg-bw/day) of As, Pb, Cd, Cr, and Ni for Children and Adults via the Consumption Fresh and Salt Water Fish and Shellfish from the Nun River, Bayelsa State.

Fish and shellfish species		Exposed population	CDI (mg/kg-bw/day)				
			As	Pb	Cd	Cr	Ni
Fresh water species	Fish	Children	1.20E^{-04}	2.70E^{-03}	1.98E^{-03}	1.28E^{-02}	2.58E^{-03}
		Adults	1.00E^{-04}	2.25E^{-03}	1.65E^{-03}	1.07E^{-02}	2.15E^{-03}
	Prawn	Children	1.20E^{-03}	3.24E^{-03}	2.10E^{-03}	1.13E^{-02}	2.34E^{-03}
		Adults	1.00E^{-03}	2.70E^{-03}	1.75E^{-03}	9.40E^{-04}	1.95E^{-03}
	Clam	Children	7.80E^{-04}	3.90E^{-03}	1.20E^{-03}	8.10E^{-02}	2.34E^{-03}
		Adults	6.50E^{-04}	3.25E^{-03}	1.00E^{-03}	6.75E^{-03}	1.95E^{-03}
Salt water species	Fish bonga-shad	Children	1.20E^{-04}	2.10E^{-03}	1.80E^{-03}	7.56E^{-03}	1.44E^{-03}
		Adult	1.00E^{-04}	1.75E^{-03}	6.50E^{-03}	6.30E^{-03}	1.20E^{-03}
	Shrimp	Children	2.40E^{-04}	1.20E^{-03}	1.80E^{-03}	1.51E^{-02}	2.04E^{-03}
		Adults	2.00E^{-04}	1.00E^{-03}	1.50E^{-03}	1.26E^{-02}	1.70E^{-03}
	Blood clam	Children	6.00E^{-04}	2.28E^{-03}	1.74E^{-03}	1.01E^{-02}	2.04E^{-03}
		Adults	5.00E^{-04}	1.90E^{-03}	1.45E^{-03}	8.54E^{-03}	1.70E^{-03}
Standard Guidelines Council of Europe [30]			3.00E^{-04}	3.60E^{-04}	3.60E^{-04}	3.00E^{-01}	3.80E^{-04}
FAO/WHO [31]			2.00E^{-03}	3.00E^{-03}	3.60E^{-04}	-	2.00E^{-02}
EVM [32]			1.00E^{-3}	-	-	1.50E^{-01}	4.30E^{-03}

Table 4. Non-carcinogenic Risk (THQ and HI), and % Contribution to HI Values of each Metal for Children and Adults via the Consumption of Fresh and Salt Water Fish and Shellfish from the Nun River.

Fish ad shellfish species		Exposed population	THQ of each metal					HI (∑THQ)	% contribution of each metal to HI				
			As	Pb	Cd	Cr	Ni		As	Pb	Cd	Cr	Ni
Fresh water species	Fish	Children	4.00E^{-05}	6.75E^{-04}	1.98E^{-03}	6.39E^{-03}	1.29E^{-04}	9.21E^{-03}	0.43	7.33	21.49	69.35	1.40
		Adult	3.33E^{-05}	5.63E^{-04}	1.65E^{-03}	5.33E^{-03}	1.08E^{-04}	9.68E^{-03}	0.43	7.33	21.49	69.35	1.40
	Prawn	Children	4.00E^{-04}	8.10E^{-04}	2.10E^{-03}	5.64E^{-03}	1.17E^{-04}	9.07E^{-03}	4.41	8.93	23.16	62.20	1.30
		Adult	3.33E^{-04}	6.75E^{-04}	1.75E^{-03}	4.70E^{-03}	9.75E^{-05}	7.56E-^{03}	4.41	8.93	23.16	62.20	1.30
	Clam	Children	2.60E^{-04}	9.75E^{-04}	1.20E^{-03}	4.05E^{-03}	1.17E^{-04}	6.60E^{-03}	3.93	14.77	18.18	61.35	1.77
		Adult	2.17E^{-04}	8.13E^{-04}	1.00E^{-03}	3.38E^{-03}	9.75E^{-05}	5.50E^{-03}	3.93	14.77	18.18	61.35	1.77
Salt water Species	Fish bonga-shad	Children	4.00E^{-05}	5.25E^{-04}	7.80E^{-04}	3.78E^{-03}	7.20E^{-05}	5.19E^{-03}	0.77	10.10	15.01	72.73	1.39
		Adult	3.33E^{-05}	4.38E^{-04}	6.50E^{-04}	3.15E^{-03}	6.00E^{-05}	4.33E^{-03}	0.77	10.10	15.01	72.73	1.39
	Shrimp	Children	8.00E^{-05}	3.00E^{-04}	1.80E^{-03}	7.56E^{-03}	1.02E^{-04}	9.84E^{-03}	0.81	3.05	18.29	76.81	1.04
		Adult	6.67E^{-05}	2.50E^{-04}	1.50E^{-03}	6.30E^{-03}	8.50E-^{05}	8.20E^{-03}	0.81	3.05	18.29	76.81	1.04
	Blood clam	Children	2.00E^{-04}	5.70E^{-04}	1.74E^{-03}	5.07E^{-03}	1.02E^{-04}	7.68E^{-03}	2.60	7.42	22.65	65.99	1.34
		Adult	1.67E^{-04}	4.75E^{-04}	1.45E^{-03}	4.23E^{-03}	8.50E^{-05}	6.40E^{-03}	2.60	7.42	22.65	65.99	1.34
Standard Guidelines RfD (oral): USEPA [22]			3.00E^{-03}	4.00E^{-03}	1.00E^{-03}	2.00E^{-03}	2.00E^{-02}						
USEPA [16]								≤ 1					

Table 5. Carcinogenic Risk (TRc) of the Metals (As, Pb, Cd, Cr and Ni) for Children and Adults via the Consumption of Fresh and Salt Water Fish and Shellfish.

Fresh and salt water species		Exposed population	TRc				
			As	Pb	Cd	Cr	Ni
Fresh water species	Fish	Children	$8.00E^{-08}$	$3.18E^{-04}$	$5.21E^{-04}$	$2.56E^{-05}$	$1.52E^{-06}$
		Adult	$6.67E^{-08}$	$2.65E^{-04}$	$4.34E^{-04}$	$2.13E^{-05}$	$1.26E^{-06}$
	Prawn	Children	$7.00E^{-07}$	$3.81E^{-04}$	$5.53E^{-06}$	$2.26E^{-05}$	$1.38E^{-06}$
		Adult	$6.67E^{-07}$	$3.18E^{-04}$	$4.61E^{-06}$	$1.85E^{-05}$	$1.15E^{-06}$
	Clam	Children	$5.20E^{-07}$	$4.59E^{-04}$	$3.16E^{-06}$	$1.62E^{-05}$	$1.38E^{-06}$
		Adult	$4.33E^{-07}$	$3.82E^{-04}$	$2.63E^{-04}$	$1.35E^{-05}$	$1.15E^{06}$
Salt water species	Fish bonga-shad	Children	$8.00E^{-07}$	$2.47E^{-04}$	$2.05E^{-06}$	$1.51E^{-05}$	$7.47E^{-07}$
		Adult	$6.67E^{-08}$	$2.06E^{-04}$	$1.71E^{-06}$	$1.26E^{-05}$	$7.06E^{-07}$
	Shrimp	Children	$1.60E^{-07}$	$1.41E^{-04}$	$4.74E^{-06}$	$3.02E^{-05}$	$1.20E^{-06}$
		Adult	$1.30E^{-07}$	$1.18E^{-04}$	$1.71E^{-06}$	$2.52E^{-05}$	$1.00E^{-06}$
	Blood clam	Children	$4.00E^{-07}$	$2.68E^{-04}$	$4.58E^{-06}$	$2.03E^{-05}$	$1.20E^{-06}$
		Adult	$3.33E^{-07}$	$2.24E^{-04}$	$3.82E^{-06}$	$1.69E^{05}$	$1.00E^{-06}$
Guidelines USEPA[16]			$1.00E^{-06} – 1.00E^{-04}$				

Evaluation of Chronic Daily Intake, (CDI) (mg/kg-bw/day)

The Chronic Daily Intake, EDI (mg/kg-bw/day) is the max concentration of a contaminant an individual can be exposed to per day that is unlikely to produced risk of deleterious health effects during a lifetime. Nevertheless, the toxicity of any contaminant or toxicant to the exposed population depend on the amount of food ingested daily and concentration of the contaminant/toxicant and the body weight of the individual. In this study, a daily ingestion rate of 0.3 mg/kg bw/day for adults (60 kg) and 0.15 mg/kg-bw/day for children (25 kg) was considered and these values were relatively high. However, the USEPA[29] reported that exposure dose is equivalent to the concentration of the contaminant in percentile of 95% times the contact ratio. Therefore, these high values were used in order to lower the probability of deleterious adverse health effects in future via the consumption of these fish and shellfish since they are commonly consumed among resident, and are the main sources of animal protein to most household. As expected, the risk of children exposed to the metals via the consumption of these fish and shellfish were higher than adults with no significant difference ($P > 0.05$). However the results in table 3 revealed that, the CDI (mg/kg) of the metals in all the fresh and salt water fishes and shellfish were either below or within the provisional tolerable daily intake (PTDI) of the metals set by regulatory bodies. Therefore, in view of lowering risk of deleterious adverse human health effects in future, these fish and shellfish should be consumed moderately.

Non-Carcinogenic Health Risks Evaluation

The target hazard quotient (THQ) and hazard index (HI) were used in evaluating the non-carcinogenic risk of children and adults from Bayelsa State consuming fishes and shellfish from the River Nun. The THQ is a dimensionless quantity that is often accompanied with chronic exposure of an individual or population to a contaminant. The THQ value defines the comparative measure between exposure to a contaminant and the average reference dose, RfD (oral) of the contaminant. As indicated in table 4, the THQ values for As, Pb, and Ni in the fresh and salt water fish and shellfish species for both children and adults were below their oral reference dose (RfD) set by USEPA [22], while the THQ of Cd and Cr were within their RfD. The hazard index (HI) defines the combine /or interactive adverse health effects of contaminants in a given environmental matrix. It expresses the additive/or interactive hazards of two or more contaminants when exposed to an environmental biota. The HI values of the fresh and salt water species for both children and adults were less than 1 ($HI < 1$) USEPA.[16] This implies that the residents of Bayelsa State are safe at the moment because, they are unlikely to experience non-carcinogenic adverse health effects via the consumption of these organisms. However, it is important to note that, Cr is a major risk contributor to the HI values, accounting for up to 61-76% of the HI values for each metal in each organism. Although $Cr+^{3}$, the most rite form of Cr in food is essential to human body and play a major key role in glucose metabolism but higher level of exposure had been reported to cause gastrointestinal, hepatic, renal, immunological, neurological, developmental and productive effects.[32]

Carcinogenic Health Risks Evaluation

Unlike the non-carcinogens that have threshold value of < 1 at a safe limit, the carcinogens have no threshold value rather, all repeated exposures to a carcinogens sum up, and the risk is never zero even at low dose of exposure. Therefore, the risks of carcinogens are proportional to the exposure and the key parameter that defines the carcinogenic risks is the carcinogenic potency slope factor (CPSFo). The potency factor is the slope of the dose response curve, that is, the risk that corresponds to a chronic daily intake of 1 mg/kg-day. Therefore, carcinogenic risk is evaluated as an individual excess life time cancer risk, and the acceptable threshold is $1.0E^{-06}$-$1.0E^{-04}$ of the exposed populations USEPA.[16] Table 5 showed the target cancer risk (TRc) for children and adults via the consumption of fresh and salt water fish and shellfish species from the River Nun. The TRc values of Pb, Cd and Cr in each species for both children and adults were in the range of 1.35E^{-05} – 4.34E^{-04}. The greatest risk pose by Pb, Cd and Cr for children and adults were; 4.59E^{-04}, 5.21E^{-04} and 3.02E^{-0E} (children) and 3.825^{-04}, 4.61E^{-04} and 2.5E^{-05} (adults). This ranges from 3 – 5 persons in a thousand which is above the threshold value of 1 in a thousand. The TRc values for Ni for children and adults were within the threshold value of 1.00E^{-06} (1 in million), but lower than 1E^{-04} while, AS values were below the threshold of 1.00 E^{-06} – 1.00 E $^{-04}$ respectively. The results also revealed that the risk of cancer pose by these metals to children were higher than adults risk. This results is similarly to some reports in literature which states that, children are susceptible to carcinogens and its activities.[33, 34, 35, 36, 37] These studies point out potentially key factors that lead to children susceptibility to carcinogens compared to adults as follows;

- The differences in metabolizability in children can lead to higher or lower internal doses of toxic chemicals.
- Continuous cell division during children developmental stages can improve mutation expression due to short time available for DNA lesion repair.
- Clonial expansion of cells with mutation from previous DNA damage can occur as a result of continuous cell division during children developmental life stages.
- Most key components of the immune system are still underdeveloped.
- The hormonal systems operate at different levels during different life stages. Also the USEPA reports on Guidelines for carcinogen risk assessment revealed that, developmental abnormalities as a result of predisposition to carcinogens can induce carcinogenic health risk later in life.[38]

Generally, the hierarchical order of carcinogenicity of these metals in each species for both children and adults were in the order of Cd > Pb > Cr > Ni > As. Cd and Pb posed the greatest carcinogenic risk and these metals have no biological role in the human body.

CONCLUSION

This study investigated the levels of As, Pb, Cd, Cr and Ni in fresh and salt water fishes and shellfish and the health risk of children and adults via the consumption of these organisms from the Nun River, Bayelsa State. The mean levels of the metals were in the hierarchical order of Cr > Pb > Ni > Cd > As. The mean values of Cr were higher than the standard tolerable limits of FAO/WHO and IAEA, while the mean values of Pb, Ni, Cd and As were either below or within the threshold values in both fresh and salt water species. The health risk evaluation results revealed that, risk of children exposed to these metals in the fresh and salt water species were higher compared to adults with no significant difference ($P > 0.05$). The CDI (mg/kg-bw/day) values for children and adults for each metal in all the species were either below or within the provisional tolerable daily intake (PTDI) of the metals set by regulatory bodies. The non-carcinogenic risk results for all the metals in both children and adults were all < 1, indicating that, the exposed population is unlikely to experience non-carcinogenic adverse health effect at the moment. The carcinogenic risk results revealed that, Pb, Cd and Cr posed the risk of 3-5 persons in a thousand for both children and adults which is above the threshold value of 1.00E^{-04}. The TRc values of Ni for children and adults were within the threshold value of 1.00E^{-06} (one in a million) but lower than 1.00E^{-04} while, the TRc values of As in both children and adults were below the threshold value of 1.00E^{-06} – 1.00E^{-04} set by USEPA. Therefore, in view of the potential risk posed by these metals, and their persistence and bio-accumulative nature in the environment, there is need for continuous monitoring of other contaminants in the Nun River.

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CONFLICT OF INTEREST

None declared

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