Health Risk Assessment of Heavy Metal Accumulation in Fish Species from Coastal Beach Waters South-South Nigeria

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ABSTRACT

Heavy metal contamination of fish is a serious public health concern worldwide and Nigeria is not an exception to this. In this study, eight commonly consumed fish species namely; African Cat Fish (Clarias gariepinus), Croacker Fish (Micropogonias undulatus), Sardine Fish (Sardinella maderensis), NileTilapia (Oreochromis niloticus), Tilapia (Tilapia zillii), Bony Tongue Fish (Heterotis niloticus), Cat Fish (Chrysichthys nigrodigitatus) and Elephant Fish (Campylomomyrus rhychophorus) were analyzed for Arsenic (As), Cadmium (Cd), Lead (Pb), Copper (Cu), Chromium (Cr), Zinc (Zn) and Mercury (Hg) using Atomic Absorption Spectrophotometer. The fish samples were collected from fisher men at the beaches. The Estimated Daily Intake, Target Hazard Quotient, Health risk index, Hazard Index, and Carcinogenic/Cancer Risk (CR) were assessed for adults and children.

Heavy metal analysis showed that Pb, Cr, Zn and Cd were observed in all the fish species, Cu in some of the fish species while Hg and As were not observed in any of the fish species. Cd and Pb exceeded the maximum permissible limit. The estimated daily intake (EDI) values for the metals were lower than the recommended dietary allowance for adults for both seasons while Pb exceeded the recommended dietary allowance for children at Tourist beach and Ibeno beach during the wet season, Tourist, Ibeno, Okpoama and Asaba beaches during the dry season. The Target Hazard Quotient (THQ) were <1 for all the fish species in adults and children for both season indicating no apparent health risk from these heavy metals over a life time of exposure.

Health Risk Index (HRI) was <1 in all the fish species in all the adults indicating no apparent health risk from these heavy metals over a life time of exposure while HRI was <1 in children from all the beach waters except Cr in Tourist and Agenobode beaches during the wet and dry season respectively. Hazard Index for all the fish species from beach waters were <1 for both adults and children for both season showing that the non-carcinogenic adverse effect is negligible. The carcinogenic risk for both adults and children, showed all estimated values for Cr, Cd, As and Pb for some of the fish species to be above the tolerable limit. This indicates that excessive consumption over a long time period might cause carcinogenic effect as the Cancer Risk (CR) values were higher than the acceptable guideline value (10^{-4}–10^{-6}) (E−6 and E−4). This indicates that consumption of fish from these beach waters should be of concern to the public that patronize barbecue sellers at the beaches. This calls for periodic monitoring of heavy metals in fish species sold at the beaches as well as sensitization of the beach tourists on the need to check what they consume.

Keywords: Coastal beach; Health risk; Heavy metal accumulation; Fish species; Carcinogenic risk**.**

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INTRODUCTION

The global increase in fish consumption is attributable to the nutritional benefits of fish (FAO, 2016). Fish serve as a good source of proteins, vitamins, omega-3-fatty acids, and other essential minerals (Varol *et al.,* 2020). Regrettably, industrialization, population explosion, increase in industrial waste discharge into the waters as well as other anthropogenic activities have heightened the contamination rate of the aquatic environment (Abdullahi, 2020). Globally, aquatic environments are being polluted with toxicants and heavy metals. Studies have shown accumulation of heavy metals in different aquatic organisms such as prawn, crayfish, crabs, bivalves and fish species (Ali *et al.,* 2020: Anandkumar *et al.,* 2019, 2020; Arulkumar *et al.,* 2017; Rawtani, *et al.,* 2016). Consequently, there is a concomitant increase in the human health risk through consumption of fish contaminated with heavy metals as reported by (Ahmed *et al.,* 2016; Ali *et al.,* 2016; Liang *et al.,* 2018).

Heavy metals are aquatic pollutants with non-biodegradable and bioaccumulation potential, high toxicity, and long-time persistence (Uysal *et al.,* 2009). The major source of heavy metal pollution into the river is the earth's crust though heavy metals are known to be transmitted into the river through industrial effluents discharged into the rivers. (Varol *et al.,* 2017). Aquatic organisms accumulate these contaminants primarily via uptake through the skin and gills through surface contacts with sediments, industrial effluent, and wastewater, as well as via the food they consume (Soltani *et al.,* 2019). Hence, serving as a secondary source of exposure to humans (Dang *et al.,* 2016). On entry into the body of the fish through the gills and other organs, heavy metals get accumulated in different parts of the fish body up to a toxic level (Kumar and Achyuthan, 2005).

MATERIALS AND METHODS

Study Area.

This research was conducted in Ibeno beach in Akwaibom State, Okpoama beach (Brass) in Bayelsa State, Port-Harcourt tourist beach in Rivers State, Marina's beach in Cross River State, Asaba (Otuogo) beach in Delta State and Agenebode beach in Edo State all in South-South geopolitical zone popularly known as Niger Delta region.

The Niger Delta region in Nigeria is situated in the Gulf of Guinea between longitude 50°E to 80°E and latitude 40°N to 60°N and it is the largest mangrove forest vegetation in Africa and the third largest in the world (Azaiki, 2003; Ana, 2011; Asanebi, 2016). The Niger Delta is classified under the tropical rainforest that is located in the North of the Delta (Aniefiok *et al;* 2013; Asanebi, 2016) which is located between 4°N to 10°N of the equator with an altitude that is less than 1000 metres and a mean annual rainfall that is always high and not the same within the region (Azaiki, 2003; Asanebi, 2016). The annual rainfall ranges from 3000 mm to 4800 mm with a wet season between July and September and a dry season from December to February. Average monthly temperature is 27°C (World bank, 1995). Over 50% of the Niger Delta is water with thousands of creeks (Ikelegbe, 2006) and all the fresh water swamps in Nigeria (Umoh, 2008).

Collection Of Fish Samples

38 Fish samples (comprising of 8 commonly consumed fish species) African Cat Fish (*Clarias gariepinus*), Croacker Fish (*Micropogonias undulatus*), Sardine Fish (*Sardinella maderensis*), Nile Tilapia (*Oreochromis niloticus*), Tilapia (*Tilapia zillii*), Bony Tongue Fish (*Heterotis niloticus*), Cat Fish (*Chrysichthys nigrodigitatus*) and Elephant Fish (*Campylomomyrus rhychophorus*) were collected between the months of March 2023 to February, 2024 (wet and dry season) from the six selected recreational beach sites from fishermen who supplied fish to barbecue and pepper soup sellers at the six selected beaches. The fish samples were thoroughly washed with sea water and placed in separate well labeled cellophane bags and preserved in ice cooled box. The samples were transported to Quality laboratory at Edo State and stored in the freezer at (-10°C) prior to laboratory analysis. The Fishes were identified to species level using guides, keys and pictures provided by Freose and Pauley (2018). The total length (cm) and weight (kg) were taken using a graduated meter rule and weighing balance.

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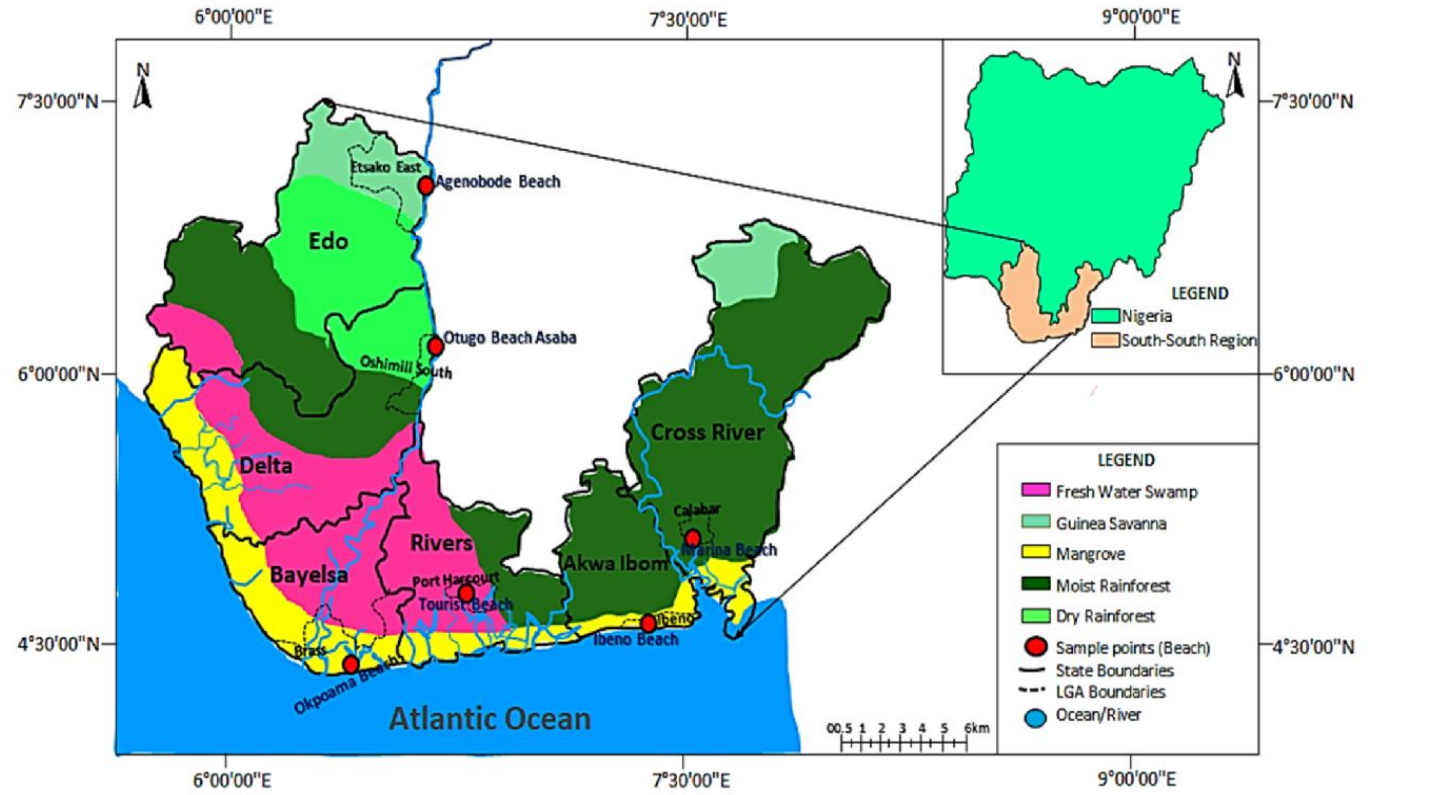

Fig.1: Map of the Study Area.

Source: Map created using Air Bus Diva GIS and ESRI ArcGIS (ver. 10.4)

African Cat Fish (Clarias gariepinus)

Tilapia (Tilapia zillii)

Elephant Fish (Campylomomyrus rhychophorus)

Nile Tilapia (Oreochromis niloticus)

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Bony Tongue Fish (Heterotis niloticus)

Sardine Fish (Sardinella maderensis)

Fish Sample Preparation

Fish samples were removed from the freezer, allowed to thaw, then the total length (TL) and the aperture length (AL) of each species were measured using measuring board. The total weight of each of the fish species (TW) were measured by weighing with an electronic meter balance. The flesh of the fish were taken using a stainless steel surgical knife, the muscles were placed in a foil paper which were oven dried for 48 hours at 80°C, after being dried for the stated hours, each was grounded to powder form using ceramic mortar and pestle and 2mm mesh size was used to obtain a uniform particle size and preserved in a well labeled plastic bottle indicating each species and was kept prior to digestion.

Fish Digestion

Dry tissue sample of fish was digested with concentrated nitric acid (HNO_3), the digestion was carried out in a fume cupboard and water bath was switched on to stabilize and attain 100°C using water bath digestion. The completely digested sample was filtered using Whatman filter paper and diluted to 100ml in standard volumetric flask with distilled water. It was analyzed in Atomic Absorption Spectrophotometer (AAS) as described by AOAC (1990).

Determination Of Heavy Metals In Fish Samples

The exposure assessment for ingestion of contaminated fish samples was calculated using the model postulated by USEPA (1999).

Human Health Risk Assessment

Assessment of health risk to humans is achieved by calculating the possibility of any severe health effects coming from the exposure of an individual to carcinogenic and or non-carcinogenic substances over a particular period of time (Kamunda *et al*., 2016; EPA 2001).

Long-term human exposure to heavy metals and toxins in the environment has been confirmed to give rise to various negative health effects (Anyanwu and Wachukwu, 2022). Such heavy metals may enter the human body through inhalation, dermal contact and ingestion. Dermal contact and ingestion are the most relevant to possible toxicity from sand beaches. These health risks are evaluated by several parameters including the estimated daily intake (EDI), Target Hazard Quotient (HQ), Hazard Index (HI) and Cancer Risk (CR) which are dependent on the Average Daily Dose (ADD) and the Reference Dose (RFD) for each heavy metal studied. RFD signifies the reference dose for each heavy metal that an individual is exposed to per day, either by

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ingestion or dermal contact, throughout his entire life without it causing any harm. ADD values, HQ values, and HI are computed using the equations shown below. Adverse non-carcinogenic effects are characterized by values of HQ > 1, while if HQ < 1, concentrations obtained signify no detrimental effects. If the Hazard Index (HI) < 1, the non-carcinogenic adverse effects are assumed to be negligible and vice versa (USEPA, 2011).

$$ADI_{ingest} = \frac{C \times IR_{ingest}}{BW} \times \frac{EF \times ED \times CF}{AT} \quad (1)$$

$$ADI_{dems} = \frac{CS \times SA \times AF \times ABS \times EF \times ED \times CF}{BW \times AT} \quad (2)$$

Where, ADI_{ing} =Average daily intake heavy metals/ pathogenic contaminant ingested from the fish in mg/kg/day

C = Concentration of heavy metals/ pathogenic contaminant in mg/kg for fish

IR = Ingestion rate in mg/day (adult: 100mg/day; children: 200mg/day)

EF = Exposure frequency in days/year (adult and children: 365 days/yr)

ED = Exposure duration in years (70 years)

BW = Body weight of exposed individual in kg (adult: 70kg; children: 15kg)

AT = Time period over which the dose is averaged in days. (365 × 70).

CF = Conversion factor in kg/mg (10^{-6}kg/mg)

ADI_{dems} =Exposure dose via contact (mg/kg/day)

SA =Exposed skin area (cm^2) (adult: 5800; children: 2100)

EF = Fraction of dermal exposure ratio to soil (0.61)

AF = Adherence factor (mg/cm^2) (adult: 0.07; children: 0.2)

ABS Fraction of the applied dose absorbed across the skin (0.1)

Estimated Daily Intake (EDI)

The EDI of Pb, Cr, Cd, Hg and As in the consumed fish and water specific to the study area was considered following the equation as modified by the United States Environmental Protection Agency (USEPA, 2020).

$$EDI = \frac{C \times QDC}{BW}$$

Where C is the mean concentration of the specific THM in the fish (mg/kg) or water (mg/ml) and BW is the average body weight (kg). The quantity of daily consumed (QDC) fish (0.25 kg).

Determination of Non Carcinogenic Risk Assessment of consuming fish from the selected beaches' water

Determination of target hazard quotient (THQ)

The THQ which is the ratio of the exposure dose to the reference dose (RfD), represents the risk of non-carcinogenic effects. If it is less than 1, the exposure level is less than the RfD. This points out the daily

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exposure at this level is not likely to cause conflicting effects during a person's lifetime, and vice versa. US EPA risk analysis (USEPA, 2000) procedures was followed in the dose calculations which was performed using standard assumptions from the combined model described by Chien *et al*. (2002) was used for estimating THQ by the following equation:

$$THQ = \frac{EFr \times EDtot \times FIR \times C \times 10^{-3}}{RfDo \times Bw \times ATn}$$

Where; EFr is the exposure frequency (350 days/year); EDtot is the exposure duration (30 years); FIR is the food ingestion rate (g/day), while 10^{-3} is the unit conversion factor; C is the heavy metal concentration in fish (mg/kg wet weight); RfDo is the oral RfD (mg/kg day−1); Bw is the average adult body weight (75 kg); and ATn is the average exposure time for non-carcinogens (365 days/year×number of exposure years, assuming 30 years).

Health Risk Index (HRI) of consuming fish from the selected beaches' water

Health risk of consumers due to intake of metal contaminated fish was assessed by using HRI. A HRI less than 1 means the exposed population is unlikely to experience adverse effects; whereas a HRI above 1 means that there is a chance of non-carcinogenic effects, with an increasing probability as the value increases. The HRI was calculated by using the equation below according to (Wang *et al.,* 2005).

$$HRI = \frac{EDI}{RfD}$$

Hazard Index (HI)

The HI which is the summary of the individual THQs of the THMs examined in the fish was calculated using the following equation:

$$HI = THQAs + THQCd + THQPb + THQHg$$

When the HI value is ≥1, it shows non carcinogenic adverse health, but when it is <1, it shows little or no non-carcinogenic effect.

Carcinogenic risk assessment of consuming fish from the selected beaches' water

According to (USEPA, 2012), carcinogenic risk assessment evaluates the likelihood of an individual developing cancer due to exposure to the potential carcinogen over a lifetime. In our estimations, a cancer slope factor was used to convert the EDI of the heavy metals over a lifetime exposure to the risk of an individual developing cancer (USEPA, 2012). Generally, the values of CR lower than 10^{-6} are considered as negligible, above 10^{-4} are considered to be unacceptable and lying in between 10^{-6} and 10^{-4} are considered as acceptable range (USEPA, 2010).

$$Risk_{pathway} = ADI + CSF_k$$

Where;

ADI = Average daily intake (mg/kg/day)

CSF =cancer slope factor for kth heavy metal for n number of heavy metals

Total excess lifetime for an individual=

$$Risk_{total} = Risk_{(ing)} + Risk_{(inh)} + Risk_{(dem)}$$

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Statistical Analysis

MS Excel 2021 (Microsoft Inc., Redmond, USA) and SPSS (v26.0) for Windows (SPSS Inc., Chicago, IL, USA) were used for data analysis. The analyzed metal concentrations have been presented as mean and standard deviations (SD), and one-way analysis of variance (ANOVA) was used to evaluate the significant differences among the fish species.

RESULTS

Estimated Daily Intake for Heavy Metals consumption in Fish from the beaches' water in adults and children for wet and dry season.

Tables 1-4 summarized the estimated daily intake for heavy metals in adults and children during the wet and dry season. At Tourist beach, Croacker Fish (*Micropogonias undulatus*) showed the highest EDI for Pb with 0.0240 mg/kg/day and 0.0354 mg/kg/day for adults during the wet and dry season respectively while Cu, As and Hg recorded the lowest EDI with 0.0000mg/kg/day for both seasons. At Okpoama beach, Sardine Fish (*Sardinella maderensis*) showed the highest EDI for Pb with 0.0194 mg/kg/day and 0.0286 mg/kg/day for adults during the wet and dry season respectively while Cu, As and Hg recorded the lowest EDI with 0.0000mg/kg/day for both seasons. At Ibeno beach, Croacker Fish (*Micropogonias undulatus*) and Nile Tilapia (*Oreochromis niloticus*) showed the highest EDI for Pb with (0.0236 mg/kg/day and 0.0236 mg/kg/day) respectively during the wet season and (0.0348 mg/kg/day and 0.0348 mg/kg/day) for adults during the dry season respectively while Cu, As and Hg recorded the lowest EDI with 0.0000mg/kg/day for both seasons. At Asaba beach, African Cat Fish (*Clarias gariepinus*) showed the highest EDI for Pb with 0.0236 mg/kg/day and 0.0348 mg/kg/day for adults during the wet and dry season respectively while Cd, As and Hg recorded the lowest EDI with 0.0000mg/kg/day for both seasons. At Marina's beach, Sardine Fish (*Sardinella maderensis*) showed the highest EDI for Zn with 0.0161mg/kg/day for adults during the wet and dry season while Cu, As and Hg recorded the lowest EDI with 0.0000mg/kg/day for both seasons. At Agenobode beach, African Cat Fish (*Clarias gariepinus*) showed the highest EDI for Cr with 0.0131mg/kg/day and 0.0192 mg/kg/day for adults during the wet and dry season respectively while Cu, As and Hg recorded the lowest EDI with 0.0000mg/kg/day for both seasons.

The calculated EDI was higher in the dry season than the wet season. The calculated EDI for the studied metals showed a low value when compared with the recommended dietary allowance value, meaning that the exposed population is unlikely to have any adverse consequence. It equally showed that an increase in the frequency of fish consumption may not lead to adverse health effects to the beach goers who eat fish at the beaches. The heavy metal contamination was in the decreasing order of Pb>Cr>Zn>Cd>Cu=As=Hg for the two seasons. The calculated EDI was higher in the dry season than the wet season.

Table 1. Estimated Daily Intake (EDI) for Heavy Metals in Fish (Adults) wet season

	EDI (Adult)						
Wet Season	**Pb**	**Cu**	**Cr**	**Cd**	**As**	**Hg**	**Zn**
Tourist Beach							
African Cat Fish (Clarias gariepinus)	0.0071	0.0000	0.0109	0.0007	0.0000	0.0000	0.0136
Croacker Fish (Micropogonias undulatus)	0.0240	0.0000	0.0166	0.0011	0.0000	0.0000	0.0056
Sardine Fish (Sardinella maderensis)	0.0074	0.0000	0.0113	0.0007	0.0000	0.0000	0.0130
Tilapia (Oreochromis niloticus)	0.0176	0.0000	0.0141	0.0011	0.0000	0.0000	0.0049
Recommended dietary allowance (mg/day/person)	0.13	0.06	0.21	0.03	0.3µg/kg/d	0.045µg/kg/d	16.4
Okpoama Beach							
African Cat Fish (Clarias gariepinus)	0.0183	0.0000	0.0152	0.0011	0.0000	0.0000	0.0105
Sardine Fish (Sardinella maderensis)	0.0194	0.0000	0.0166	0.0011	0.0000	0.0000	0.0107
Tilapia (Tilapia zillii)	0.0191	0.0000	0.0155	0.0011	0.0000	0.0000	0.0108

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Recommended dietary allowance (mg/day/person)	0.13	0.06	0.21	0.03	0.3µg/kg/d	0.045µg/kg/d	16.4
Ibeno Beach							
Cat Fish (Chrysichthys nigrodigitatus)	0.0078	0.0000	0.0124	0.0011	0.0000	0.0000	0.0174
Croacker Fish (Micropogonias undulatus)	0.0236	0.0000	0.0166	0.0011	0.0000	0.0000	0.0056
Nile Tilapia (Oreochromis niloticus)	0.0236	0.0000	0.0166	0.0011	0.0000	0.0000	0.0056
Recommended dietary allowance (mg/day/person)	0.13	0.06	0.21	0.03	0.3µg/kg/d	0.045µg/kg/d	16.4
Asaba Beach							
African Cat Fish (Clarias gariepinus)	0.0236	0.0085	0.0134	0.0000	0.0000	0.0000	0.0124
Bony Tongue Fish (Heterotis niloticus)	0.0222	0.0078	0.0120	0.0000	0.0000	0.0000	0.0114
Tilapia (Tilapia zillii)	0.0198	0.0071	0.0124	0.0000	0.0000	0.0000	0.0107
Recommended dietary allowance (mg/day/person)	0.13	0.06	0.21	0.03	0.3µg/kg/d	0.045µg/kg/d	16.4
Marina-s Beach							
African Cat Fish (Clarias gariepinus)	0.0064	0.0000	0.0141	0.0011	0.0000	0.0000	0.0159
Sardine Fish (Sardinella maderensis)	0.0064	0.0000	0.0141	0.0011	0.0000	0.0000	0.0161
Tilapia (Tilapia zillii)	0.0060	0.0000	0.0141	0.0007	0.0000	0.0000	0.0142
Recommended dietary allowance (mg/day/person)	0.13	0.06	0.21	0.03	0.3µg/kg/d	0.045µg/kg/d	16.4
Agenebode Beach							
African Cat Fish (Clarias gariepinus)	0.0064	0.0000	0.0131	0.0007	0.0000	0.0000	0.0114
Elephant Fish (Campylomomyrus rhychophorus)	0.0067	0.0000	0.0124	0.0011	0.0000	0.0000	0.0118
Tilapia (Tilapia zillii)	0.0056	0.0000	0.0124	0.0007	0.0000	0.0000	0.0106
Recommended dietary allowance (mg/day/person)	0.13	0.06	0.21	0.03	0.3µg/kg/d	0.045µg/kg/d	16.4

Table 2. Estimated Daily Intake for Heavy Metals in Fish (Adults) Dry season

	EDI (Adult)						
Dry Season	**Pb**	**Cu**	**Cr**	**Cd**	**As**	**Hg**	**Zn**
Tourist Beach							
African Cat Fish (Clarias gariepinus)	0.0104	0.0000	0.0161	0.0010	0.0000	0.0000	0.0136
Croacker Fish (Micropogonias undulatus)	0.0354	0.0000	0.0244	0.0016	0.0000	0.0000	0.0056
Sardine Fish (Sardinella maderensis)	0.0109	0.0000	0.0166	0.0010	0.0000	0.0000	0.0130
Tilapia (Oreochromis niloticus)	0.0260	0.0000	0.0208	0.0016	0.0000	0.0000	0.0049
Recommended dietary allowance (mg/day/person)	0.13	0.06	0.21	0.03	0.3µg/kg/d	0.045µg/kg/d	16.4
Okpoama Beach							
African Cat Fish (Clarias gariepinus)	0.0270	0.0000	0.0224	0.0016	0.0000	0.0000	0.0105
Sardine Fish (Sardinella maderensis)	0.0286	0.0000	0.0244	0.0016	0.0000	0.0000	0.0107
Tilapia (Tilapia zillii)	0.0281	0.0000	0.0229	0.0016	0.0000	0.0000	0.0108
Recommended dietary allowance (mg/day/person)	0.13	0.06	0.21	0.03	0.3µg/kg/d	0.045µg/kg/d	16.4
Ibeno Beach							

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Cat Fish (Chrysichthys nigrodigitatus)	0.0114	0.0000	0.0182	0.0016	0.0000	0.0000	0.0174
Croacker Fish (Micropogonias undulatus)	0.0348	0.0000	0.0244	0.0016	0.0000	0.0000	0.0056
Nile Tilapia (Oreochromis niloticus)	0.0348	0.0000	0.0244	0.0016	0.0000	0.0000	0.0056
Recommended dietary allowance (mg/day/person)	0.13	0.06	0.21	0.03	0.3µg/kg/d	0.045µg/kg/d	16.4
Asaba Beach							
African Cat Fish (Clarias gariepinus)	0.0348	0.0125	0.0198	0.0000	0.0000	0.0000	0.0124
Bony Tongue Fish (Heterotis niloticus)	0.0328	0.0114	0.0177	0.0000	0.0000	0.0000	0.0114
Tilapia (Tilapia zillii)	0.0291	0.0104	0.0182	0.0000	0.0000	0.0000	0.0107
Recommended dietary allowance (mg/day/person)	0.13	0.06	0.21	0.03	0.3µg/kg/d	0.045µg/kg/d	16.4
Marina-s Beach							
African Cat Fish (Clarias gariepinus)	0.0094	0.0000	0.0208	0.0016	0.0000	0.0000	0.0159
Sardine Fish (Sardinella maderensis)	0.0094	0.0000	0.0208	0.0016	0.0000	0.0000	0.0161
Tilapia (Tilapia zillii)	0.0088	0.0000	0.0208	0.0010	0.0000	0.0000	0.0142
Recommended dietary allowance (mg/day/person)	0.13	0.06	0.21	0.03	0.3µg/kg/d	0.045µg/kg/d	16.4
Agenebode Beach							
African Cat Fish (Clarias gariepinus)	0.0094	0.0000	0.0192	0.0010	0.0000	0.0000	0.0114
Elephant Fish (Campylomomyrus rhychophorus)	0.0099	0.0000	0.0182	0.0016	0.0000	0.0000	0.0118
Tilapia (Tilapia zillii)	0.0083	0.0000	0.0182	0.0010	0.0000	0.0000	0.0106
Recommended dietary allowance (mg/day/person)	0.13	0.06	0.21	0.03	0.3µg/kg/d	0.045µg/kg/d	16.4

Estimated Daily Intake for Heavy Metals Consumption in Fish from the beaches' Water in Children for Wet and Dry Season.

Tables 3 and 4 summarized the estimated daily intake for heavy metals in children during the wet and dry season. At Tourist beach, Croacker Fish (*Micropogonias undulatus*) showed the highest EDI for Pb with 0.1400 mg/kg/day and 0.2063mg/kg/day for children during the wet and dry season respectively while Cu, As and Hg recorded the lowest EDI with 0.0000mg/kg/day for both seasons. At Okpoama beach, Sardine Fish (*Sardinella maderensis*) showed the highest EDI for Pb with 0.1132 mg/kg/day and 0.1668mg/kg/day for children during the wet and dry season respectively while Cu, As and Hg recorded the lowest EDI with 0.0000mg/kg/day for both seasons. . At Ibeno beach, African Cat Fish (*Clarias gariepinus*) and Sardine Fish (*Sardinella maderensis*) showed the highest EDI for Pb with 0.1379 mg/kg/day and 0.1379 mg/kg/day for children during the wet season while Croacker Fish (*Micropogonias undulatus*) and Nile Tilapia (*Oreochromis niloticus*) showed the highest EDI for Pb with 0.2032mg/kg/day and 0.2032 mg/kg/day for children during the dry season. Arsenic, Cu and Hg recorded the lowest EDI with 0.0000mg/kg/day for both seasons. At Asaba beach, African Cat Fish (*Clarias gariepinus*) showed the highest EDI for Pb with 0.1379 mg/kg/day and 0.2032mg/kg/day for children during the wet and dry season respectively while Cu, As and Hg recorded the lowest EDI with 0.0000mg/kg/day for both seasons. The calculated EDI was higher in the dry season than the wet season. The calculated EDI for the studied metals showed a high value when compared with the recommended dietary allowance value, meaning that the exposed population is likely to have an adverse

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consequence from consuming the fish species. It equally showed that an increase in the frequency of fish consumption may lead to adverse health effects to the beach goers who eat fish at Tourist, Okpoama, Ibeno and Asaba beaches. The heavy metal contamination was in the decreasing order of Cr> Zn> Pb> Cd>Cu=As=Hg for the two seasons while at Marina's beach, Sardine Fish (*Sardinella maderensis*) showed the highest EDI for Zn with 0.0937 mg/kg/day and 0.0937mg/kg/day for children during the wet and dry season respectively while Cu, As and Hg recorded the lowest EDI with 0.0000mg/kg/day for both seasons. Also at Agenobode beach, African Cat Fish (*Clarias gariepinus*) showed the highest EDI for Cr with 0.0762 mg/kg/day and 0.1122mg/kg/day for children during the wet and dry season respectively while Cu, As and Hg recorded the lowest EDI with 0.0000mg/kg/day for both seasons. The calculated EDI was higher in the dry season than the wet season. The calculated EDI for the studied metals showed a low value when compared with the recommended dietary allowance value, meaning that the exposed population is unlikely to have any adverse effect from consuming the fish species from Marina's and Agenobode beaches. The heavy metal contamination was in the decreasing order of Cr> Zn> Pb> Cd>Cu=As=Hg for the two seasons.

Table 3. Estimated Daily Intake for Heavy Metals in Fish (Children) during the wet season

	EDI (Children)						
Wet Season	**Pb**	**Cu**	**Cr**	**Cd**	**As**	**Hg**	**Zn**
Tourist Beach							
African Cat Fish (Clarias gariepinus)	0.0412	0.0000	0.0638	0.0041	0.0000	0.0000	0.0795
Croacker Fish (Micropogonias undulatus)	0.1400	0.0000	0.0967	0.0062	0.0000	0.0000	0.0329
Sardine Fish (Sardinella maderensis)	0.0432	0.0000	0.0659	0.0041	0.0000	0.0000	0.0760
Tilapia (Oreochromis niloticus)	0.1029	0.0000	0.0823	0.0062	0.0000	0.0000	0.0288
Recommended dietary allowance (mg/day/person)	0.13	0.06	0.21	0.03	0.3µg/kg/d	0.045µg/kg/d	10.7
Okpoama Beach							
African Cat Fish (Clarias gariepinus)	0.1070	0.0000	0.0885	0.0062	0.0000	0.0000	0.0613
Sardine Fish (Sardinella maderensis)	0.1132	0.0000	0.0967	0.0062	0.0000	0.0000	0.0626
Tilapia (Tilapia zillii)	0.1112	0.0000	0.0906	0.0062	0.0000	0.0000	0.0632
Recommended dietary allowance (mg/day/person)	0.13	0.06	0.21	0.03	0.3µg/kg/d	0.045µg/kg/d	10.7
Ibeno Beach							
Cat Fish (Chrysichthys nigrodigitatus)	0.0453	0.0000	0.0720	0.0062	0.0000	0.0000	0.1015
Croacker Fish (Micropogonias undulatus)	0.1379	0.0000	0.0967	0.0062	0.0000	0.0000	0.0329
Nile Tilapia (Oreochromis niloticus)	0.1379	0.0000	0.0967	0.0062	0.0000	0.0000	0.0329
Recommended dietary allowance (mg/day/person)	0.13	0.06	0.21	0.03	0.3µg/kg/d	0.045µg/kg/d	10.7
Asaba Beach							
African Cat Fish (Clarias gariepinus)	0.1379	0.0494	0.0782	0.0000	0.0000	0.0000	0.0720
Bony Tongue Fish (Heterotis niloticus)	0.1297	0.0453	0.0700	0.0000	0.0000	0.0000	0.0667
Tilapia (Tilapia zillii)	0.1153	0.0412	0.0720	0.0000	0.0000	0.0000	0.0622
Recommended dietary allowance (mg/day/person)	0.13	0.06	0.21	0.03	0.3µg/kg/d	0.045µg/kg/d	10.7
Marina-s Beach							

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African Cat Fish (Clarias gariepinus)	0.0371	0.0000	0.0823	0.0062	0.0000	0.0000	0.0930
Sardine Fish (Sardinella maderensis)	0.0371	0.0000	0.0823	0.0062	0.0000	0.0000	0.0937
Tilapia (Tilapia zillii)	0.0350	0.0000	0.0823	0.0041	0.0000	0.0000	0.0827
Recommended dietary allowance (mg/day/person)	0.13	0.06	0.21	0.03	0.3µg/kg/d	0.045µg/kg/d	10.7
Agenebode Beach							
African Cat Fish (Clarias gariepinus)	0.0371	0.0000	0.0762	0.0041	0.0000	0.0000	0.0667
Elephant Fish (Campylomomyrus rhychophorus)	0.0391	0.0000	0.0720	0.0062	0.0000	0.0000	0.0687
Tilapia (Tilapia zillii)	0.0329	0.0000	0.0720	0.0041	0.0000	0.0000	0.0620
Recommended dietary allowance (mg/day/person)	0.13	0.06	0.21	0.03	0.3µg/kg/d	0.045µg/kg/d	10.7

Table 4: Estimated Daily Intake for Heavy Metals in Fish (Children) during the dry season

	EDI (Children)						
Dry Season	**Pb**	**Cu**	**Cr**	**Cd**	**As**	**Hg**	**Zn**
Tourist Beach							
African Cat Fish (Clarias gariepinus)	0.0607	0.0000	0.0940	0.0061	0.0000	0.0000	0.0795
Croacker Fish (Micropogonias undulatus)	0.2063	0.0000	0.1426	0.0091	0.0000	0.0000	0.0329
Sardine Fish (Sardinella maderensis)	0.0637	0.0000	0.0971	0.0061	0.0000	0.0000	0.0760
Tilapia (Oreochromis niloticus)	0.1517	0.0000	0.1213	0.0091	0.0000	0.0000	0.0288
Recommended dietary allowance (mg/day/person)	0.13	0.06	0.21	0.03	0.3µg/kg/d	0.045µg/kg/d	10.7
Okpoama Beach							
African Cat Fish (Clarias gariepinus)	0.1577	0.0000	0.1304	0.0091	0.0000	0.0000	0.0613
Sardine Fish (Sardinella maderensis)	0.1668	0.0000	0.1426	0.0091	0.0000	0.0000	0.0626
Tilapia (Tilapia zillii)	0.1638	0.0000	0.1335	0.0091	0.0000	0.0000	0.0632
Recommended dietary allowance (mg/day/person)	0.13	0.06	0.21	0.03	0.3µg/kg/d	0.045µg/kg/d	10.7
Ibeno Beach							
Cat Fish (Chrysichthys nigrodigitatus)	0.0667	0.0000	0.1062	0.0091	0.0000	0.0000	0.1015
Croacker Fish (Micropogonias undulatus)	0.2032	0.0000	0.1426	0.0091	0.0000	0.0000	0.0329
Nile Tilapia (Oreochromis niloticus)	0.2032	0.0000	0.1426	0.0091	0.0000	0.0000	0.0329
Recommended dietary allowance (mg/day/person)	0.13	0.06	0.21	0.03	0.3µg/kg/d	0.045µg/kg/d	10.7
Asaba Beach							
African Cat Fish (Clarias gariepinus)	0.2032	0.0728	0.1153	0.0000	0.0000	0.0000	0.0720
Bony Tongue Fish (Heterotis niloticus)	0.1911	0.0667	0.1031	0.0000	0.0000	0.0000	0.0667

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Tilapia (Tilapia zillii)	0.1699	0.0607	0.1062	0.0000	0.0000	0.0000	0.0622
Recommended dietary allowance (mg/day/person)	0.13	0.06	0.21	0.03	0.3µg/kg/d	0.045µg/kg/d	10.7
Marina-s Beach							
African Cat Fish (Clarias gariepinus)	0.0546	0.0000	0.1213	0.0091	0.0000	0.0000	0.0930
Sardine Fish (Sardinella maderensis)	0.0546	0.0000	0.1213	0.0091	0.0000	0.0000	0.0937
Tilapia (Tilapia zillii)	0.0516	0.0000	0.1213	0.0061	0.0000	0.0000	0.0827
Recommended dietary allowance (mg/day/person)	0.13	0.06	0.21	0.03	0.3µg/kg/d	0.045µg/kg/d	10.7
Agenebode Beach							
African Cat Fish (Clarias gariepinus)	0.0546	0.0000	0.1122	0.0061	0.0000	0.0000	0.0667
Elephant Fish (Campylomomyrus rhychophorus)	0.0576	0.0000	0.1062	0.0091	0.0000	0.0000	0.0687
Tilapia (Tilapia zillii)	0.0485	0.0000	0.1062	0.0061	0.0000	0.0000	0.0620
Recommended dietary allowance (mg/day/person)	0.13	0.06	0.21	0.03	0.3µg/kg/d	0.045µg/kg/d	10.7

Target Hazard Quotient for Heavy Metals in Fish (in Adults and Children) during the wet and dry season

The result of the Target Hazard Quotient for all the fish species (African Cat Fish (*Clarias gariepinus*), Croacker Fish (*Micropogonias undulatus*), Sardine Fish (*Sardinella maderensis*) and Tilapia (*Oreochromis niloticus*) sampled at Tourist beach, during the wet and dry season for adults and children showed that all the values for the heavy metals assessed were less than 1(<1), indicating no apparent health risk from these heavy metals over a life time of exposure. Tables 4-8 summarized the result of the Target Hazard Quotient (adults and children) for all the fish species; African Cat Fish (*Clarias gariepinus*), Sardine Fish (*Sardinella maderensis*) and Tilapia (*Tilapia zillii*) sampled at Okpoama beach during the wet and dry season. The values for all the heavy metals assessed were less than 1(<1), indicating no apparent health risk from these heavy metals over a life time of exposure. The result of the Target Hazard Quotient (adult and children) for all the fish species; Cat Fish (*Chrysichthys nigrodigitatus*), Croaker Fish (*Micropogonias undulatus*), Nile Tilapia (*Oreochromis niloticus*) sampled at Ibeno beach during the wet and dry season are shown in Tables 5-8. The values for all the heavy metals assessed were less than 1(<1), indicating no apparent health risk from these heavy metals over a life time of exposure. At Asaba beach, three fish species: African Cat Fish (*Clarias gariepinus*), Sardine Fish (*Sardinella maderensis*) and Tilapia (*Tilapia zillii*) were analysed for heavy metals. The result of the Target Hazard Quotient (in adults and children) for the three fish species sampled at Asaba beach during the wet and dry season showed that all the values for the heavy metals assessed were less than 1(<1), indicating no apparent health risk from these heavy metals over a life time of exposure. African Cat Fish (*Clarias gariepinus*), Sardine Fish (*Sardinella maderensis*) and Tilapia (*Tilapia zillii*) were three fish species analyzed for heavy metals at Marina's beach Calabar during the wet and dry season as can be seen in tables 5-8. The result of the Target Hazard Quotient (in adults and children) for the three fish species sampled at Marina's beach during the wet and dry season showed that all the values for the heavy metals assessed were less than 1(<1), indicating no apparent health risk from these heavy metals over a life time of exposure. At Agenobode beach, three fish species: African Cat Fish (*Clarias gariepinus*), Elephant Fish (*Campylomomyrus rhychophorus*) and Tilapia (*Tilapia zillii*) were analysed for heavy metals during the wet and dry season as can be seen in tables 5-8. The result of the Target Hazard Quotient (in adults and children) for the three fish species sampled at Agenobode beach during the wet and dry season showed that all the values for the heavy metals assessed were less than 1(<1), indicating no apparent health risk from these heavy metals over a life time of exposure.

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Table 5. Target Hazard Quotient for Heavy Metals in Fish (Adults) during the wet season

	THQ (Adult)					
Wet Season	**Pb**	**Cu**	**Cr**	**Cd**	**As**	**Hg**
Tourist Beach						
African Cat Fish (Clarias gariepinus)	0.0020	0.0000	0.0365	0.0014	0.0000	0.0000
Croacker Fish (Micropogonias undulatus)	0.0069	0.0000	0.0553	0.0021	0.0000	0.0000
Sardine Fish (Sardinella maderensis)	0.0021	0.0000	0.0376	0.0014	0.0000	0.0000
NileTilapia (Oreochromis niloticus)	0.0050	0.0000	0.0470	0.0021	0.0000	0.0000
Okpoama Beach						
African Cat Fish (Clarias gariepinus)	0.0052	0.0000	0.0506	0.0021	0.0000	0.0000
Sardine Fish (Sardinella maderensis)	0.0055	0.0000	0.0553	0.0021	0.0000	0.0000
Tilapia (Tilapia zillii)	0.0054	0.0000	0.0518	0.0021	0.0000	0.0000
Ibeno Beach						
Cat Fish (Chrysichthys nigrodigitatus)	0.0022	0.0000	0.0412	0.0021	0.0000	0.0000
Croacker Fish (Micropogonias undulatus)	0.0068	0.0000	0.0553	0.0021	0.0000	0.0000
Nile Tilapia (Oreochromis niloticus)	0.0068	0.0000	0.0553	0.0021	0.0000	0.0000
Asaba Beach						
African Cat Fish (Clarias gariepinus)	0.0068	0.0002	0.0447	0.0000	0.0000	0.0000
Bony Tongue Fish (Heterotis niloticus)	0.0064	0.0002	0.0400	0.0000	0.0000	0.0000
Tilapia (Tilapia zillii)	0.0056	0.0002	0.0412	0.0000	0.0000	0.0000
Marina-s Beach						
African Cat Fish (Clarias gariepinus)	0.0018	0.0000	0.0470	0.0021	0.0000	0.0000
Sardine Fish (Sardinella maderensis)	0.0018	0.0000	0.0470	0.0021	0.0000	0.0000
Tilapia (Tilapia zillii)	0.0017	0.0000	0.0470	0.0014	0.0000	0.0000
Agenebode Beach						
African Cat Fish (Clarias gariepinus)	0.0018	0.0000	0.0435	0.0014	0.0000	0.0000
Elephant Fish (Campylomomyrus rhychophorus)	0.0019	0.0000	0.0412	0.0021	0.0000	0.0000
Tilapia (Tilapia zillii)	0.0016	0.0000	0.0412	0.0014	0.0000	0.0000

Values >1 indicates apparent health risk over a life time of exposure while values <1 indicates no apparent health risk from these heavy metals over a life time of exposure.

Table 6. Target Hazard Quotient for Heavy Metals in Fish (Adults) during the dry season.

	THQ (Adult)					
Dry Season	**Pb**	**Cu**	**Cr**	**Cd**	**As**	**Hg**
Tourist Beach						
African Cat Fish (Clarias gariepinus)	0.0030	0.0000	0.0537	0.0021	0.0000	0.0000
Croacker Fish (Micropogonias undulatus)	0.0101	0.0000	0.0815	0.0031	0.0000	0.0000
Sardine Fish (Sardinella maderensis)	0.0031	0.0000	0.0555	0.0021	0.0000	0.0000
Tilapia (Oreochromis niloticus)	0.0074	0.0000	0.0693	0.0031	0.0000	0.0000
Okpoama Beach						
African Cat Fish (Clarias gariepinus)	0.0077	0.0000	0.0745	0.0031	0.0000	0.0000
Sardine Fish (Sardinella maderensis)	0.0082	0.0000	0.0815	0.0031	0.0000	0.0000
Tilapia (Tilapia zillii)	0.0080	0.0000	0.0763	0.0031	0.0000	0.0000
Ibeno Beach						
Cat Fish (Chrysichthys nigrodigitatus)	0.0033	0.0000	0.0607	0.0031	0.0000	0.0000
Croacker Fish (Micropogonias undulatus)	0.0100	0.0000	0.0815	0.0031	0.0000	0.0000
Nile Tilapia (Oreochromis niloticus)	0.0100	0.0000	0.0815	0.0031	0.0000	0.0000
Asaba Beach						
African Cat Fish (Clarias gariepinus)	0.0100	0.0003	0.0659	0.0000	0.0000	0.0000

Bony Tongue Fish (Heterotis niloticus)	0.0094	0.0003	0.0589	0.0000	0.0000	0.0000
Tilapia (Tilapia zillii)	0.0083	0.0003	0.0607	0.0000	0.0000	0.0000
Marina-s Beach						
African Cat Fish (Clarias gariepinus)	0.0027	0.0000	0.0693	0.0031	0.0000	0.0000
Sardine Fish (Sardinella maderensis)	0.0027	0.0000	0.0693	0.0031	0.0000	0.0000
Tilapia (Tilapia zillii)	0.0025	0.0000	0.0693	0.0021	0.0000	0.0000
Agenebode Beach						
African Cat Fish (Clarias gariepinus)	0.0027	0.0000	0.0641	0.0021	0.0000	0.0000
Elephant Fish (Campylomomyrus rhychophorus)	0.0028	0.0000	0.0607	0.0031	0.0000	0.0000
Tilapia (Tilapia zillii)	0.0024	0.0000	0.0607	0.0021	0.0000	0.0000

Values >1 indicates apparent health risk over a life time of exposure while values <1 indicates no apparent health risk from these heavy metals over a life time of exposure.

Table 7 . Target Hazard Quotient for Heavy Metals in Fish (Children) during the wet season.

	THQ (Children)					
Wet Season	**Pb**	**Cu**	**Cr**	**Cd**	**As**	**Hg**
Tourist Beach						
African Cat Fish (Clarias gariepinus)	0.0118	0.0000	0.2127	0.0082	0.0000	0.0000
Croacker Fish (Micropogonias undulatus)	0.0400	0.0000	0.3225	0.0124	0.0000	0.0000
Sardine Fish (Sardinella maderensis)	0.0124	0.0000	0.2196	0.0082	0.0000	0.0000
Tilapia (Oreochromis niloticus)	0.0294	0.0000	0.2744	0.0124	0.0000	0.0000
Okpoama Beach						
African Cat Fish (Clarias gariepinus)	0.0306	0.0000	0.2950	0.0124	0.0000	0.0000
Sardine Fish (Sardinella maderensis)	0.0323	0.0000	0.3225	0.0124	0.0000	0.0000
Tilapia (Tilapia zillii)	0.0318	0.0000	0.3019	0.0124	0.0000	0.0000
Ibeno Beach						
Cat Fish (Chrysichthys nigrodigitatus)	0.0129	0.0000	0.2401	0.0124	0.0000	0.0000
Croacker Fish (Micropogonias undulatus)	0.0394	0.0000	0.3225	0.0124	0.0000	0.0000
Nile Tilapia (Oreochromis niloticus)	0.0394	0.0000	0.3225	0.0124	0.0000	0.0000
Asaba Beach						
African Cat Fish (Clarias gariepinus)	0.0394	0.0012	0.2607	0.0000	0.0000	0.0000
Bony Tongue Fish (Heterotis niloticus)	0.0371	0.0011	0.2333	0.0000	0.0000	0.0000
Tilapia (Tilapia zillii)	0.0329	0.0010	0.2401	0.0000	0.0000	0.0000
Marina-s Beach						
African Cat Fish (Clarias gariepinus)	0.0106	0.0000	0.2744	0.0124	0.0000	0.0000
Sardine Fish (Sardinella maderensis)	0.0106	0.0000	0.2744	0.0124	0.0000	0.0000
Tilapia (Tilapia zillii)	0.0100	0.0000	0.2744	0.0082	0.0000	0.0000
Agenebode Beach						
African Cat Fish (Clarias gariepinus)	0.0106	0.0000	0.2539	0.0082	0.0000	0.0000
Elephant Fish (Campylomomyrus rhychophorus)	0.0112	0.0000	0.2401	0.0124	0.0000	0.0000
Tilapia (Tilapia zillii)	0.0094	0.0000	0.2401	0.0082	0.0000	0.0000

Values >1 indicates apparent health risk over a life time of exposure while values <1 indicates no apparent health risk from these heavy metals over a life time of exposure.

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Table 8. Target Hazard Quotient for Heavy Metals in Fish (Children) during the dry season.

	THQ (Children)					
Dry Season	**Pb**	**Cu**	**Cr**	**Cd**	**As**	**Hg**
Tourist Beach						
African Cat Fish (Clarias gariepinus)	0.0173	0.0000	0.3134	0.0121	0.0000	0.0000
Croacker Fish (Micropogonias undulatus)	0.0589	0.0000	0.4752	0.0182	0.0000	0.0000
Sardine Fish (Sardinella maderensis)	0.0182	0.0000	0.3236	0.0121	0.0000	0.0000
Tilapia (Oreochromis niloticus)	0.0433	0.0000	0.4044	0.0182	0.0000	0.0000
Okpoama Beach						
African Cat Fish (Clarias gariepinus)	0.0451	0.0000	0.4348	0.0182	0.0000	0.0000
Sardine Fish (Sardinella maderensis)	0.0477	0.0000	0.4752	0.0182	0.0000	0.0000
Tilapia (Tilapia zillii)	0.0468	0.0000	0.4449	0.0182	0.0000	0.0000
Ibeno Beach						
Cat Fish (Chrysichthys nigrodigitatus)	0.0191	0.0000	0.3539	0.0182	0.0000	0.0000
Croacker Fish (Micropogonias undulatus)	0.0581	0.0000	0.4752	0.0182	0.0000	0.0000
Nile Tilapia (Oreochromis niloticus)	0.0581	0.0000	0.4752	0.0182	0.0000	0.0000
Asaba Beach						
African Cat Fish (Clarias gariepinus)	0.0581	0.0018	0.3842	0.0000	0.0000	0.0000
Bony Tongue Fish (Heterotis niloticus)	0.0546	0.0017	0.3438	0.0000	0.0000	0.0000
Tilapia (Tilapia zillii)	0.0485	0.0015	0.3539	0.0000	0.0000	0.0000
Marina-s Beach						
African Cat Fish (Clarias gariepinus)	0.0156	0.0000	0.4044	0.0182	0.0000	0.0000
Sardine Fish (Sardinella maderensis)	0.0156	0.0000	0.4044	0.0182	0.0000	0.0000
Tilapia (Tilapia zillii)	0.0147	0.0000	0.4044	0.0121	0.0000	0.0000
Agenebode Beach						
African Cat Fish (Clarias gariepinus)	0.0156	0.0000	0.3741	0.0121	0.0000	0.0000
Elephant Fish (Campylomomyrus rhychophorus)	0.0165	0.0000	0.3539	0.0182	0.0000	0.0000
Tilapia (Tilapia zillii)	0.0139	0.0000	0.3539	0.0121	0.0000	0.0000

Values >1 indicates apparent health risk over a life time of exposure while values <1 indicates no apparent health risk from these heavy metals over a life time of exposure.

Health Risk Index for Heavy Metals consumption in Fish from beaches' water in adults and children during the wet and dry season.

Tables 9 and 10 summarized the result of the health risk indexes for heavy metals in fish (in adults and children) during the wet and dry season. The values for health risk indexes for adults during the wet and dry season were all <1, indicating no apparent health risk from these heavy metals over a life time of exposure. In children, during the wet season, all the heavy metals showed health risk indexes <1 except Cr at Tourist beach. During the dry season, Cr showed a health risk index >1 in all the sampled beaches except Agenobode beach. Arsenic and Mercury (Hg) equally showed health risk indexes >1 except at Agenobode beach. The health risk index (HRI) showed that consumption of the fish species (except Cr in Children during the wet season at Tourist beach, Cr, As and Hg in children during the dry season in all the beaches except Agenobode) beach does not pose any risk to adults and children respectively.

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Table 9. Health Risk Index for Heavy Metals in Fish (Adults) during the wet and dry season.

Health Risk Index, HRI (Adults)							
Wet Season	**Tourist Beach**	**Okpoama Beach**	**Ibeno Beach**	**Asaba Beach**	**Marina-s Beach**	**Agenebode Beach**	**Mean**
Pb	0.0160	0.0162	0.0157	0.0056	0.0053	0.0053	0.0106
Cu	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000
Cr	0.1764	0.1576	0.1517	0.0412	0.1411	0.1259	0.1323
Cd	0.0071	0.0064	0.0064	0.0000	0.0056	0.0049	0.0050
As	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Hg	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Dry season							
Pb	0.0236	0.0239	0.0232	0.0276	0.0079	0.0079	0.0189
Cu	0	0	0	0.0009	0	0	0.0001
Cr	0.2600	0.2323	0.2236	0.1855	0.2080	0.1855	0.2158
Cd	0.0104	0.0094	0.0094	0	0.0083	0.0073	0.0074
As	0.000007	0.0000052	0.0000052	0.0000052	0.0000052	0.0000052	0.0000055
Hg	0.000007	0.0000052	0.0000052	0.0000052	0.0000052	0.0000052	0.0000055

Values >1 indicates apparent health risk over a life time of exposure while values <1 indicates no apparent health risk from these heavy metals over a life time of exposure.

Table 10. Health Risk Index for Heavy Metals in Fish (Children) during the wet and dry season.

	Health Risk Index, HRI (Children)						
Wet Season	**Tourist Beach**	**Okpoama Beach**	**Ibeno Beach**	**Asaba Beach**	**Marina-s Beach**	**Agenebode Beach**	**Mean**
Pb	0.0935	0.0947	0.0917	0.1094	0.0312	0.0312	0.1220
Cu	0.0000	0.0000	0.0000	0.0034	0.0000	0.0000	0.0034
Cr	1.0292	0.9194	0.8851	0.7341	0.8233	0.7341	0.8542
Cd	0.0412	0.0371	0.0371	0.0000	0.0329	0.0288	0.0913
As	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Hg	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Dry season							
Pb	0.1378	0.1395	0.1352	0.1612	0.0459	0.0312	0.1084
Cu	0	0	0	0.0051	0	0.0000	0.0008
Cr	1.5167	1.3549	1.3043	1.0819	1.2133	0.7341	0.3382
Cd	0.0607	0.0546	0.0546	0	0.0485	0.0288	0.0412
As	4.044E-05	3.033E-05	3.033E-05	3.033E-05	3.033E-05	0.0000	2.696E-05
Hg	4.044E-05	3.033E-05	3.033E-05	3.033E-05	3.033E-05	0.0000	2.696E-05

Values >1 indicates apparent health risk over a life time of exposure while values <1 indicates no apparent health risk from these heavy metals over a life time of exposure

Hazard Index for Heavy Metals consumption in Fish from beaches' in adult and children during the wet and dry season.

Tables 11 and 12 summarized the hazard indexes for heavy metal in fish species (in adults and children) during the wet and dry season. The hazard indexes for heavy metals from fish in all the sampled beaches consumed by adults during the wet season ranged from 0.399-0.643. During the wet season, the hazard indexes recorded for adults, ranged from 0.588-0.947. All the beaches recorded hazard indexes were less than the threshold value of 1, showing that the non-carcinogenic adverse effect is negligible. The hazard indexes in children during the wet season, ranged from 0.2578-0.3748. During the dry season, children recorded a hazard index range of 0.3429-0.5524. All the beaches recorded hazard indexes were less than the threshold value of 1, showing that the non-carcinogenic adverse effect is negligible.

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Table 11. Hazard Index for Heavy Metals in Fish (Adult) during the wet and dry season.

Wet Season	Hazard Index, HI (Adult)	Dry Season	Hazard Index, HI (Adult)
Tourist Beach		**Tourist Beach**	
African Cat Fish (Clarias gariepinus)	0.0399	African Cat Fish (Clarias gariepinus)	0.0588
Croacker Fish (Micropogonias undulatus)	0.0643	Croacker Fish (Micropogonias undulatus)	0.0947
Sardine Fish (Sardinella maderensis)	0.0412	Sardine Fish (Sardinella maderensis)	0.0607
Tilapia (Oreochromis niloticus)	0.0542	Tilapia (Oreochromis niloticus)	0.0799
Okpoama Beach		**Okpoama Beach**	
African Cat Fish (Clarias gariepinus)	0.0579	African Cat Fish (Clarias gariepinus)	0.0854
Sardine Fish (Sardinella maderensis)	0.0629	Sardine Fish (Sardinella maderensis)	0.0928
Tilapia (Tilapia zillii)	0.0593	Tilapia (Tilapia zillii)	0.0874
Ibeno Beach		**Ibeno Beach**	
Cat Fish (Chrysichthys nigrodigitatus)	0.0455	Cat Fish (Chrysichthys nigrodigitatus)	0.0671
Croacker Fish (Micropogonias undulatus)	0.0642	Croacker Fish (Micropogonias undulatus)	0.0945
Nile Tilapia (Oreochromis niloticus)	0.0642	Nile Tilapia (Oreochromis niloticus)	0.0945
Asaba Beach		**Asaba Beach**	
African Cat Fish (Clarias gariepinus)	0.0517	African Cat Fish (Clarias gariepinus)	0.0761
Bony Tongue Fish (Heterotis niloticus)	0.0465	Bony Tongue Fish (Heterotis niloticus)	0.0686
Tilapia (Tilapia zillii)	0.0470	Tilapia (Tilapia zillii)	0.0693
Marina-s Beach		**Marina-s Beach**	
African Cat Fish (Clarias gariepinus)	0.0510	African Cat Fish (Clarias gariepinus)	0.0751
Sardine Fish (Sardinella maderensis)	0.0510	Sardine Fish (Sardinella maderensis)	0.0751
Tilapia (Tilapia zillii)	0.0502	Tilapia (Tilapia zillii)	0.0739
Agenebode Beach		**Agenebode Beach**	
African Cat Fish (Clarias gariepinus)	0.0467	African Cat Fish (Clarias gariepinus)	0.0689
Elephant Fish (Campylomomyrus rhychophorus)	0.0452	Elephant Fish (Campylomomyrus rhychophorus)	0.0666
Tilapia (Tilapia zillii)	0.0442	Tilapia (Tilapia zillii)	0.0651

Values >1 indicates non-carcinogenic adverse health effect while values <1 indicates that the non-carcinogenic adverse health effect is negligible.

Table 12. Hazard Index for Heavy Metals in Fish (Children) during the wet and dry season.

Wet Season	Hazard Index, HI (Children)	Dry Season	Hazard Index, HI (Children)
Tourist Beach		**Tourist Beach**	
African Cat Fish (Clarias gariepinus)	0.2327	African Cat Fish (Clarias gariepinus)	0.3429
Croacker Fish (Micropogonias undulatus)	0.3748	Croacker Fish (Micropogonias undulatus)	0.5524
Sardine Fish (Sardinella maderensis)	0.2402	Sardine Fish (Sardinella maderensis)	0.3539
Tilapia (Oreochromis niloticus)	0.3162	Tilapia (Oreochromis niloticus)	0.4660
Okpoama Beach		**Okpoama Beach**	
African Cat Fish (Clarias gariepinus)	0.3380	African Cat Fish (Clarias gariepinus)	0.4981
Sardine Fish (Sardinella maderensis)	0.3672	Sardine Fish (Sardinella maderensis)	0.5411
Tilapia (Tilapia zillii)	0.3460	Tilapia (Tilapia zillii)	0.5099
Ibeno Beach		**Ibeno Beach**	
Cat Fish (Chrysichthys nigrodigitatus)	0.2654	Cat Fish (Chrysichthys nigrodigitatus)	0.3912
Croacker Fish (Micropogonias undulatus)	0.3742	Croacker Fish (Micropogonias undulatus)	0.5515
Nile Tilapia (Oreochromis niloticus)	0.3742	Nile Tilapia (Oreochromis niloticus)	0.5515
Asaba Beach		**Asaba Beach**	
African Cat Fish (Clarias gariepinus)	0.3014	African Cat Fish (Clarias gariepinus)	0.4441
Bony Tongue Fish (Heterotis niloticus)	0.2715	Bony Tongue Fish (Heterotis niloticus)	0.4001
Tilapia (Tilapia zillii)	0.2741	Tilapia (Tilapia zillii)	0.4040
Marina-s Beach		**Marina-s Beach**	
African Cat Fish (Clarias gariepinus)	0.2974	African Cat Fish (Clarias gariepinus)	0.4383
Sardine Fish (Sardinella maderensis)	0.2974	Sardine Fish (Sardinella maderensis)	0.4383
Tilapia (Tilapia zillii)	0.2927	Tilapia (Tilapia zillii)	0.4313
Agenebode Beach		**Agenebode Beach**	
African Cat Fish (Clarias gariepinus)	0.2727	African Cat Fish (Clarias gariepinus)	0.4019
Elephant Fish (Campylomomyrus rhychophorus)	0.2637	Elephant Fish (Campylomomyrus rhychophorus)	0.3886
Tilapia (Tilapia zillii)	0.2578	Tilapia (Tilapia zillii)	0.3799

Values >1 indicates non-carcinogenic adverse health effect while values <1 indicates that the non-carcinogenic adverse health effect is negligible.

Carcinogenic Risk for Heavy Metals consumption in Fish from beaches' water in adults and children during the wet and dry season.

The carcinogenic risk (cancer risk) for heavy metals in fish (adults and children) during the wet and dry season is summarized in Tables 13 and 14. The carcinogenic risk values of heavy metals due to exposure from the

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consumption of fish species at Tourist beach was recorded highest in Pb (0.0600 and 0.0884000) in African Cat Fish (Clarias gariepinus) in adults during the wet and dry season respectively, highest in Cd (0.0926 and 0.1365) in Croacker Fish (*Micropogonias undulatus*) and Tilapia (*Oreochromis niloticus*) in children during the wet and dry season respectively, while it was recorded lowest in As (0.0000005 and 0.0000008) in Tilapia (Oreochromis niloticus) in adults during the wet and dry season respectively as well as As (4.550E-06) in all the fish species consumed by children at Tourist beach. The Carcinogenic risk was in the decreasing order of Pb>Cd>Cr>As for adults (both season) Cd>Cr>Pb>As for children (both season). The CR values in all the fish species consumed from Tourist beach by adults and children were greater than the accepted range (10^{-4}–10^{-6}) (E−6 and E−4). This indicates that consumption of fish from this beach should be of concern.

The carcinogenic risk values of heavy metals due to exposure from the consumption of fish species at Okpoama beach was recorded highest in Cd (0.0159 and 0.0234000) in African Cat Fish (*Clarias gariepinus*), Sardine Fish (*Sardinella maderensis*) and Tilapia (*Tilapia zillii*) in adults during the wet and dry season, highest in Cd (0.0926 and 0.1365), African Cat Fish (*Clarias gariepinus*), Sardine Fish (*Sardinella maderensis*) in children during the wet and dry season respectively, while it recorded lowest in As (0.0000005 and 0.0000008) in all the fish species (adults) during the wet and dry season respectively as well as As (3.0875E-06 and 0.00000455) in all the fish species consumed by children at Okpoama beach during the wet and dry season. The carcinogenic risk was in the decreasing order of Cd>Cr>Pb>As for adult and children for both season. This also indicates that consumption of fish from this beach should be of concern.

The carcinogenic risk values of heavy metals due to exposure from the consumption of fish species at Ibeno beach was recorded highest in Cd (0.0159 and 0.0234000) in Cat Fish (*Chrysichthys nigrodigitatus*), Croacker Fish (*Micropogonias undulatus*) and Nile Tilapia (*Oreochromis niloticus*) in adults during the wet and dry season, highest in Cd (0.0926 and 0.1365), in Cat Fish (*Chrysichthys nigrodigitatus*), Croacker Fish (*Micropogonias undulatus*) and Nile Tilapia (*Oreochromis niloticus*) (children) during the wet and dry season respectively, while it was recorded lowest (0.0000005 and 0.0000008) in As in all the fish species in adults during the wet and dry season respectively as well as As (3.0875E-06 and 0.00000455) in all the fish species consumed by children at Ibeno beach during the wet and dry season. The carcinogenic risk was in the decreasing order of Cd>Cr>Pb>As for adult and children for both season. This also indicates that consumption of fish from Ibeno beach should be of concern.

The carcinogenic risk values of heavy metals due to exposure from the consumption of fish species at Asaba beach was recorded highest in Cr (0.0067 and 0.0098800) in African Cat Fish (*Clarias gariepinus*) in adults during the wet and dry season, highest in Cr (0.0391 and 0.057633333), in African Cat Fish (*Clarias gariepinus*) (children) during the wet and dry season respectively, while it was recorded lowest (0.0000005 and 0.0000000) in Cd in all the fish species in adults during the wet and dry season respectively as well as Cd (0 and 0) in all the fish species consumed by children at Asaba beach during the wet and dry season. The carcinogenic risk was in the decreasing order of Cr> Pb>Cd>As for adult and children for both season. This showed that consumption of fish from Asaba beach should be of concern.

The carcinogenic risk values of heavy metals due to exposure from the consumption of fish species at Marina's beach was recorded highest in Cd (0.0159 and 0.0234000) in African Cat Fish (*Clarias gariepinus*) and Sardine Fish (*Sardinella maderensis*) in adults during the wet and dry season, highest in Cd (0.926 and 0.1365), in African Cat Fish (*Clarias gariepinus*) and and Sardine Fish (*Sardinella maderensis*) (children) during the wet and dry season respectively, while it was recorded lowest (0.0000005 and 0.0000008) in As in all the fish species in adults during the wet and dry season respectively as well as As (3.0875E-06 and 0.00000455) in all the fish species consumed by children at Marina's beach during the wet and dry season. The carcinogenic risk was in the decreasing order of Cd>Cr>Pb>As for adult and children for both season. This showed that consumption of fish from Marina's beach should be of concern to the tourists that patronize fish barbecue at the beach.

The carcinogenic risk values of heavy metals due to exposure from the consumption of fish species at Agenobode beach was recorded highest in Cd (0.0159 and 0.0234000) in Elephant Fish (*Campylomomyrus rhychophorus*) in adults during the wet and dry season, highest in Cd (0.926 and 0.1365), in Elephant Fish (*Campylomomyrus rhychophorus*) (children) during the wet and dry season respectively, while it was recorded

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lowest (0.0000005 and 0.0000008) in As in all the fish species in adults during the wet and dry season respectively as well as As (3.0875E-06 and 0.00000455) in all the fish species consumed by children at Agenobode beach during the wet and dry season. The carcinogenic risk was in the decreasing order of Cd>Cr>Pb>As for adult and children for both season. This showed that consumption of fish from Agenobode beach should be of concern to the tourists that patronize fish barbecue at the beach.

Table 13. Carcinogenic Risk for Heavy Metals in Fish (Adult) during the wet and dry season.

	Carcinogenic Risk, CR (Adult) Wet season				**Carcinogenic Risk, CR (Adult) Dry season**			
	Pb	**Cr**	**Cd**	**As**	**Pb**	**Cr**	**Cd**	**As**
Tourist Beach								
African Cat Fish (Clarias gariepinus)	0.0600	0.0055	0.0106	0.0000005	0.0884000	0.0080600	0.0156000	0.0000008
Croacker Fish (Micropogonias undulatus)	0.0002	0.0083	0.0159	0.0000005	0.0003006	0.0122200	0.0234000	0.0000008
Sardine Fish (Sardinella maderensis)	0.0001	0.0057	0.0106	0.0000005	0.0000928	0.0083200	0.0156000	0.0000008
Tilapia (Oreochromis niloticus)	0.0002	0.0071	0.0159	0.0000005	0.0002210	0.0104000	0.0234000	0.0000008
Okpoama Beach								
African Cat Fish (Clarias gariepinus)	0.0002	0.0076	0.0159	0.0000005	0.0002298	0.0111800	0.0234000	0.0000008
Sardine Fish (Sardinella maderensis)	0.0002	0.0083	0.0159	0.0000005	0.0002431	0.0122200	0.0234000	0.0000008
Tilapia (Tilapia zillii)	0.0002	0.0078	0.0159	0.0000005	0.0002387	0.0114400	0.0234000	0.0000008
Ibeno Beach								
Cat Fish (Chrysichthys nigrodigitatus)	0.0001	0.0061	0.0159	0.0000005	0.0000972	0.0091000	0.0234000	0.0000008
Croacker Fish (Micropogonias undulatus)	0.0002	0.0083	0.0159	0.0000005	0.0002961	0.0122200	0.0234000	0.0000008
Nile Tilapia (Oreochromis niloticus)	0.0002	0.0083	0.0159	0.0000005	0.0002961	0.0122200	0.0234000	0.0000008
Asaba Beach								
African Cat Fish (Clarias gariepinus)	0.0002	0.0067	0.0000	0.0000005	0.0002961	0.0098800	0.0000000	0.0000008
Bony Tongue Fish (Heterotis niloticus)	0.0002	0.0060	0.0000	0.0000005	0.0002785	0.0088400	0.0000000	0.0000008
Tilapia (Tilapia zillii)	0.0002	0.0062	0.0000	0.0000005	0.0002475	0.0091000	0.0000000	0.0000008
Marina-s Beach								
African Cat Fish (Clarias gariepinus)	0.0001	0.0071	0.0159	0.0000005	0.0000796	0.0104000	0.0234000	0.0000008
Sardine Fish (Sardinella maderensis)	0.0001	0.0071	0.0159	0.0000005	0.0000796	0.0104000	0.0234000	0.0000008
Tilapia (Tilapia zillii)	0.0001	0.0071	0.0106	0.0000005	0.0000751	0.0104000	0.0156000	0.0000008
Agenebode Beach								
African Cat Fish (Clarias gariepinus)	0.0001	0.0062 79	0.0106	0.0000005	0.0000796	0.0096200	0.0156000	0.0000008
Elephant Fish (Campylomomyrus rhychophorus)	0.0001	0.0062	0.0159	0.0000005	0.0000840	0.0091000	0.0234000	0.0000008
Tilapia (Tilapia zillii)	0.0001	0.0062	0.0106	0.0000005	0.0000707	0.0091000	0.0156000	0.0000008

Carcinogenic Risk (CR): CR values lower than10^{-6} are considered as negligible, above 10^{-4} are considered unacceptable while between 10^{-6} and 10^{-4} are considered acceptable (USEPA, 2010)

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Table 14. Carcinogenic Risk for Heavy Metals in Fish (Children) during the wet and dry season.

	Carcinogenic Risk, CR (Children) Wet Season				Carcinogenic Risk, CR (Children) Dry Season			
	Pb	**Cr**	**Cd**	**As**	**Pb**	**Cr**	**Cd**	**As**
Tourist Beach								
African Cat Fish (Clarias gariepinus)	0.0004	0.0319	0.0617	3.088E-06	0.000515667	0.047016667	0.091	4.550E-06
Croacker Fish (Micropogonias undulatus)	0.0011	0.0484	0.0926	3.088E-06	0.001753267	0.071283333	0.1365	4.550E-06
Sardine Fish (Sardinella maderensis)	0.0004	0.0329	0.0618	3.088E-06	0.00054145	0.048533333	0.091	4.550E-06
Tilapia (Oreochromis niloticus)	0.0000	0.0412	0.0926	3.088E-06	0.001289167	0.060666667	0.1365	4.550E-06
Okpoama Beach								
African Cat Fish (Clarias gariepinus)	0.0009	0.0443	0.0926	3.0875E-06	0.001340733	0.065216667	0.1365	0.00000455
Sardine Fish (Sardinella maderensis)	0.0010	0.0484	0.0926	3.0875E-06	0.001418083	0.071283333	0.1365	0.00000455
Tilapia (Tilapia zillii)	0.0010	0.0453	0.0926	3.0875E-06	0.0013923	0.066733333	0.1365	0.00000455
Ibeno Beach								
Cat Fish (Chrysichthys nigrodigitatus)	0.0004	0.0360	0.0926	3.0875E-06	0.000567233	0.053083333	0.1365	0.00000455
Croacker Fish (Micropogonias undulatus)	0.0012	0.0484	0.0926	3.0875E-06	0.001727483	0.071283333	0.1365	0.00000455
Nile Tilapia (Oreochromis niloticus)	0.0012	0.0484	0.0926	3.0875E-06	0.001727483	0.071283333	0.1365	0.00000455
Asaba Beach								
African Cat Fish (Clarias gariepinus)	0.0012	0.0391	0	3.0875E-06	0.001727483	0.057633333	0	0.00000455
Bony Tongue Fish (Heterotis niloticus)	0.0011	0.03450	0	3.0875E-06	0.00162435	0.051566667	0	0.00000455
Tilapia (Tilapia zillii)	0.0010	0.03602	0	3.0875E-06	0.001443867	0.053083333	0	0.00000455
Marina-s Beach								
African Cat Fish (Clarias gariepinus)	0.0003	0.0412	0.0926	3.0875E-06	0.0004641	0.060666667	0.1365	0.00000455
Sardine Fish (Sardinella maderensis)	0.0003	0.0412	0.0926	3.0875E-06	0.0004641	0.060666667	0.1365	0.00000455
Tilapia (Tilapia zillii)	0.0003	0.0412	0.0618	3.0875E-06	0.000438317	0.060666667	0.091	0.00000455
Agenebode Beach								
African Cat Fish (Clarias gariepinus)	0.0003	0.0381	0.0618	3.0875E-06	0.0004641	0.056116667	0.091	0.00000455
Elephant Fish (Campylomomyrus rhychophorus)	0.0003	0.0360	0.0926	3.0875E-06	0.000489883	0.053083333	0.1365	0.00000455
Tilapia (Tilapia zillii)	0.0003	0.0360	0.06175	3.0875E-06	0.000412533	0.053083333	0.091	0.00000455

Carcinogenic Risk (CR): CR values lower than10^{-6} are considered as negligible, above 10^{-4} are considered unacceptable while between 10^{-6} and 10^{-4} are considered acceptable (USEPA, 2010)

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DISCUSSION

Human Health Risk Assessment Of Heavy Metal Contamination Of Fish From The Six Sampled Coastal Beaches During The Wet And Dry Season.

Estimated Daily Intake for Heavy Metals Consumption in Fish from beaches' water in adults and children for wet and dry season.

The results of the EDI for heavy metals in fish (adults and children) during the wet and dry season, all the fish species sampled across the six beaches showed EDI that is less than the maximum permissible limit (recommended dietary allowance) in adults for both seasons while the EDI result for children showed that Croacker Fish (*Micropogonias undulatus*) (0.1400mg/kg/day and 0.2063mg/kg/day) at Tourist beach showed high EDI for Pb during the wet and dry season, African Cat Fish (*Clarias gariepinus*), Sardine Fish (*Sardinella maderensis*) and Tilapia (*Tilapia zillii*) (0.1577 mg/kg/day, 0.1668 mg/kg/day and 0.1638mg/kg/day) showed high EDI for Pb during the dry season only, Croacker Fish (*Micropogonias undulates*) and Nile Tilapia (*Oreochromis niloticus*) (0.1379mg/kg/day and 0.2032mg/kg/day) at Ibeno beach showed high EDI for Pb during the wet and dry season, African Cat Fish (*Clarias gariepinus*) (0.1379mg/kg/day) at Asaba beach showed high EDI for Pb during the wet season, while African Cat Fish (*Clarias gariepinus*), Bony Tongue Fish (*Heterotis niloticus*) and Tilapia (*Tilapia zillii*) at Asaba beach showed high EDI for Pb (0.2032 mg/kg/day, 0.1911 mg/kg/day and 0.1699mg/kg/day) and Cr (0.0728 mg/kg/day, 0.0667 mg/kg/day and 0.0607 mg/kg/day) in children during the dry season. Exceedance of EDI was observed to be more in children than adults. It was equally observed to be more in the dry season than the wet season. The present study disagreed with Matouke and Abdullahi (2020) who observed that the EDI for lead (Pb) were the highest 1.3mg/kg and 0.274mg/kg for adult and child, respectively in their work on assessment of heavy metals contamination and human health risk in *Clarias gariepinus* collected from Jabi Lake, Abuja, Nigeria. This work however, agreed with Rafat *et al*. (2021) who reported higher EDI for heavy metal (Fe) in children (0.577mg/kg/day) than adults (0.131mg/kg/day) in their work on levels and health risk assessment of heavy metals in dried fish consumed in Bangladesh. It equally agreed with that of Akoto *et al.* (2014) who observed high values for Pb above the permissible limit in their work on concentrations and health risk assessments of heavy metals in fish from the Fosu Lagoon. It equally agreed with the work of Ullah *et al*. (2017) who reported that Pb contributed mostly to the estimated daily intake of heavy metals consumed in their work on dietary intake of heavy metals from 8 highly consumed species of cultured fish and possible human health risk implication in Bangladesh.

Target Hazard Quotient for Heavy Metals Consumption in Fish from beaches' water in Adults and Children during the wet and dry season

The result of the Target Hazard Quotient (in adults and children) for all the fish species sampled at the six coastal beaches during the wet and dry season showed that all the values for the heavy metals assessed were less than 1(<1), indicating no apparent health risk from these heavy metals over a life time of exposure. The result of the present study agreed with that of Salam *et al*. (2019) who reported THQ values in all the sampled fish species to be <1 in their work on contamination profile of heavy metals in marine fish and shellfish. It equally agreed with Zhao *et al*. (2012) who recorded THQ <1 in their work on role of living environments in the accumulation characteristics of heavy metals n fishes and crabs in the Yangtze River Estuary, China. The present study is also in tandem with Matouke and Abdullahi (2020) who reported THQ <1 for adult and children respectively in their work on assessment of heavy metals contamination and human health risk in *Clarias gariepinus* collected from Jabi Lake, Abuja, Nigeria.

Health Risk Index for Heavy Metals Consumption in Fish from beaches' water in adults and children during the wet and dry season.

The result of the Health Risk Indexes (in adults and children) for all the fish species sampled at the six coastal beaches showed that the health risk indexes for adults during the wet and dry season were all <1, indicating no apparent health risk from these heavy metals over a life time of exposure. In children, during the wet season, all the heavy metals showed health risk indexes <1 except Cr at Tourist beach. During the dry season, Cr

showed a health risk index >1 in all the sampled beaches except Agenobode beach. As and Hg equally showed health risk indexes >1 except at Agenobode beach. The health risk index (HRI) showed that consumption of the fish species (except Cr in Children during the wet season at Tourist beach, Cr, As and Hg in children during the dry season in all the beaches except Agenobode beach) does not pose any risk to adults and children. Akoto *et al*. (2014) reported that all the HRI values were < 1 in their work on concentrations and health risk assessments of heavy metals in fish from the Fosu Lagoon. María *et al*. (2022) and Maigari *et al*. (2016) reported a hazard index less than (<1) 1 in their works.

Hazard Index for Heavy Metals Consumption in Fish from beaches' water in Adult and children during the wet and dry season.

The hazard indexes for heavy metals from fish in all the sampled beaches consumed by adults during the wet season ranged from 0.399mg/kg-0.643mg/kg and 0.588mg/kg-0.947mg/kg during the dry season. The hazard indexes in children during the wet season ranged from 0.2578mg/kg-0.3748mg/kg and 0.3429mg/kg-0.5524mg/kg during the dry season. All the beaches recorded hazard indexes less than the threshold value of 1, showing that the non-carcinogenic adverse effect is negligible. The present work is at variance with Jian-Long *et al.* (2021) who reported HI values >1 in their work on levels of health risk assessment of heavy metals in marine fish to the population in Zhejiang China. Rafat *et al*. (2021) reported HI values <1 in adult and HI values >1 in children in their work on levels and health risk assessment of heavy metals in dried fish consumed in Bangladesh.

Carcinogenic Risk for Heavy Metals Consumption in Fish from beaches' water in Adults and Children during the wet and dry season.

This study found that all the fish species sampled at Tourist beach except Sardine Fish (*Sardinella maderensis*) in adults and Tilapia (*Oreochromis niloticus*) in children poses carcinogenic risk from Pb consumption for both season. All the fish species sampled at Okpoama beach poses carcinogenic risk from Pb, Cr, Cd and As consumption for both seasons in adult and children. All the fish species sampled at Ibeno beach (except Cat Fish (*Chrysichthys nigrodigitatus*) in adults) poses carcinogenic risk from Pb, Cr, Cd and As consumption for both seasons in adults and children. All the fish species sampled at Asaba beach poses carcinogenic risk from Pb, Cr and As consumption for both seasons (except Cd in all the fish species sampled). All the fish species sampled at Marina's beach and Agenobode beach poses carcinogenic risk from Pb, Cr, Cd and As consumption for both seasons (except Pb in all the fish species sampled during the wet season). For both adults and children, the obtained results showed all estimated values for Cr, Cd, As and Pb for all fish species to be above the safe limiting range. This indicates that excessive consumption over a long time period might cause carcinogenic effect as the CR values were higher than the acceptable guideline value of (tolerable limit lies between 10^{-6} and 10^{-4} or between E−6 and E−4). The probability of contracting cancer is present for continuous consumption for 70 years. The present study is in line with Kawser Ahmed *et al*. (2016) who recorded similar result in their work on Human health risks from heavy metals in fish of Buriganga River, Bangladesh. Kawser Ahmed *et al*. (2015) recorded similar result in their work on human health risk assessment of heavy metals in tropical fish and shellfish collected from the river Buriganga, Bangladesh. The present study is at variance with the work of Nazma *et al.* (2024) who reported CR for As, Cd, Pb and Ni for the studied fish species to be below 10^{-4}.

CONCLUSION

The EDI results of the heavy metals in fish (adults and children) revealed that all the fish species sampled across the six beaches showed EDI that is less than the recommended dietary allowance in adults for both season while EDI result for children showed some fish species have an EDI higher than the recommended dietary allowance.

The result of the Target Hazard Quotient (in adults and children) for all the fish species sampled at the six coastal beaches during the wet and dry season showed that all the values for the heavy metals assessed were less than 1(<1), indicating no apparent health risk from these heavy metals over a life time of exposure. The result of the Health Risk Indexes (in adults and children) for all the fish species sampled at the six coastal

beaches showed that the health risk indexes for adults during the wet and dry season were all <1, indicating no apparent health risk from these heavy metals over a life time of exposure. In children, during the wet and dry season, some of the heavy metals showed health risk indexes >1. All the beaches recorded hazard indexes less than the threshold value of 1, showing that the non-carcinogenic adverse effect is negligible. The carcinogenic risk for both adults and children, showed all estimated values for Cr, Cd, As and Pb for some of the fish species to be above the safe limiting range. This indicates that excessive consumption over a long time period might cause carcinogenic effect as the CR values were higher than the acceptable guideline value.

RECOMMENDATIONS

- The different anthropogenic activities at Ibeno beach, Asaba beach, Marina's beach as well as Agenobode beach should trigger environmental management and regulatory actions to be taken towards combating the impacts resulting from heavy metals in the sampled locations. The present study showed that the indigenous people and tourists who patronize barbecue fish sellers at the beaches may be at risk of lead and chromium toxicity due to bioaccumulation from different fish species sold at the beaches.
- To reduce exposure to heavy metals and the risk of toxicity in the study locations, sand dredging, boat transportation, lumbering of wood, indiscriminate dumping of wastes into the water and other anthropogenic activities should be regulated and violators made to pay commensurate penalty.
- Again, based on the wide range of adverse health effect that heavy metals can trigger in humans, the whole coastal beaches used for recreation in the Niger-Delta as well as the fish species consumed there in should be constantly monitored for heavy metals and other pollutants
- I equally recommend that the industries operating within these areas should be placed under routine and impromptu checks to make sure that their waste water is well treated before discharging into the waterways.

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