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Accumulation of metal residues in the tissues of *Caranx hippos* from rivers affected by industrial operations and its potential health risk implications

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ABSTRACT: Background: This study assessed the human health risks caused by heavy metal (Fe, Pb, Cr, Cd, Zn, Ni, Cu, and Co) contamination in Crevalle Jack (Caranx Hippos) from Ogbogoro, Rumuokani, and Choba in Rivers State.

Methods: The study used the Adaptive Risk Assessment Modeling System (ARAMS) to evaluate the non-carcinogenic and carcinogenic risks associated with heavy metal contamination in C. hippos.

Results: The results showed that the daily intake of all the studied heavy metals via C. hippos was within their respective health-based guidance values and may not pose any non-cancer health effects to human consumers. However, the results for the Hazard quotient (HQ) and the hazard index (HI) in the three locations were less than one (Hi>), which means there is a lack of potency to cause non-cancer effects in human consumers. However, the cumulative consumption of heavy metals via C. hippos has the probability of impacting the non-cancer effect in human consumers in locations 2 but may not cause a non-cancer effect in human consumers in locations 1 and 3.

Conclusion: The research underscores the significance of enforcing regulations, conducting regular monitoring, and promoting safe food consumption practices to address heavy metal pollution in the studied regions and safeguard public health. The implementation of effective public policies aimed at reducing these risks among the Brazilian population would yield substantial benefits for public health.

KEYWORDS: Heavy metals, human health risks, Pollution, Crevalle Jack.

INTRODUCTION

Heavy metal pollution in the Niger Delta region of Nigeria is caused by both industrial and artisanal refining of crude oil [1, 2]. This has resulted in significant environmental and health impacts on the local population [3]. Some researchers reported that heavy metals such as lead, cadmium, and mercury are found in water, soil and air samples in the Niger Delta region, and have been associated with a range of health problems, together with cancer, neurological damage, and respiratory illness [4, 5, 6]. According to [7, 8]. pollution impacts have a negative impact on local agriculture and fishing, which are important sources of livelihood for many communities in the Niger Delta.

The aquatic ecosystem in some communities in the Niger Delta has been impacted significantly by heavy metals as a result of anthropogenic pollution from many sources [9, 10, 11]. Effluence from industrialized and artisanal refining of crude oil has also led to the release of toxic metals like mercury, lead, chromium, cadmium, and arsenic into the aquatic environment [12, 13]. Recently, it was established that these pollutants can be detrimental to the region's water and sediment quality and the health of people living around that region [14, 15].

High levels of heavy metals in the water can lead to lethal and chronic health problems, such as skin and respiratory diseases, and even cancer [16, 17, 18, 19]. According to [20, 21], heavy metals bioaccumulate in the flesh of fin and shellfish, and other aquatic biota, leading to accumulation and biomagnification in the food chain.

Fish and other aquatic animals are particularly vulnerable to heavy metal contamination because they live in water [22], which is an important pathway for pollutants to enter the food chain [23]. Once in the food chain, heavy metals can accumulate in fish and other animals over time, making them a source of exposure to humans who consume them [23, 24]. Heavy metal contamination in fish can have a significant impact on human health, and it is important to understand the levels of contamination and the potential risks associated with consuming contaminated fish [25, 22, 26, 27, 28]. Furthermore, some individuals may be more susceptible to metal toxicity than others, such as pregnant women, young children, the elderly, and people with pre-existing health conditions [29, 30]. Therefore, it's important to consider the characteristics of the population and the environment when assessing the risk of metal toxicity [23].

Heavy metal contamination is a significant threat to protein-rich foods such as fish and meat, including Crevalle Jack (Caranx hippos) [31, 32, 33]. Heavy metals can be found in different food channels via bioaccumulation when pollutants enter the soil and water are absorbed by faunas and floras, and then accumulate in their tissue over time [34, 23, 35]. Several published pieces of literature have been established on the health effects of metals on humans [36, 37, 38, 39, 5]. Metal effects have been shown to affect the health of humans. Some health effects of these metals include dementia, damage to the central nervous system, neurological disorders, increases in systolic cardiovascular diseases and diastolic blood pressure, gastric upset, loss of memory, constipation, nausea, vomiting, listlessness and severe trembling, abdominal pain and faintness, cancer and renal dysfunction [40, 41].

Previous studies have reported on metal concentrations in other fishes like crayfish, meat, and cowskin, etc., but the human health risks associated with Crevalle Jack (*Caranx Hippos*) in Ogbogoro, Rumuokani and Choba situated in Obioakpo Local Government area of Rivers State, Nigeria have not been extensively studied. This study aims to fill this gap by assessing the potential health risks associated with consuming fish contaminated with heavy metals. The objective of the present study is to assess the carcinogenic and non-carcinogenic effects of heavy metals in commonly consumed fish Caranx Hippos (*Crevalle Jack*) from three locations in Rivers State, Nigeria. This study will provide an overview of the human health risk assessment and simulation of heavy metal-contaminated fish in these rivers affected by industrial activities.

The study will provide useful information on the potential risk associated with consuming this fish species from this river and will inform managerial decisions to protect human health and the environment. However, the study will also serve as a baseline for future studies on heavy metal contamination in fish and other aquatic organisms within this area thereby providing useful data for modelling the potential health risks to individuals who consume the fish, the carcinogenic and non-carcinogenic related risk in the Niger Delta region of Nigeria.

MATERIALS AND METHODS

Study area

The study was conducted in three sampled locations (Ogbogoro, Rumuokani, and Choba) situated in Obioakpo Local Government area of Rivers State in the Niger Delta area of Nigeria (Figure 1). Ogbogoro is located at longitude and latitude (4°50'29.7"N 6°55'28.5" E), which is situated near a small waterway that passes through a bridge close to a major market in the community. Activities carried out around the area range from fishing to dredging and sales of fish, the fish caught from the creek are sold directly to the Ogbogoro daily market. The Ogbogoro market site, where the river is largely linked to the New Calabar River Anthropogenic activity in this area is high as there is high deposition of consumer wastes and landfills with plastic wastes, pollution at the shores of the river, and very highly impacted by dragging activities.

The Rumuokani sampled location is close to the Oduaha market and health centre adjacent to the Ikukiri (4°48'55.9"N 6°55'02.5" E). A trunk road leads to a sand dredging site, where the river is relatively larger in size and links to another river with more dredging sites in front of the river. Abattoir and domestic waste are sited near an unrestricted burrow pit, which harbours a refuse dump. The Choba sampled location (4°53'33.8"N 6°53'58.0" E) is close to the University of Port Harcourt. This station is also very close to the new Calabar River where water flows into the major Sombreiro River. Choba's sampled location is adjacent to the dredging site where fishing activities take place. The water is salty, close to the weekly market (the market operates every eight days), the bottom substrate consists of mud and silt, and the water is continuously turbid due to the presence of anthropogenic activities ranging from wastes deposited and oil spillage. These three research areas are located in an area with a humid environment, where it rains virtually the entire year.

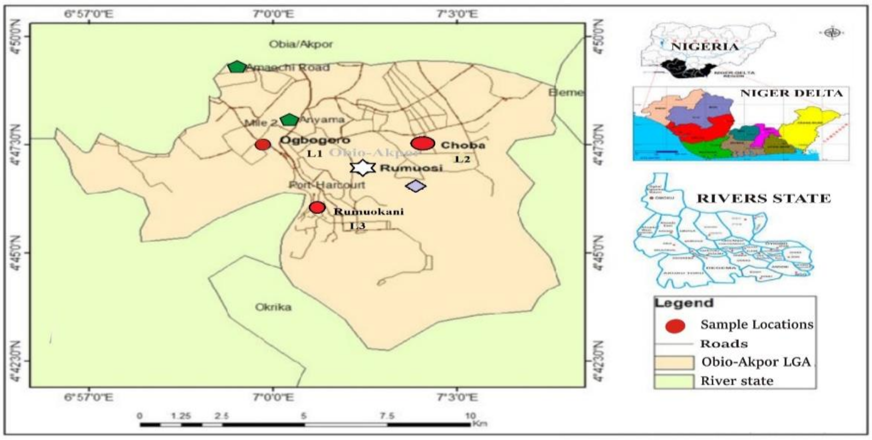

Fig 1. Map of the sampling locations studied (with three red dots) in Rivers State, Nigeria.

Sample collection of crevalle jack (Caranx hippos)

Fish samples were collected from the different stations (Fig. 1) of the three sampled rivers where fishing effort is high. Fish samples were collected from professional fishermen while they were fishing in the river from February to July 2020. This was carried out during the first week of each sampling month. The fish sample was of similar size and weight. The samples collected were preserved immediately in air-sealed plastic bags placed in an ice pack before being transported to the laboratory. The sampled species were identified using the FAO species identification guide for fishery purposes [42]. The fish sample was identified as Crevalle Jack (*Caranx hippos*) with a mean weight of 210 ± 0.57 g (Fig 2). The fish tissues were dried and stored in a clean, clearly labeled, plastic container.

Fig 2. Crevalle Jack (*Caranx hippos*)

Sample preparation and digestion

The fish samples were granulated using a blender and the water was digested using 20ml conc. H_2SO_4. Tissue samples from Crevalle Jack (*Caranx Hippos*) measuring 0.5±0.01 g were measured straight into MDS-81D Teflon digestion containers. Each vessel was treated with ten millilitres of ultra-pure nitric acid before being heated to 1000 degrees Celsius using an XT-9800 pre-treatment heater until virtually all of the nitrogen dioxide was released. A 4 mL aliquot of concentrated HNO_3: HF (1:1 v/v) acid mixture was administered prior to microwave digestion. To guarantee homogeneity and process efficacy, each digestion batch included a representative reference standard, a sample replication, and at least one reagent blank. Microwave digestion consisted of three phases: 0.5 MPa for one minute, 1.0 MPa for two minutes, and 1.5 MPa for three minutes. After cooling for at least 1 hour, the digested sample was transferred to a graduated plastic test tube and the volume was raised up to 100 mL with Milli-Q water [43].

The dried fish samples were digested according to the method of [44] as described by [22]. The tissues were oven-dried at 65ºC overnight and allowed to cool at room temperature. 0.5g of dried powdered fish tissues (three replications) was taken in a digestion apparatus and 2.5 ml conc. H_2SO_4 and 4ml conc. HNO_3 was taken. The mixture was slowly heated using a hot plate for 20 min. at 130ºC and allow to cool at room temperature [45]. The content was deionized distilled water (DDW) and filtered quantitatively into a 50 ml volumetric flask.

Determination of heavy metals and analysis

The heavy metal analysis was done using APHA 3111 [46]. The heavy metals analyzed were Fe, Pb, Cr, Cd, Zn, Ni, Cu, and Co. The instrument setting and operational conditions were done in accordance with the manufacturers' specifications.

Statistical Analysis

Descriptive statistics and Analyses of Variance (ANOVA) were done using SPSS version 16. Significant means were separated with the Duncan Multiple Range Test at 0.05. Fish tissue concentration was calculated with the mean values generated. Microsoft Excel software was used to interpret the data presented. Mean, standard deviation and standard error of the mean were the statistical quantities employed to manage the data.

Non-cancer risk assessment

Chronic daily intake (CDI)

The concentrations of the heavy metals were determined in order to evaluate the adverse effects of exposure on human health. Intake, purposeful or unintentional inhalation and skin absorption of heavy metals into the body are all possible [47]. Estimated daily intake (EDI; mg/kg/day) aids in determining the degree of health risk brought on by various paths of heavy metal exposure. The EDI of metals from the tissues of crevalle jack (*Caranx hippos*) was calculated in this study using the procedure outlined by [48] and represented in Eq. (1):

$$CDI = (EF \times ED \times FIR \times Cm)/(BAW \times AT) \quad (1)$$

where CDI = Chronic daily intake (the estimated (derived) exposure dose, mg/kg/day).

EF is the exposure frequency (365 days/year), This was done following the United States Environmental Protection Agency [49], Office of Research and Development, and National Centre for Environmental Assessment's guidance and risk assessments for fish and shellfish intake. The conversion of metal concentrations measured in dry weight to wet weight was done using a moisture content percentage of 13.458, according to Eq. (2):

$$Cww = Cdw\,[(100-W)/100] \quad (2)$$

Cww represents the wet weight concentration, Cdw represents the dry weight concentration, and W is the moisture content.

Hazard quotients (HQ)

The health risks associated with human exposure to heavy metals in samples from the Isaka-Bundu tidal mangrove swamp were assessed using hazard quotients (HQ) as non-carcinogenic hazards defined by the [50]. The hazard index (HI), developed to quantify the cumulative non-carcinogenic exposures, indicates the total exposed hazard quotients across the various exposure routes [48] as shown in Eq. (3):

$$HQ = \frac{CDI}{RfD} \quad (3)$$

where CDI = chronic daily intake (the estimated (derived) exposure dose, mg/kg/day).
RfDo = Oral Reference dose (mg/kg/day)

RfDo is an estimate (used with uncertainty) of a daily exposure (ingestion) to the human population (infants and adults) that is likely to be taken without an appreciable risk of deleterious effects during a lifetime. The RfDo is used as a standard value from which to compare the potential effects of the chemical at other doses. Average or estimated intakes less than the RfDo are not likely to elicit any adverse health risks [50].

Hazard index (HI)

The hazard index (HI) is the total of hazards posed by the possible forms of pollutant absorption. It is calculated using Eq. (4), which is a summing of non-carcinogenic effects:

$$HI = \sum HQ1 + HQ2 + HQ3\, HQ4 \ldots\ldots\ldots n \quad (4)$$

where, HI = Hazard index for a specific exposure pathway. It represents the cumulative potential hazard that may arise from ingesting a particular chemical via a given diet. It is a unitless quantity. 1, 2, 3, 4, ---- n represent the individual heavy metals present in the studied fish. HI, value is an estimate of the combined effect of more than one heavy metal consumed via the same route.

HI <1 for non-carcinogenic effects (acceptable risk, no action required from a human health perspective (policy decision) [51], while HI > 1 reflects the occurrence of negative consequences, HI > 4 is regarded as a high negative effect according to [51].

Carcinogenic risk assessment (CR)

Cancer Risk Assessment

$$Riskofingestion = \frac{CsfxCDIxEfxED}{ATx365days} = \frac{CsfxCDIxIRxEfxxED}{BwxATx365days} = \text{mg kg}^{-1}\text{ day}^{-1} \quad (5)$$

where:
CDI = Chronic Daily Intake in mgkg $^{-1}$ day $^{-1}$
IR = ingestion rate = 0.036kg person-1day-1 converted from per capita fish consumption in Nigeria [52].
Bw = Standard body weight of an adult which is given as 70kg for an adult [51] CHM is the average concentration of individual heavy metals in the studied shellfish species
E_f = exposure frequency (days/yr) = 350 days/y
ED = exposure duration (yr) = 30yr (adult)
AT = Averaging time the period over which exposure is averaged (days); for carcinogens, the average time is 25,550 days (lifetime exposure of 70 years multiplied by 365 days per year), and 30 years for non-cancer HI (equal to ED).
Age-Adjusted Parameters for Children (5 – 31 Yr Old) Risk Assessment
$EDage_{5\text{-}31}$ = exposure duration during ages 5-31 (yr) = 26 yr
$IR_{fish/age\ 5\text{-}31}$ = ingestion rate of soil age 5 - 31 (mg/day) 0.0364 mg/day (13.3 per capita/365 days for Nigerians).
$BW_{age5\text{-}31}$ = average body weight from ages 5-31 (kg) = 35 kg (half the average body weight of an adult as established by [52].

The total lifetime cancer risk (TLCR)

The total lifetime cancer risk (ILCR) is an effective tool for predicting the health risks associated with human exposure to carcinogenic metals. The total lifetime cancer risk of the present study will be calculated using the expression:

$$CR = CDI \times CSF \quad (6)$$

$$ILCR = CLRIng + CLRInh + CLRDerm \quad (7)$$

Where CR determines the probability calculated in proportion (of the populaces) in mg/kg/day, CADD is chronic average daily doses while CSF is cancer slope factor (mg/kg/day). According to [52], when the cancer risk (CR) ranges are greater than 10^{-6} or 10^{-4}, then the concentrations of the said metals can be regarded as hazardous to health [22].

RESULTS AND DISCUSSION

Table 1 shows results (mean concentrations) obtained from the analysis of heavy metals (Fe, Pb, Cr, Cd, Zn, Ni, Cu, and Co) in crevalle jack (*Caranx hippos*) sampled from three (3) different creeks. Results are presented as mean concentration (mg/kg wet weight).

Table 1: Concentrations of Heavy Metals (Mean ± STD, mg/kg) in Crevalle Jack (*Caranx hippos*)

Heavy Metal (mg/kg)	Location 1 (L1)	Location 2 (L2)	Location 3 (L3)	WHO (2011)/UNEP (2007) Standard
Zn	0.26±0.03	0.64±0.20	0.32±0.04	3
Pb	0.16±0.03	0.30±0.06	0.20±0.03	0.01
Cd	0.06±0.01	0.17±0.04	0.07±0.01	3
Cr	0.50±0.24	1.53±0.15	1.03±0.24	0.05
Cu	0.26±0.03	0.55±0.11	0.42±0.09	2
Fe	1.22±0.09	2.86±0.26	1.65±0.2	0.3
Ni	0.16±0.02	0.3±0.04	0.21±0.03	0.02
Co	0.18±0.02	0.42±0.06	0.25±0.03	0.005

Noncancer Risk Assessment of Heavy Metals in Crevalle Jack (Adults and Children's Exposure Risk Assessment)

Results obtained from the assessment of the non-carcinogenic potential effect of heavy metals (Fe, Pb, Cr, Cd, Zn, Ni, Cu, and Co) consumption of Crevalle Jack (*Caranx hippos*) sampled by Adults and Children from the three (3) different locations are presented in Table 2. The human exposure to toxins in diets commonly expressed as estimated daily intake (EDI) is presented as chronic daily intake (CDI) of all the studied heavy metals with their corresponding oral reference doses (RfD_o), hazard quotient (HQ), and hazard index (HI) in Figure 3.

Table 2: Presents the Chronic Daily Intake (CDI), Oral reference dose (RfD_o), and Hazard quotients (HQ) for Human Noncancer Risk Assessment due to Consumption ($mgkg^{-1}$ day^{-1}) Crevalle Jack (*Caranx hippos*) by Children (Community residents) within the age of 5-31 (35kg body weight) and adults within the age of 30yr and above (Standard body weight of an adult which is given as 70kg for an adult by [51] from Three Study Locations, Nigeria.

Heavy Metal	Chronic Daily Intake (CDI)			RfDo (mg/kg/day)	Hazard Quotient (HQ)		
Adults							
	CDI_1	CDI_2	CDI_3		HQ_1	HQ_2	HQ_3
Zn	1.4 x10^{-4}	3.0 x10^{-4}	1.7 x10^{-4}	0.3	4.5 x10^{-4}	1.1 x10^{-3}	6.0 x10^{-4}
Pb	8.0 x10^{-5}	1.6 x10^{-4}	1.0 x10^{-4}	0.004	2.1 x10^{-2}	3.9 x10^{-2}	2.6 x10^{-2}
Cd	3. x10^{-5}	8.8 x10^{-4}	3.6 x10^{-5}	0.001	3.1 x10^{-2}	8.8 x10^{-2}	3.6 x10^{-2}
Cr	2.6 x10^{-4}	7.9 x10^{-4}	5.4 x10^{-4}	0.0009	2.9 x10^{-2}	8.8 x10^{-1}	5.9 x10^{-1}
Cu	1.4 x10^{-4}	2.8 x10^{-4}	2.2 x10^{-4}	0.2	7.0 x10^{-4}	1.4 x10^{-3}	1.1 x10^{-3}
Fe	6.3 x10^{-4}	1.48 x10^{-3}	8.6 x10^{-4}	0.8	8.0 x10^{-4}	1.9 x10^{-3}	1.1 x10^{-3}
Ni	8.0 x10^{-5}	1.6 x10^{-4}	1.1 x10^{-4}	0.02	4.2 x10^{-3}	7.8 x10^{-3}	5.5 x10^{-3}
Co	9.0 x10^{-5}	2.2 x10^{-4}	1.3 x10^{-4}	0.01	9.4 x10^{-3}	2.18 x10^{-2}	1.3 x10^{-2}
Children							
	CDI_1	CDI_2	CDI_3	RfDo (mg/kg/day)	HQ_1	HQ_2	HQ_3
Zn	2.70 x10^{-4}	6.66 x10^{-4}	3.33 x10^{-4}	0.3	9.01 x10^{-4}	2.22 x10^{-3}	1.11 x10^{-3}
Pb	1.66 x10^{-4}	3.12 x10^{-4}	2.08 x10^{-4}	0.004	4.16 x10^{-2}	7.80 x10^{-2}	5.20 x10^{-2}
Cd	6.24 x10^{-5}	1.77 x10^{-4}	7.28 x10^{-5}	0.001	6.24 x10^{-4}	1.77 x10^{-1}	7.28 x10^{-2}
Cr	5.20 x10^{-4}	1.591 x10^{-3}	1.07 x10^{-3}	0.0009	5.78 x10^{-1}	1.77 x10^{0}	1.19 x10^{0}
Cu	2.70 x10^{-4}	5.72 x10^{-4}	4.37 x10^{-4}	0.2	1.35 x10^{-3}	2.86 x10^{-2}	2.18 x10^{-3}
Fe	1.27 x10^{-3}	2.974 x10^{-3}	1.72 x10^{-3}	0.8	1.59 x10^{-3}	3.72 x10^{-3}	2.15 x10^{-3}
Ni	1.66 x10^{-4}	3.12 x10^{-4}	2.18 x10^{-4}	0.02	8.32 x10^{-3}	1.56 x10^{-2}	1.09 x10^{-2}
Co	1.87 x10^{-4}	4.37 x10^{-4}	2.6 x10^{-4}	0.01	1.87 x10^{-2}	4.37 x10^{-2}	2.60 x10^{-2}

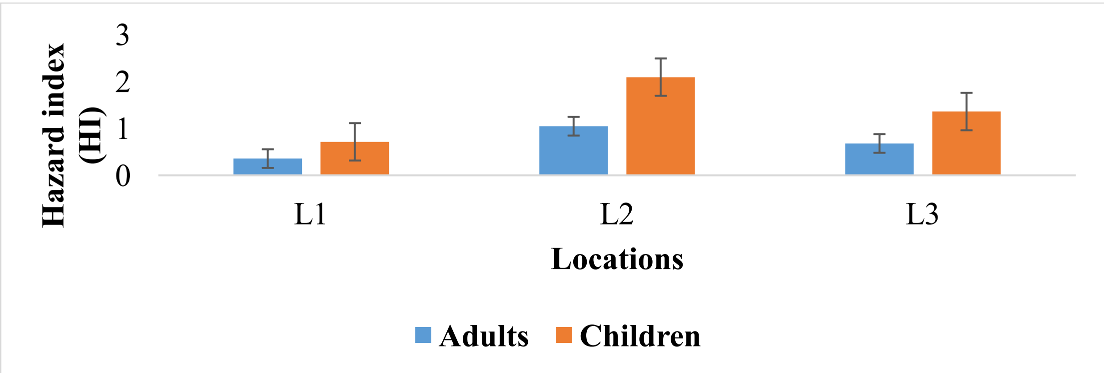

Fig 3. Showing the hazard index (HI) for Adults and Children in the three sampled locations

Results from the evaluation of the chronic daily intake (CDI) also known as estimated daily intake (EDI) of all studied heavy metals in *C. hippos* between the three locations were in the order of $CDI_2 > CDI_3 > CDI_1$. Results obtained from the study revealed that intake of all studied heavy metals via *C. hippos* was within their respective health-based guidance values (standard reference doses). This observation implies that daily consumption of *C. hippos* from the three (3) locations of the study may pose no non-cancer health effects to human consumers the results are presented in Table 2. However, the evaluation of the Hazard quotient (HQ) in the 3 locations shows HQ_1, HQ_2, and $HQ_3 < 1$. This indicates the lack of potency of consumption of heavy metals via *C. hippos* to cause non-cancer effects in human consumers. HQ greater than one ($HQ \geq 1$) implies the likeliness of a toxic substance to impact non-cancer adverse effects. Evaluation of HI revealed that HI_1 and HI_3 were less than unity (0.356 and 0.678 < 1) while HI_2 was equal to and above unity ($1.045 \geq 1$) the results are presented in Figure 3. Hence, cumulative consumption of heavy metals (Fe, Pb, Cr, Cd, Zn, Ni, Cu, and Co) by residents via *C. hippos* has the probability of impacting non-cancer effect in human consumers in location 2 but may not cause non-cancer effect in human's consumers in location 1 and 3.

Non-cancer Risk Assessment of Heavy Metals in Crevalle Jack (Children's Exposure Risk Assessment)

Data obtained from the analysis revealed the total chronic daily intake (EDI) of all studied heavy metals in *C. hippos* by children (aged 5-31) between the three locations were in the order of CDI_2 (0.007041)> CDI_3 (0.004316)> CDI_1 (0.002912). The children's estimated intake of the individual heavy metals is all below the [54, 55, 56, 57] oral reference doses. This indicates that the children's consumption of C. hippos in the studied location is likely to be without an appreciable risk of deleterious effects during their resident period or lifetime.

It is observed via analysis of the relative exposure of Zn, Cu, Fe, and Ni by children to the reference dose (HQ) in all study locations within their respective oral reference doses (RfD_o). Hence, the daily oral intake rate by children with the target age range (5-31 years) is estimated to pose no appreciable risk of adverse health effects during an average lifetime duration of 26 years. On the contrary, consumption of Pb, Cr, Cd, and Co by children was above their respective reference doses. Hence, there is potential for this sensitive population to show noncancer effects due to chronic intake of C. hippos from all studied locations.

However, the evaluation of Hazard indices (HI) in the three locations occurs in the order of HI_2 (2.09)> HI_3 (1.35) > 1. This indicates that children consuming *C. hippos* obtained from creeks in Locations 3 and 2 have a high potential to exhibit noncancer effects. This observation is in contrast to those obtained from adult risk assessment (HI_2 and HI_3 < 1) implying that children are highly sensitive and more prone to health concerns via consumption of heavy metals contaminated foods than adults. In contrast, the evaluation of the Hazard index (HI) in location one (HI_1 = 0.71) was found below the threshold level of 1. This observation revealed that the cumulative consumption of heavy metals (Fe, Pb, Cr, Cd, Zn, Ni, Cu, and Co) via *C. hippos* has the probability of impacting non-cancer effects in children's populations in locations 2 and 3 but may not cause non-cancer effect in resident consumers in location 1.

The intake of some heavy metals (Pb, Cr, Cd, and Ni) by children population from three studied locations via *C. Hippos* was evaluated as chronic daily intake (CDI) for an exposure period of 26 years used to estimate the probability of cancer effect in children with the adjusted age of 5-31yrs old. The cancer risk was evaluated as Individual Lifetime Cancer risk (ILCR) and the results are presented in Table 3.

The observed results show that the children population (5-31yrs) are exposed to all studied carcinogenic heavy metals mostly at L_2 followed by L_3 before L_1. Hence, the Exposure to heavy metals in all study areas was found in the order of Cr > Ni > Pb > Cd while the cumulative exposure due to intake of all heavy metals was in the order of L_2 (0.000852) > L_3 (0.000559) > L_1 (0.000325962). This trend is similar to the exposure by adults from the same study location. Consumption of Cr was the highest in all three locations implying a high tendency of carcinogenicity due to Cr than other ingested heavy metals. A similar result was reported by [61] from research carried out to estimate the health risk of heavy metals on children residents near the largest cooking plant in China. The study reported carcinogenic risks to children 30 to 200 times higher than the safe level ($1.0\times E^{-6}$- $1.0\times E^{-4}$) and attributed it to Cr, As and Ni pollution from ingestion of locally produced food.

Cancer Risk Assessment of Heavy Metals in Crevalle Jack (Adults and Children's Exposure Risk Assessment

Health risk (cancer risk) assessment of the potential effect of heavy metals (Pb, Cr, Cd, and Ni) due to Crevalle Jack (*Caranx hippos*) exposure sampled from three (3) different locations are presented in Table 3. Human exposure to toxins in diets is expressed as chronic daily intake (CDI) of all the studied heavy metals with their corresponding Oral Cancer Slope Factors (CSF_o). The Cumulative cancer risks (∑ILCR) due to consumption of ($mgkg^{-1}day^{-1}$) Crevalle Jack (*Caranx hippos*) by Adults and Children from three Study Locations, in Rivers State, Nigeria is presented in Figure 4.

Table 3: Chronic Daily Intake (CDI) for Individual lifetime cancer risks (ILCR) assessment and cumulative cancer risks (∑ILCR) due to consumption of ($mgkg^{-1}day^{-1}$) Crevalle Jack (*Caranx hippos*) by Children between the ages of 5-31 (35kg body weight) and Adults within the age of 30yr and above (Standard body weight of an adult which is given as 70kg for an adult by [52] WHO (2000) (Community residents) from Three Study Locations, Nigeria.

Adults							
	Chronic Daily Intake (CDI)			**Oral**	**Risk (ILCR)**		
Heavy metal	**L1**	**L2**	**L3**	**Cancer Slope Factor (CSF_o)**	**L1**	**L2**	**L3**
Pb	3.419 $x10^{-5}$	6.41 $x10^{-5}$	4.27 $x10^{-5}$	0.0085	2.91 $x10^{-7}$	5.45 $x10^{-5}$	3.633 $x10^{-7}$
Cd	1.282 $x10^{-5}$	3.63 $x10^{-5}$	1.5 $x10^{-5}$	0.38	4.87 $x10^{-5}$	1.38 $x10^{-5}$	5.684 $x10^{-6}$
Cr	1.068 $x10^{-4}$	3.27 $x10^{-4}$	2.2 $x10^{-4}$	0.5	5.34 $x10^{-5}$	1.64 $x10^{-4}$	1.101 $x10^{-4}$
Ni	3.419 $x10^{-5}$	6.41 $x10^{-5}$	4.48 $x10^{-5}$	0.91	3.11 $x10^{-5}$	5.83 $x10^{-5}$	4.076 $x10^{-5}$
Children							
	L1	**L2**	**L3**	**Oral Cancer Slope Factor (CSF_o)**	**L1**	**L2**	**L3**
Pb	5.93 $x10^{-5}$	1.11 $x10^{-4}$	7.41 $x10^{-4}$	0.0085	5.04 $x10^{-6}$	9.45 $x10^{-4}$	6.3 $x10^{-6}$
Cd	2.22 $x10^{-4}$	6.3 $x10^{-4}$	2.59 $x10^{-4}$	0.38	8.45 $x10^{-5}$	2.39 $x10^{-4}$	9.85 $x10^{-4}$

Cr	1.85 x10^{-4}	5.67 x10^{-4}	3.82 x10^{-4}	0.5	9.26 x10^{-4}	2.83 x10^{-4}	1.91 x10^{-4}
Ni	5.93 x10^{-4}	1.11 x10^{-4}	7.78 x10^{-4}	0.91	5.39 x10^{-4}	1.01 x10^{-4}	7.08 x10^{-4}

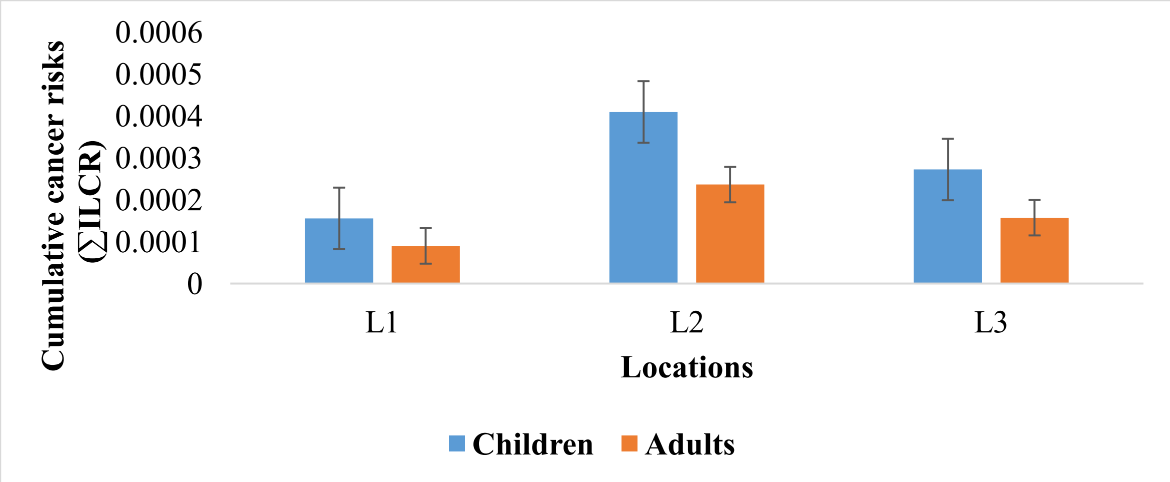

Fig 4. Cumulative cancer risks (∑ILCR) due to consumption of (mgkg^{-1}day^{-1}) Crevalle Jack (*Caranx hippos*) by Adults and Children from three Study Locations, Rivers State, Nigeria.

The exposure and consumption rate of heavy metals via *C. Hippos* was evaluated as chronic daily intake (CDI) for an exposure period of 70 years while the probability of cancer effect in humans that may arise due to consumption of heavy metals (Fe, Pb, Cr, Cd, Zn, Ni, Cu, and Co) in Crevalle Jack (*Caranx hippos*) sampled from three (3) different creeks were assayed according to the standard risk assessment indices developed by [53]. The cancer risk was evaluated as Individual Lifetime Cancer risk (ILCR) and the results are presented in Table 3. The observed results show that an individual in all studied locations (L1, L2, and L3) consumes Chromium (L2:3.27 E^{-4}>L3: 2.2E^{-4}>L1: 1.0685 E^{-4}) more than all other carcinogenic heavy metals (Pb, Cd, and Ni). The same mean concentration of Pb and Ni was observed in locations 1 and 2 and a slight variation at location 3. Hence, the Exposure to heavy metals in all study areas was found in the order of Cr >Ni>Pb>Cd. It is observed that the tissue concentration of heavy metals in *C. hippos* is directly proportional to the rate of exposure and the probability of impacting human health negatively with the cancer effect.

Results obtained from the evaluation of Individual Lifetime Cancer Risk also referred to as Incremental Lifetime Cancer Risk (ILCR) show that the probability of Pb to induce cancer risk in an individual via *C. hippos* during a lifetime of 70 years from all study locations was below and within the safe limit (1.0x10^{-6}). There is therefore no concern for increased cancer risk due to Pb intake. The ILCR for Cd also falls within the safe cancer limit value at L1 and L3 but violates the standard at L2 (1.38 x 10^{-5}). These values indicate that there is only 1 probability of an individual in every 1,000,000 people developing cancer due to intake of Pb in all study locations and also due to Cd in locations 1 and 3 but at L2, 1 individual may be at risk of cancer in every 100,000 persons within the population of the area.

However, ILCR for Cr violates the threshold cancer risk limit value (≥1x10^{-4}) at locations 2 and 3 indicating a concern for increased cancer risk at study locations 2 and 3 and a high probability of 1 individual developing cancer effects in every 10,000 persons but 1 in every 100,000 persons within the population of Location 1. ILCR value for Ni intake in all study areas shows that there is a probability of 1 individual developing cancer in every 100,000 persons within the study population. The results obtained in this study show that the increasing tendency of the carcinogenic heavy metals to induce cancer effects in humans via intake of *C.hippos* is in the order of Cr > Ni > Cd > Pb. The cumulative individual cancer risk (ΣILCR) for Location 1 (Figure 4) due to consumption of all carcinogenic heavy metals (Pb, Cr, Cd, and Ni) studied was above 1.0E^{-5} implying an increased tendency of 1 individual to develop cancer in every 100,000 persons in the population. However, Locations 2 and 3 revealed a cumulative cancer risk of 2.36E^{-4} and 1.57E^{-4} respectively above the threshold risk level of 1.0E^{-4}. The result from this study has revealed that consumers of *C. hippos* from these study areas over a 70 years period are at high risk of developing cancer due to the combined effects of carcinogenic heavy metals intake.

A recent study by [24, 58] to evaluate the non-carcinogenic health risk and carcinogenic health risks following USEPA risk assessment indices (HQ and ILCR) revealed that hazard quotients of Cd in all shellfish at an artisanal refining site in K-Dere, Ogoniland, Nigeria were greater than 1 but less than 1 for other studied metals. HQ for Cd was found to be greater than one (HQ>1) in *C armatum* at the control site. The probability of an individual developing cancer exceeded the [53] threshold limit of 1.0 x 10^{-4} for Cd, Cr, and Ni. Only Pb had ILCR within the safe limit (1.0 x 10^{-6}). However, the cumulative lifetime cancer risk (∑ILCR) due to intake of the carcinogenic heavy metals via all three studied shellfish was higher than the moderate risk level of 1.0x10^{-3}. The researchers concluded that there is a high probability of human consumers of shellfish developing cancer due to the combined effects of carcinogenic heavy metals intake at K-Dere.

The carcinogenic and non-carcinogenic health risks of heavy metals associated with the drinking water of Khorramabad; Iran assayed by **[59]**. Results from the study showed that the carcinogenic risk of Cd, Pd, Cr, and Ni were all above the cancer-safe limit of 1 × 10^{-6}. The researchers recommended the results to individual human consumers of Khorramabad water to take relevant health safety measures and governments in decision-making.

Another study was carried out in California state, USA by [60] to evaluate the Cancer and non-cancer health effects from food contaminant exposures for children (preschool and school-age) and adults (young parents and older parents). The results reported indicate that all sampled children were at risk of developing cancer due to ingestion of Arsenic, DDE, Dioxins, and Dieldrin. It is observed that the tissue concentration of heavy metals in *C. hippos* is directly proportional to the rate of exposure and the probability of impacting human health negatively with the cancer effect. Similar to the risk assessment of adults and their corresponding chronic ingestion rates, children (5-31yrs) cumulative cancer risk assessment (ΣILCR) due to consumption of *C. hippos* were in the order of L_2 ($4.1x10^{-4}$) > L_3 ($2.72x10^{-4}$) > L_1 ($1.5x10^{-4}$). This observation in ΣILCR due to intake of carcinogenic heavy metals (Cr, Pb, Cd, Ni) violates the threshold cancer risk limit value ($\geq 1x10^{-4}$) at all three locations in this study indicating a concern for increased cancer risk children (ages 5-31yrs) and presenting a high probability of 1 individual to develop cancer effects in every 10,000 children. The result from this study has revealed that chronic ingestion of *C. hippos* by children over a period of 26 years of residency this study is at high risk of developing cancer due to the combined effects of carcinogenic heavy metals intake. Adults are more likely to be exposed to a contaminant than children due to age differences. They may also consume higher doses of a toxicant than children. Hence, to assess the real exposure of children to a toxicant, different parameters have been developed and applied for children's risk assessment.

Due to their constantly changing metabolism during growth and development, children have age-specific periods of susceptibility which are commonly termed "critical windows of exposure/susceptibility" to toxicants when they are more (or less) biologically vulnerable to various environmental hazards. Hence, even within a given developmental stage; shorter exposure intervals may determine susceptibility for particular outcomes. Children's developmental stages have been proven to be accompanied by changes in organ system functioning, metabolic capabilities, increase in physical size, and changing behavioural patterns that can modify the effects, the illness, or both caused by toxicant exposure [62].

CONCLUSION

The study showed that the intake of heavy metals (Fe, Pb, Cr, Cd, Zn, Ni, Cu, and Co) in *C. hippos* in the three studied locations were within health-based guidance values and may not likely cause non-cancer health effects to human consumers. However, cumulative intake of these metals could have the potential to cause non-cancer effects in the second location. The results also showed that Cr was the carcinogenic heavy metal with the highest concentration in location 2, followed by location 3 and then location 1. It was noted that the concentration of heavy metals in *C. hippos* is proportional to the rate of exposure and could negatively impact human health with cancer risk. The results indicated no potential risk of cancer due to Pb intake at any of the study locations. However, Cd intake at locations 1 and 3 is only within the safe cancer limit value, but at Location 2, there is a risk of 1 individual in every 100,000 people developing cancer. Cr intake at locations 2 and 3 violates the threshold cancer risk limit value and there is a probability of 1 individual developing cancer in every 10,000 people. Ni showed a probability of 1 individual developing cancer in every 100,000 people. The study found that the increasing tendency for carcinogenic heavy metals to induce cancer effects in humans was in the order of Cr > Ni > Cd > Pb.

Consequently, consuming this fish species (*C. hippos*) from Locations 1, 2, and 3 over a 70-year period can increase the risk of developing cancer due to the presence of carcinogenic heavy metals in the environment. The cumulative individual cancer risk values for the three locations are above the threshold risk level, indicating that individuals in the population are at an increased risk of developing cancer from consuming *C. hippos* in these locations. Therefore, it is important to conduct more assessments to identify potential hazards and inform management decisions to protect human health and the environment. This can include monitoring the levels of heavy metals in the environment, such as in soil and water, as well as in food sources, including protein-rich foods like fish, meat and other animal products. Implementing regulations and recommendations to minimize exposure and protect public health. This can help to protect human health and the environment.

AUTHOR CONTRIBUTIONS

All authors have read and agreed to the publishing of this manuscript.

DATA AVAILABILITY STATEMENT

Upon request, the dataset used in the study will be available by the corresponding author.

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The authors declare that they have no known competing interests both personal and financial that could have appeared to influence the work reported in this manuscript.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

Davies I. Chris: Formal analysis, Conceptualization, Data Collection and Analysis, Writing- Original Draft Preparation. **Sibe Lebari:** Conceptualization, Investigation, Data Analysis Writing-Original & editing. **Brilliance O. Anyanwu:** Conceptualization, Data Analysis, Writing-Original Draft Preparation, Review & Editing of Manuscript.

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Not applicable

CONSENT TO PARTICIPATE

Not applicable

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