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HUMAN HEALTH RISK APPRIASAL OF SOME ESSENTIAL HEAVY METALS IN EDIBLE SEAFOOD COLLECTED FROM RIVER NUN, BAYELSA STATE, NIGERIA.

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ABSTRACT

Essential heavy metals are metals required in small amount for normal metabolic and physiological function in living systems. They enhance growth, development, maintenance of cells and tissue and increased general well-beings. They are found naturally in food produces and food supplements. However this study investigated only five essential heavy metals (Zn, Fe, Cu, Mn and Co) in some commonly consumed seafood from the Nun River. The mean metal concentrations (mg/kg/dry weight basis) were determined using AAS, and the results varied considerably among the different seafood species. The fresh water species were found in the hierarchical order of Mn > Fe > Zn > Co > Cu, while the salt water species were in the order of Fe > Mn > Zn > Co > Mn. The mean metals concentrations in this study were all lower than the standard limits of FAO/WHO and IAEA. The non-carcinogenic health risk evaluation also revealed that, the TDI, THQ and HI values were all lower than standard of guidelines limits set by regularly bodies. The results also revealed that, Mn was a major contributor to the HI values accounting over 89% of the HI values of each seafood for both children and adults. Therefore, considering the toxicity of Mn at prolong higher level of exposure and bio-accumulative properties of these metals, moderate intake of these seafood species is recommended.

KEYWORDS: Essential Heavy Metals, Seafood, Health Risk, Non-carcinogenic, Nun River.

INTRODUCTION

Nutritionally essential heavy metals are metals that play important biological roles in the human system and other living organisms. Examples are Fe, Zn, Cu, Co, Mn, Cr, Ni, Se, V and MO.[1] These metals produce essential nutrients that are required for various biochemical and physiological enzymatic functions in the human body and insufficient supply of these nutrients can result in variety of deficiency diseases or syndromes.[1] However, higher level can produce toxic effects. For example, Co is a key component of Vitamin B_{12} and is essential for human health because it induces the production of red blood cells and combat anemia in pregnant women but higher exposure can lead to harmful health effects such as lung disease (asthma and pneumonia) and cardiovascular disease.[2] Fe and Mn are known to cause physical and mental disorder such as Parkinson's disease.[3] Cu and Zn are micronutrients needed by plants and animals for growth repair and maintenance of cells and tissues, but high level causes adverse effects ranging from reduced immune body function to anemia, liver and kidney damage, stomach and intestinal irritation.[2] Also, excessive absorption of zinc suppresses copper and iron absorption.[4] These metallic elements are disposed in the sea and rivers indiscriminately via industrial and oil related activities. Once disposed, the metals persist, and bio-accumulate within the environment and its biota, and bio-magnify within the food chain, and this has made sea, rivers and biota (especially seafood) a major sink of these metallic toxicants.[5,6]

Seafood such as clam, prawn, shrimp, bonga-shad, whelk, oyster etc constitutes high quality protein and other essential nutrients. They have low saturated fat and contain omega-3 and omega-6 fatty acids which promote healthy cardiovascular system.[7,8] These and many other benefits have increased the consumption rates of these organisms all over the world, including Bayelsa State, Nigeria. Seafood also, provides a healthy and cheap source of protein and other nutrients for many households in rural areas where sea and rivers are located.[6] However, the levels of heavy metals and other contaminants in seafood is threatening because of their potential adverse effects on the organism themselves as well as other organisms that consume them including man.

Health risk associated with the consumption of seafood (shell fish and fishes) contaminated by toxic metals have been reported.[5,6,9,10,11,12] Toxic metals are present in sea, and rivers as freely dissolved ions, and are easily taken up by shellfish and fishes due to their mode of feeding as filter feeding organisms.[13] Since, these organisms are filter feeders, they may likely take up these metals into their tissues and this may pose risks to the consumers. Therefore, it is important to investigate the non-carcinogenic health risks of Cu, Zn, Fe, Mn and Co in fresh water fish and shellfish (fish; *synodontis budgetti*; prawn*: Microbrachium felicinum*, and clam: *Galatea paradoxa*) and salt water (Blood clam: *Tegillarca granosa*; shrimp: *Penaeus monodon*; fish-bonga shad: *Ethmalosa fimbriata*) collected from River Nun.

2.0. MATERIALS AND METHODS

2.1 Study Area

The River Nun is a natural river geographically located in the Niger Delta region, Nigeria. The Nun River is a complex coastal water body that has long fresh water river system as well as estuary where ocean tides (salt water) and river water merge within an outlet linked to the Atlantic Ocean. The Nun River is also a stretch of fresh water flowing into the Gulf of Guinea, a wide inlet of the Atlantic Ocean at Akassa, Bayelsa State.[14] In Bayelsa State, Niger Delta region, the Nun River drains and receives effluents from the activities of oil companies and commercial boat drivers. The river also serves as sewage/rubbish disposals for the local residents. Recently, the river has become a sink to illegal artisanal refineries activities as well as receptacle of runoff from surrounding agricultural fields to mention but a few. The river lies between the coordinates of Latitude 50 50’N and Longitude 60 05’ E-60 15’E. There is no doubt that, these anthropogenic activities have contaminated the Nun River systems and its aquatic organisms.

2.2. Sample Collection

Fresh water shellfish, Prawn (*Microbrachium felicinum.*), Clam (*Galatea paradoxa*) and fish (*Synodotis budgetti*) were collected from the Nun River in Igbomatoru Community, Southern Ijaw, Bayelsa State, while the salt water shellfish shrimp (*penaeus monodon*) and blood clam (*Tegillarca. granosa*) and bonga-shad fish (*Ethmalosa fimbriata*) were collected from the Nun River in Sangana community of Akassa, Bayelsa State. All samples were collected from local farmers, stored in plastic containers and transported to the Central Research Laboratory, Department of Chemical Sciences, Niger Delta University, Wilberforce Island, Bayelsa State.

2.3 Sample Preparation and Analysis

All edible parts of the samples were thoroughly washed with distilled water and placed in an oven at 105 ^{0}C to a constant weight. The oven dried samples were crushed using a manual laboratory mortar and pestle and then sieved to obtain a uniform particle size. Then 1 gram (g) of each fresh water sample: Clam (*G. paradoxa*), Prawn (*M. Felicinum*) and Fish (*S. budgetti*) and salt water sample: shrimp (*P. Monodon*), blood clam (*T. granosa*) and bonga shad fish (*fimbriata*) was digested with 20 mL conc. H_2SO_4/HNO_3 solution containing 3:1 V/V and 5 mL of $HClO_4$. The digests were cooled, and diluted with 20 mL of distilled water, then filtered and transferred into 100 mL flask and makeup the marks with distilled water and put in sample bottles, then labeled appropriately.

The metals (Zn, Fe, Cu, Mn and Co) concentrations in each sample were analyzed with AAS, Thermo-Electric Atomic Absorption Spectrophotometer (S-471096 model).

2.4 Health Risk Appraisal

Health risk appraisal of metals in food and the environment as a whole provide information arising from metal pollution in the food and the health indices via the consumption of the food. This solely depends on the concentration of the metal as well as the rate of food consumed daily. This study appraised the health risk via the consumption of these seafood using the Tolerable Dietary Intake (TDI), Target Hazard Quotient, and Hazard Index commonly known as the non-carcinogenic risk.[15,16]

2.4.1: Tolerable Dietary Intake of Metals in Seafood

The estimation of Tolerable Dietary Intake of the Metals (Zn, Fe, Cu, Mn and Co) via consumption of fresh and salt water fish and shellfish by children and adults of Bayelsa State, Nigeria were calculated using equation 1.

$$\text{TDI (mg/kg-bw/day)} = \frac{C_{metal} \times D_{seafood}}{BW} \quad \ldots\ldots\ldots\ldots\ldots 1$$

Where; C_{metal} = metal concentration (mg/kg) in each seafood; $D_{seafood}$ = Dietary Intake of seafood (0.3 kg/person for adults and 0.15 kg/person for children), and BW = average body weight (60 kg for adults and 25 kg for children).[17]

The tolerable daily intake of 0.3 kg/person/day for adults, and 0.15kg/person/day for children used in this study was relatively high. However, the USEPA,[18] reported that, the dose of exposure is equal to the chemical concentration (percentile of 95%) times the contact ratio. Therefore, these high values were considered in view of reducing the probability of occurrence of deleterious effects during a lifetime so as to protect adverse human health effects in future since, these fishes and shellfish are commonly consumed among local residents, and are the main sources of animal protein to most households.

2.4.2 Target Hazard Quotient (THQ).

The THQ is the estimation of non-carcinogenic risk level due to pollutant exposure. THQ was estimated based on USEPA Region III Risk-based concentration Table,[15] and was expressed as follows;

$$\text{THQ} = \frac{EF \times ED \times C_{metal} \times D_{sseafood}}{RFD \times BW \times ATn} \text{ X } 10^3 \quad \ldots\ldots\ldots\ldots 2$$

Where; EF = exposure frequency (365 days/year), ED = the exposure duration (70 years), $C_{metal,}$ and $D_{seafood}$ and BW have been defined in equation 1; RfD = Reference dose (oral) in mg/kg –bw/day. The RfD defines a daily exposure of a contaminant or pollutant to human population including vulnerable sub-group (such as children, pregnant women and elderly) that is likely to be without an appreciable risk of deleterious effect during life time. The RfD (mg/kg/bw/day) of the metals used in this study were; Zn (0.3), Fe (0.7), Cu (0.04), Mn (0.014), Co (0.043) respectively; AT_n = is the average exposure time for non-carcinogens (365 days/year × ED) which is equal to 365 days/year × 70 years = 25550 days, 10^3 is the unit conversion factor.[15,16]

2.4.4: Hazard Index (HI)

Hazard index (HI) is the sum total of THQ of the individual metal in the seafood and was expressed as follows;

$$HI = THQ_{Zn} + THQ_{Fe} + THQ_{Cu} + THQ_{Mn} + THQ_{Co} \ldots\ldots\ldots\ldots\ldots\ldots\ldots 3$$

The lower range of acceptable risk distribution of HI value defined by a single constraint on the 95th percentile is ≤ 1, when HI value is > 1 then, the exposed population is at risk and this indicates reason for concern.[15,19]

3.0 RESULTS AND DISCUSSION

3.1. Zu, Fe, Cu, Mn and Co Concentrations in Seafood

Table 1 Showed the concentrations of the essential metals, Fe, Zn, Fe, Cu, Mn and Co in fresh and salt water fish and shellfish.

Table 1: Mean + SD Concentrations of Zn, Cu, Fe, Mn and Co (mg/kg) in Fresh and Salt Water Seafood Collected from Nun River, Bayelsa State in Comparison to Standard Values.

Seafood		Essential Heavy Metal (mg/kg)				
		Zn	Fe	Cu	Mn	Co
Fresh water seafood	Fish (*S. budgetti)*	0.58 ± 0.11	2.88 ± 0.53	0.05 ± 0.01	3.89 ± 0.19	0.19 ± 0.02
	Prawn *(M. felicinum)*	1.03 ± 0.13	3.00 ± 0.00	0.09 ± 0.01	5.46 ± 0.39	0.30 ± 0.01
	Clam (*G.paradoxa)*	0.30 ± 0.01	4.27 ± 0.62	0.05 ± 0.01	4.01 ± 0.16	0.01 ± 0.00
Salt water samples	Fish bonga shad (*E. fimbriata)*	0.37 ± 0.19	1.33 ± 0.60	0.02 ± 0.01	2.23 ± 0.98	0.58 ± 0.52
	Shrimp (*P. Monodon)*	0.67 ± 0.06	2.65 ± 0.21	0.06 ± 0.01	1.14 ± 0.06	0.10 ± 0.01
	Blood clam *(T. granosa)*	0.70 ± 0.13	5.50 ± 1.20	0.05 ± 0.02	3.63 ± 2.69	0.17 ± 0.03
Guidelines values FAO/WHO[20]		50.00	2.00	20.00	0.40	0.30
IAEA[21]		67.10	146.00	3.28	3.52	0.023

Zinc (Zn)

The mean + SD values of Zn in the fresh water fish and shellfish: *S. budgetti, M. felicinum* and *G. paradoxa* were; 0.58 ± 0.11 mg/kg, 1.03 ± 0.13 mg/kg and 1.13 ± 0.45 mg/kg, and the salt water samples: *R. fimbriata, P. monodon* and *T. granosa* were; 0.37 ± 0.19 mg/kg, 0.67 ± 0.06 mg/kg and 0.70 ± 0.13 mg/kg respectively. The highest concentration of Zn (1.13 ± 0.45 mg/kg) was found in fresh water clam and the lower value (0.37 ± 0.18 mg/kg) was found in salt water fish-bonga shad (*E. fimbriata*). However, there were no significant difference (p> 0.05) between the concentrations of Zn in fresh water and salt water fish and shellfish samples. Zn is an essential micronutrient required to maintain certain biological functions in humans and animals systems. The mean values of Zn in this study were lower than the recommended standard values of FAO/WHO,[20] and IAEA.[21] These values were also lower than the value of Zn reported by Markmanuel *et al*;[6] in marine perewinkles but similar to the values reported by Ijeomah *et al.*[22]

Iron (Fe)

Fe values (mean ± SD) in fresh water samples *S. budgetti* (fish), *M. felicinum* (prawn) and *G. paradoxa* (Clam) were; 2.88 ± 0.53 mg/kg, 3.00 ± 0.00 mg/kg and 4.27 ± 0.62 mg/kg. While the salt water samples of fish-bonga shad (*E. fimbriata*), Shrimp (*P. monodon)* and blood clam (*T. granosa*) were, 1.33 ± 0.60 mg/kg, 2.65 ± 0.21 mg/kg and 5.50 ± 1.20 mg/kg. The highest mean concentration of Fe was found in *T. granosa* (5.50 ± 1.2.0 mg/kg) while, the lowest value was found in *R. fimbriata* (1.33 ± 0.60 mg/kg). The value of Fe in the samples were higher than the standard guideline value of FAO/WHO except in *E. fimbriata* but lower than the standard limits of IAEA. However, the values of Fe in this study were lower than the value reported by Nwabueze and Oghenevwairha,[23] in African Clam (*E. radiate*) from Delta State Nigeria but, higher than the value reported by Oguzi and Ehigiator [24] in *M. felicium* from Edo State, Nigeria.

Fe is an indispensable metal, requisite for the formation of red blood cells as a salient component of the hemoglobin in human systems. However, higher concentration is potentially toxic and is known to generate oxidative stress.[25] Other toxic symptoms are; abdominal pains, vomiting, seizures, gastric perforation, diarrhea to renal failure, coma and cardiogenic arrest.[26]

Copper (Cu)

The mean ± SD levels of Cu in the fresh samples were; fish (S.*budgetti*); 0.05 ± 0.01 mg/kg, Prawn (*M. felicinum*); 0.09 ± 0.01 mg/kg, Clam (*G. paradoxa*); 0.05 ± 0.01, and salt water samples were; fish-bonga shad (*E. fimbriata*); 0.02 ± 0.01 mg/kg, Shrimp (*P. monodon*); 0.06 ± 0.01 mg/kg and Blood clam (*T. granosa.*); 0.05 ± 0.02 mg/kg respectively. *M. felicinum* has the highest mean value of 0.09 ± 0.01 mg/kg and the *E. fimbriata* has the lowest mean value of 0.02 ± 0.01 mg/kg. However, there were no significant difference (P>0.05) between the mean concentration of Cu in fresh water and salt water species. The value of Cu in this study in all samples were generally lower than the standard limits of FAO/WHO and IAEA. These values were also lower than the mean values reported by Baki *et al*.,[12] in marine fishes and crustacean in Saint Matin Island Bangladesh and Carmen *et al.*, [26] in seafood. Copper is an essential trace dietary metal required by living systems. In molluses and crustaceans, Cu is a key component of the blood pigment hemocyanin but prolonged exposure can cause diverse health effects such as liver, lung, brain and kidney damage.[27]

Manganese (Mn)

The mean concentrations of Mn in the fresh water samples were; 3.89 ± 0.19 mg/kg in *S. budgetti*, 5.46 + 0.39 mg/kg in *M. felicinum*, 4.01 ± 0.16 mg/kg in *G. paradox* and the salt water samples were; 2.23 ± 0.98 mg/kg in *E. fimbriata*, 1.14 ± 0.06 mg/kg in *P. monodon* and 3.63 ± 2.69 mg/kg in *T. granosa.* Also, *M. felicinum* has the highest mean value of 5.46 ± 0.39 mg/kg while, *P. monodon* has the lowest value of 1.14 ± 0.06 mg/kg. The value of Mn in the seafood is higher than the recommended standard value of FAO/WHO and IAEA as indicated in table 2, except in *P. monodon* and *E. fimbriata* that the values are lower than the guideline value of IAEA. But these values were lower than the values reported by Baka; *et al*.,[12] in crustacean. Low intake of Mn is vital for normal growth and development in the human system because Mn has been reported to be involved in many chemical processes in the body such as processing of cholesterol, carbohydrate and protein. However, excessive ingestion can lead to several adverse health effects which include central nervous system damage, muscle spasms, hearing loss etc.[28]

Cobalt (Co)

The mean ± SD values of Co in the fresh water species were; 0.19 ± 0.02 mg/kg (*S. budgetti*), 0.30 ± 0.01 mg/kg (*M. felicinum*) and 0.01 ± 0.00 mg/kg (*G. paradox*) and salt water samples were; 0.58 ± 0.52 mg/kg (*E. fimbriata*), 0.10 ± 0.01 mg/kg and 0.17 + 0.03 mg/kg (*T. granosa.)* respectively. The highest mean value was found in *E. fimbriata* (0.58 ± 0.52 mg/kg and the lowest value was found in *P. monodon* (0.10 ± 0.01 mg/kg). The mean values of Co in the fresh and salt water samples were lower than the standard values of FAO/WHO and IAEA except in *E. fimbriata*, and also lower than the values reported by Manuel et al.,[17] in some shellfish from Todos os santos Bay, Balia, Brazil and Godwin *et al.*,[29] in tilapia nicolitica from selected rivers in Bayelsa State.

Collectively, the mean concentration of the metals varies considerably among the different seafood samples. This can be attributed to the bioavailability of the metal to each organisms and subsequent capacity of each species to absorb, excrete, store and regulate these toxicants within its system. Similarly, Manuel *et al*.,[17] and Baki *et al.*,[12] have reported accumulation pattern of heavy metals among different species of seafood. However, in this study the mean concentrations of the metals in the fresh water samples were found in the hierarchy order of Mn > Fe > Zn > Co > Cu, and the salt water species were found in the order of Fe > Mn > Zn > Co > Cu. Also, the mean metal values obtained in this study were lower than the recommended standard values of FAO/WHO and IAEA except Mn. Since these metals are essential for healthy life, therefore, these seafood samples are good sources of essential nutrients to consumers at the moment.

3.2. Health Risk Appraisal

The non-carcinogenic risk appraisal via the consumption of seafood by adults and children residence in Bayelsa State, Nigeria were estimated based on the estimation of tolerable dietary intake (TDI), target hazard quotient (THQ) and hazard index (HI). The results obtained are presented in Table 2, and 3 respectively.

Appraisal of Total Dietary Intake (TDI)

Table 2 shows the tolerable dietary intake (TDI) of the metals (Zn, Fe, Cu, Mn and Co) via the consumption of seafood from the Nun River. The tolerable dietary intake (TDI) is the quantitative amount of the nutrient substance ingested from source (seafood or any other food products) that is considered adequate for a daily requirement of almost 97-98% healthy individual during a life-time. This study considered a total dietary intake of 0.3 mg/ kg-person/day (adults) and 0.15 mg/kg person/day (children) as a safe limit through the consumption of seafood contaminated with Zn, Fe, Cu, Mn and Co. The results obtained from this study were compared with standard limits for tolerable upper daily intake set by regularly bodies. As indicated in table 2, the results showed that, the TDI values of all metals in the different seafood samples for both children and adults were lower than the tolerable upper daily intake (mg/kg-bw/day) set by EFSA [30] and EVM,[31] respectively. Also these values were lower than EDI values of Zn, Cu and Fe reported by Markmanuel *et al*.,[6] in marine periwinkles from Bayelsa State, but similar to the value reported by Baki *et al*.,[12] in marine fish and crustacean. Notwithstanding, it should be noted that, these seafood are safe based on the concentration of the metal investigated in study and the tolerable dietary intake of 0.3 mg/kg/bw/day (adults) and 0.15 mg/kg –bw/day. Therefore, concentration above these values may pose adverse health effects to consumers.

Appraisal of Non-Carcinogenic Risk

The non-carcinogenic risk appraisal was conducted in order to determine the target hazard quotient of (THQ) of each metal and the combined hazard indices (HI) of all the metals (Zn, Fe, Cu, Mn and Co) via the consumption of the seafood by children and adults as to prevent adverse health effects in future. The results showed that, the THQ values of each metal in all seafood samples for children and adults were less than their oral reference dose (mg/kg – bw /day). The aggregated hazard indices of all the metals in the seafood for children and adults were all less than one (HI < 1), USEPA,[11,15] This implies that, the exposed population (children and adults) via the consumption of contaminated seafood with Zn, Fe, Cu, Mn and Co are unlikely to experienced adverse health hazard at the moment. The THQ and HI values from this is also lower than the values reported by Baki *et al.*,[12] in marine fish and Crustacean and Markmanuel *et al.*,[6] in marine periwinkles.

Nevertheless, it is eminent to note that, Mn was a major risk contributor to the HI values in the seafood ranging between 89-96% of the HI values for each seafood sample for both children and adults. Studies had shown that manganese is neurotoxic at high levels of exposure and can also damage the central nervous system.[32] Martin[33] has also reported low level of chronic exposure to cause neurotoxicity, manifesting itself as sub-clinical and sub-functional decline in the performance of specialized neuropsychological tests. Anemic patients have also been reported to be more vulnerable to the toxic effects of manganese due to increased absorption during iron deficiency.[31] Hence the increased % contribution of manganese to the HI values in each seafood sample in this study indicates a result for health concern.

Table 2: Tolerable Dietary Intake TDI (mg/kg-bw) of The Heavy Metals for Children and Adults via the Consumption of Seafoods in Comparison to Standard Values.

Seafood species		Exposed population	TDI for each metal				
			Zn	Fe	Cu	Mn	Co
Fresh water species	*S. budgetti*	Children Adult	$3.48 X 10^{-3}$ $2.90 X 10^{-3}$	$1.73 X 10^{-2}$ $1.44 X 10^{-2}$	$3.00 X 10^{-4}$ $2.50 X 10^{-4}$	$2.33 X 10^{-2}$ $1.95 X 10^{-2}$	$1.14 X 10^{-3}$ $9.50 X 10^{-3}$
	M. felicinum	Children Adult	$6.18 X 10^{-3}$ $5.15 X 10^{-3}$	$1.80 X 10^{-2}$ $1.50 X 10^{-2}$	$5.44 X 10^{-4}$ $4.50 X 10^{-4}$	$3.28 X 10^{-2}$ $2.73 X 10^{-2}$	$1.80 X 10^{-3}$ $1.50 X 10^{-3}$
	G. paradox	Children Adult	$6.78 X 10^{-3}$ $5.65 X 10^{-3}$	$2.56 X 10^{-2}$ $2.14 X 10^{-2}$	$3.00 X 10^{-4}$ $2.50 X 10^{-4}$	$2.41 X 10^{-2}$ $2.01 X 10^{-2}$	$6.00 X 10^{-5}$ $5.00 X 10^{-5}$
Salt water species	*E. fimbriata*	Children Adult	$2.22 X 10^{-3}$ $1.85 X 10^{-3}$	$7.98 X 10^{-2}$ $6.65 X 10^{-2}$	$1.20 X 10^{-4}$ $1.00 X 10^{-4}$	$1.34 X 10^{-2}$ $1.12 X 10^{-2}$	$3.48 X 10^{-3}$ $2.90 X 10^{-3}$
	P. moradox	Children Adult	$4.02 X 10^{-3}$ $3.35 X 10^{-3}$	$1.59 X 10^{-2}$ $1.33 X 10^{-2}$	$3.60 X 10^{-4}$ $3.00 X 10^{-4}$	$6.84 X 10^{-2}$ $5.70 X 10^{-2}$	$6.00 X 10^{-4}$ $5.00 X 10^{-4}$
	T. granosa	Children Adult	$4.20 X 10^{-3}$ $3.50 X 10^{-3}$	$3.30 X 10^{-2}$ $2.75 X 10^{-2}$	$3.00 X 10^{-4}$ $2.50 X 10^{-4}$	$2.18 X 10^{-2}$ $1.82 X 10^{-2}$	$1.02 X 10^{-3}$ $8.50 X 10^{-4}$
	Standard Guidelines EFSA[30] (mg/kg-bw/day)		$4.0 X 10^{-1}$	$3.0 X 10^{-1}$	$8. 0 X 10^{-2}$	$9.0 X 10^{-3}$	$1.4 X 10^{-3}$
	EVM[31] (mg/kg-bw/day)		$7.0 X 10^{-1}$	$1.7 X 10^{-2}$	$1.6 X 10^{-1}$	$4.0 X 10^{-3}$	-

Table 3: Non-Carcinogenic Risk: THQ, HI and the Percentage HI of Metal for Children and Adults via Seafood Consumption.

Seafood species		Exposed population	THQ of each metal					HI (∑THQ)	% contribution of each metal to HI				
			Zn	Fe	Cu	Mn	Co		Ze	Fe	Cu	Mn	Co
Fresh water species	*S. budgetti*	Children Adult	$1.6 X 10^{-5}$ $9.67 X 10^{-6}$	$2.47 X 10^{-5}$ $2.06 X 10^{-5}$	$7.50 X 10^{-6}$ $6.25 X 10^{-5}$	$1.67 X 10^{-3}$ $1.39 X 10^{-3}$	$2.65 X 10^{-5}$ $2.21 X 10^{-5}$	$1.74 X 10^{-3}$ $1.46 X 10^{-3}$	0.67 1.36	1.42 1.41	0.43 0.43	95.95 95.29	1.53 1.52
	M. felicinum	Children Adult	$2.06 X 10^{-5}$ $1.72 X 10^{-5}$	$2.57 X 10^{-5}$ $2.14 X 10^{-5}$	$1.30 X 10^{-5}$ $1.13 X 10^{-5}$	$2.34 X 10^{-2}$ $1.95 X 10^{-3}$	$4.19 X 10^{-5}$ $3.49 X 10^{-5}$	$2.44 X 10^{-3}$ $2.03 X 10^{-3}$	0.84 0.84	1.05 1.05	0.55 0.55	95.84 95.84	1.72 1.72
	G. paradoxa	Children Adult	$2.26 X 10^{-5}$ $1.88 X 10^{-5}$	$3.66 X 10^{-5}$ $3.05 X 10^{-5}$	$7.50 X 10^{-6}$ $6.25 X 10^{-6}$	$1.72 X 10^{-3}$ $1.43 X 10^{-3}$	$1.39 X 10^{-6}$ $1.15 X 10^{-6}$	$1.79 X 10^{-3}$ $1.49 X 10^{-3}$	1.26 1.26	2.05 2.05	0.42 0.42	96.19 96.19	0.08 0.08
Salt water species	*E. fimbriata*	Children Adult	$7.40 X 10^{-6}$ $6.12 X 10^{-5}$	$1.44 X 10^{-5}$ $9.50 X 10^{-6}$	$3.00 X 10^{-6}$ $2.50 X 10^{-6}$	$9.51 X 10^{-4}$ $7.90 X 10^{-4}$	$8.09 X 10^{-5}$ $6.74 X 10^{-5}$	$1.05 X 10^{-3}$ $8.78 X 10^{-4}$	0.70 0.70	1.08 1.08	0.28 0.28	90.26 90.26	7.68 7.68
	P. monodox	Children Adult	$1.34 X 10^{-5}$ $1.12 X 10^{-5}$	$2.27 X 10^{-5}$ 1.89 X	$9.00 X 10^{-6}$ 7.50 X	$4.89 X 10^{-4}$ 4.07 X 10-	$1.39 X 10^{-5}$ 1.16 X 10-	$5.48 X 10^{-4}$ 4.56 X	2.45 2.45	4.15 4.15	1.64 1.64	89.21 89.21	2.55 2.55

				10^{-5}	10^{-6}	4	5	10^{-4}					
	T. garamosa	Children Adult	1.40×10^{-5} 1.17×10^{-5}	4.71×10^{-05} 3.93×10^{-3}	7.50×10^{-6} 6.25×10^{-6}	7.54×10^{-4} 6.29×10^{-5}	2.37×10^{-5} 1.98×10^{-5}	8.47×10^{-4} 7.06×10^{-4}	1.65 10.65	5.57 5.57	0.89 0.89	89.09 89.09	2.80 2.80
Standard Guidelines USEPA,[15,16,19]								≤ 1					

CONCLUSION

Nutritional essential metals; Zn, Fe, Cu, Mn and Co in seafood from the Nun River were investigated in this study. The results of the mean concentrations shows variability among the metals in each seafood sample, which depends on the bioavailability, solubility and absorption of the metals by these seafood species. Collectively, the mean concentrations of the metals in the fresh water species were in the hierarchical order of Mn > Fe > Zn > Co > Cu, while the salt water species were in the order of Fe > Mn > Zn > Co and Cu. The mean values of the metals in this study were lower than standard recommended limits of FAO/WHO and IAEA except for Mn. The health risk appraisal results also revealed that, the TDI values of the metals in each seafood samples for children and adults were all lower than tolerable daily intake set by regularly bodies. Also the THQ and HI values for non-carcinogenic health effects were lower than I. This implies that the exposed population (children and adults) are unlikely to experienced adverse health hazard via the consumption of these seafood contaminated with Zn, Fe, Cu, Mn and Co at the moment. However, continuous monitoring of other contaminants in the Nun River system is recommended.

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CONFLICT OF INTEREST

The authors declared that, there is no conflict of interest.

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