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Concentration of Heavy Metals and Health Risk Assessment of Consumption of Fish (*Sarotherodon melanotheron*) from an Estuarine Creek in the Niger Delta, Nigeria

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Abstract: *Health risk assessment with respect to heavy metals concentration and consumption of fish (Sarotherodon melanotheron) obtained from Azuabie creek was carried out. Five fish samples composited were obtained from fishermen on a monthly basis from January - December 2015. Heavy metals (Cr, Ni, Cu, Pb, Ag and Cd) analysis was done using Atomic Absorption Spectrophotometery while health risk to consumers was evaluated using Estimated Daily Intake, Target Harzard Quotient, Hazard Index and Target Cancer Risk. Metal concentration in fish tissue were Cu > Pb> Cr > Ni > Ag > Cd with the following mean values 5.59 ± 1.06 mgkg^{-1}, 5.12 ± 1.23 mgkg^{-1}, 2.69 ± 1.44 mgkg^{-1}, 1.94 ± 0.34 mgkg^{-1}, 1.02 ± 0.34 mgkg^{-1} and 0.38 ± 0.08 mgkg^{-1} respectively. Ni, Pb and Cd had mean values above recommended FAO/WHO limits. EDI values (mgkg^{-1} bw/day) were Cu 0.93 x10^{-3}, Pb 0.85 x 10^{-3}, Cr 0.45 x 10^{-3}, Ni 0.32 x 10^{-3}, Ag 0.17 x 10^{-3} and Cd 0.063 x 10^{-3}. THQ values were as follows: Cr 0.29, Pb 0.24, Cd 0.06, Cu 0.023 and Ni 0.016 while the HI for all metals had a value of 0.64 and the TR for Ni had a value of 2.63 x 10^{-3}mgkg^{-1} bw-day^{-1}.The study concluded that fish muscle obtained from the study area showed bio-accumulation of metals over time but health risk assessment indices indicated minimal to moderate risk levels suggesting insignificant health risk. This could douse public health concerns in terms of human exposure via consumption of fish but regular monitoring is advised to detect changes in metal concentration.*

Keyword: *Azuabie creek, Fish, Heavy metals, Health Risk, Niger Delta*

I. Introduction

Increase in population has induced urbanization and industrialization with corresponding discharge of wastes such as heavy metals into the environment. Heavy metals occur naturally in aquatic ecosystem, but deposits of anthropogenic origin increase their levels and create environmental problems in coastal zones and rivers [1]. Such metals have been described as non-biodegradable and persistent in the environment and known to cause deleterious effects on animal and human health [2, 3, 4]. Heavy metal pollution is one of the challenges of coastal water pollution as a result of human activities such as oil exploration and exploitation, construction and fabrication of marine boats, disposal of industrial and domestic wastes and sailing [5]. It has also been reported that heavy metals are significant environmental pollutants and their toxicity is a problem of increasing significance for ecological, evolutionary, nutritional and environmental reasons [6, 7]. Fishes are sensitive indicators of heavy metals pollution [8]. Fish from natural aquatic environment are consumed everyday for nutritional requirements and this could expose such consumers of fish from presumed polluted areas to health risks. [9] and [10] had stated that dietary intake of toxic elements is the main route of exposure for most people. Excess amounts of these metals entering into the aquatic ecosystem may pollute the environment and also affect the food chain and ultimately pose serious human health risks to those who depend directly or indirectly on the water body for the supply of fish and water [11]. [12] also found that fish raised in contaminated waters take up heavy metals in large quantities enough to cause potential health risks to the consumers. [13] then stated that analysis of fish muscle helps to determine the direct transfer of heavy metals and other contaminants to humans via fish consumption. Data on health risk assessment with regards to heavy metal level and consumption of *Sarotherodon melanotheron* obtained in the study area was scarce. This study therefore, aimed to examine the concentrations of some heavy metals (Cr, Ni, Cu, Pb, Ag and Cd) and health risks exposure to consumers of *Sarotherodon melanotheron* obtained from a presumed polluted creek (Azuabie) in the upper Bonny estuary of the Niger Delta, Nigeria.

II. Materials And Methods

All fish samples were collected from the Azuabie creek in the Niger Delta, Nigeria (Fig. 1). The method of collection was by cast net via fishermen on the creek. Five samples of fish (*Sarotherodon melanotheron*) were collected and made composite samples every month for twelve months (January - December 2015). The composited samples were dried and digested using HCl/HNO_3 following the method of the American Society for Testing and Materials [14](ASTM, 1986). The heavy metals concentration was assessed using an Atomic Absorption Spectrophotometer (GB Avanta PM AAS, S/N A6600). The concentrations were blank-corrected and expressed as $mgkg^{-1}$ dry weight of sample.

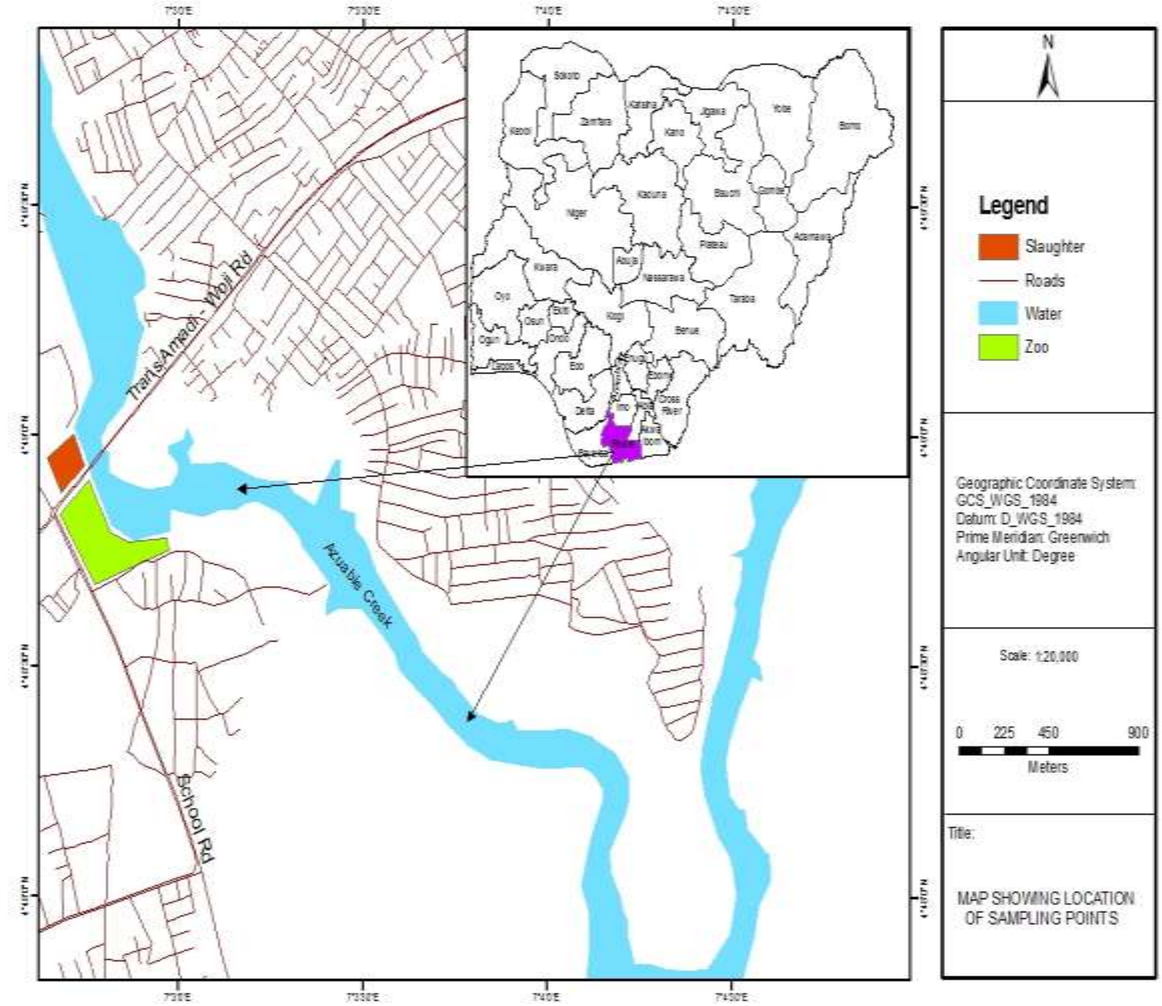


Fig. 1: Location of Study site.

***Estimated daily intake (EDI)*:** Studies have shown that ingestion of contaminated food is exposure pathway of heavy metals to human [12, 15]. Estimated daily intake (EDI) of heavy metals examined in this study determined using the equation:

$$\textbf{EDI} = \frac{E_F \ x \ E_D \ x \ F_{IR} \ x \ C_F \ x \ C_M}{W_{AB} \ x \ T_A} \ x \ 10^{-3}$$

E_F = Exposure frequency, 365 days/year
E_D = Exposure duration, equivalent to verge life time (65 years)
F_{IR} = Fresh food ingestion rate (g/person/day) which was considered to be 48/g/person/day [16]
C_F = Conversion factor = 0.208
C_M = Heavy metal concentration in food stuffs ($mgkg^{-1}$ dry-weight)
W_{AB} = Average body weight (bw) was taken as 60 kg)
T_A = (E_F x E_D) Is the average exposure of time for non-carcinogens as used by previous studies [17]. The public health risk was evaluated using the EDI [18] to determine the Target Hazard Quotient (THQ).

Target hazard quotient (THQ) is given by: **THQ =** $\frac{EDI}{RFDO}$

Where EDI = Estimated daily intake

RFDO = the reference oral dose of individual metal ($mgkg^{-1}$ day^{-1}).
Reference oral doses (RfD) used for Cr, Cu, Ni, Pb, and Cd are 1.5x 10^{-3}, 4.0 x 10^{-2}, 2.0 x 10-^{2}, 3.5 x 10^{-3}, 1.4 x 10^{-1} and 1.0 x 10^{-3} $mgkg^{-1}$ day^{-1} respectively [19].
Hazardous index (HI): Estimation of the risk of more than one heavy metal to human health, the hazard index (HI) was developed [20] which is the sum of the hazard quotients for all metals and calculated by the equation [21].

$$HI = \sum HQ = HQ_{cr} + HQ_{Cu} + HQ_{Ni} + HQ_{pb} + HQ_{cd}$$

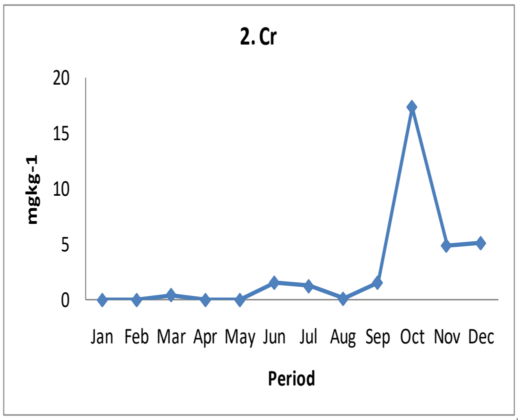
Target Cancer Risk **(TR):** The Target cancer risk (TR) was evaluated based on USEPA (2011) using the formula

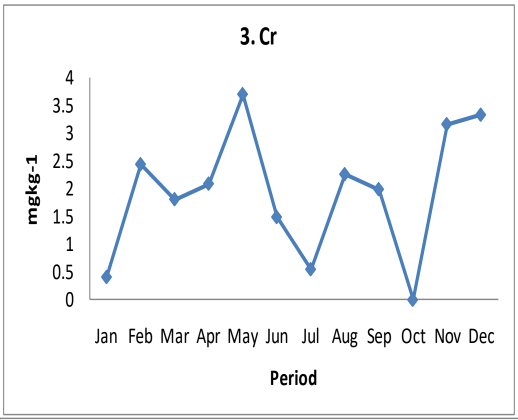
$$TR = \frac{Mc \times IR \times 10^{-3} \times CPSo \times EF \times ED}{BW \times ATc}$$

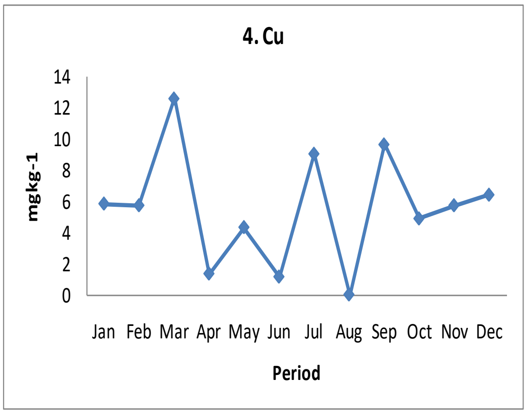
where MC = metal concentration, IR = ingestion rate, EF = exposure frequency, ED = Exposure duration, BW = Body weight, CPSo = carcinogenic potency slope, oral ($mgkg^{-1}$ bw-day^{-1} which is 1.7 for Ni - [22, 23]. ATc is the averaging time for carcinogens (365 days/year × 67 years)

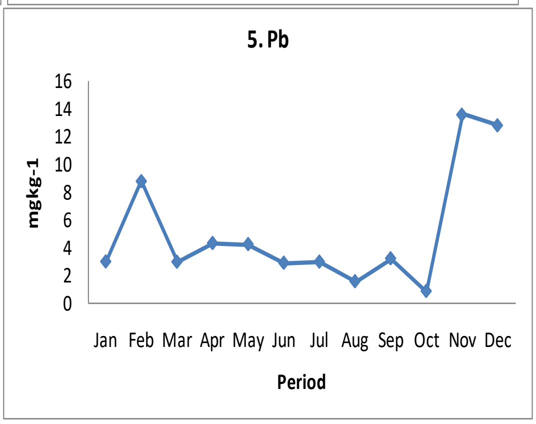
III. Results

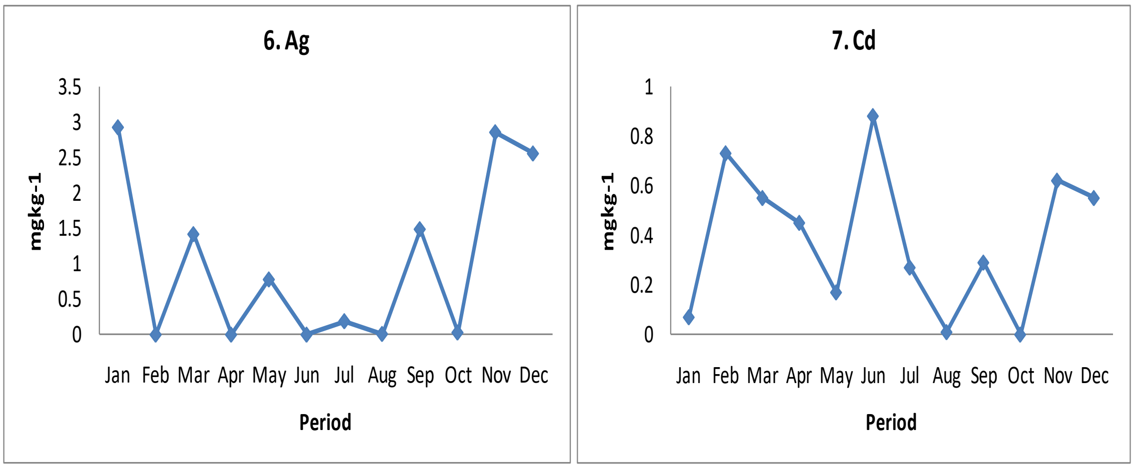
Temporal variation in the distribution of heavy metals in fish tissue (muscle) was obvious but of no particular trend (Figs. 2 - 7) even though, values seemed to be higher during the dry season months of November and December. In order of increasing metal concentrations, Cu > Pb > Cr > Ni > Ag > Cd with the following mean values 5.59 ± 1.06 $mgkg^{-1}$, 5.12 ± 1.23 $mgkg^{-1}$, 2.69 ± 1.44 $mgkg^{-1}$, 1.94 ± 0.34 $mgkg^{-1}$, 1.02 ± 0.34 $mgkg^{-1}$ and 0.38 ± 0.08 $mgkg^{-1}$ respectively (Table 1). The concentrations of Ni, Pb and Cd were above their respective FAO/WHO recommended limits while Cu and Cr had values below. The values of the estimated daily intake ($mgkg^{-1}$ body weight day^{-1}) for the metals were Cu 0.93 x10^{-3}, Pb 0.85 x 10^{-3}, Cr 0.45 x 10^{-3}, Ni 0.32 x 10^{-3}, Ag 0.17 x 10^{-3} and Cd 0.063 x 10^{-3}. Target hazard quotient was evaluated to determine potential health risk to consumers of fish and the values were as follows: Cr 0.29, Pb 0.24, Cd 0.06, Cu 0.023 and Ni 0.016 while the Hazard index (HI) was done in view of the interactive and synergistic effect of more than one heavy metal in tissues. The HI value for all metals in this study had a value of 0.64 while the Target cancer risk (TR) was determined for Ni only and had a value of 2.63 x 10^{-3}. Only the CPSo of Ni was available.











Figs. 2 -7: Temporal fluctuation of heavy metal concentration fish tissue (Muscles)

Table 1: Mean Concentration of Heavy Metals in Fish tissue (Muscle) and Recommended Limits

Heavy Metals	Concentration in fish Muscle	Recommended limits (ppm)
Cr ($mgkg^{-1}$)	2.69 ± 1.44	12 - 13 [24, 25]
Ni ($mgkg^{-1}$)	1.94 ± 0.34	0.2 [26]
Cu ($mgkg^{-1}$)	5.59 ± 1.06	30 [27]
Pb ($mgkg^{-1}$)	5.12 ± 1.23	0.5 [28]
Ag ($mgkg^{-1}$)	1.02 ± 0.34	No guideline
Cd ($mgkg^{-1}$)	0.38 ± 0.08	0.1 [29]

Table 2: Values of EDI, THQ, HI and TR of the Heavy Metals Examined

Heavy Metals	EDI	THQ	HI	TR
Cr	0.45×10^{-3}	0.298		
Ni	0.32×10^{-3}	0.016		2.63×10^{-3}
Cu	0.93×10^{-3}	0.023		
Pb	0.85×10^{-3}	0.024		
Ag	0.17×10^{-3}			
Cd	0.063×10^{-3}	0.063	0.64	

IV. Discussion

Fish muscle tissue was examined in this study because it is the most consumed part of the fish but it has been reported to be inactive in accumulating heavy metals [30]. The concentration of heavy metals observed in this study is comparable to the range reported in fish (mudskipper) muscle tissues [5] but generally higher compared to values recorded in different fish species from the study area [31]. The implication of this is gradual accumulation of heavy metal in biota of the Azuabie creek which is attributable to anthropogenic activities in the study area including the discharge of domestic, industrial and municipal wastes into the creek [32, 33, 34, 35, 5]. The levels of Pb, Cd and Ni observed in this study also exceeded the recommended maximum permissible limits [28] and [36]. These concentrations may pose contamination concern for consumers of such fish from the Azuabie area. The level of Pb observed in this study is however, within the range recorded elsewhere [37, 12] but generally higher than values obtained by [38] while those of Cu found in the current study compared well with the range (3.01 - 17.47 $mgkg^{-1}$) observed in fish tissue in Gaza stripe [38] and could be considered as concentrations found in uncontaminated fish During feeding fish ingest contaminants indiscriminately including heavy metals which build up gradually along the food chain with subsequent exposure of humans who consume such fish. Since intake of fish is a possible source of accumulation of metals [38] stated that there is an important need in calculating the daily and weekly consumptions of heavy metals through fish eating. Health risk assessment in view of human exposure to heavy metals via consumption of fish from Azuabie creek was done for this study with the EDI values of the metals generally less than their respective oral reference doses (RFD) suggesting minimal risk of human exposure. The EDI values obtained in this study were generally less compared to the findings of [39] who worked on *Scomber scombrus* in Zaria Nigeria. They reported daily intake of metal (DIM) for three categories of individuals as Cd 1.162×10^{-3}, 1.482×10^{-3}, and 2.633×10^{-3} $mg{\cdot}kg^{-1}$, Pb 5.833×10^{-3}, 7.559×10^{-3}, and 1.289×10^{-2} $mg{\cdot}kg^{-1}$ and Ni 3.906×10^{-3}, 4.861×10^{-3}, and 8.636×10^{-3}. EDI values obtained in this study however, compared favourably with values reported by [13] within the West African region and those found by [40] around the Persian Gulf. [13] Stated that RfD represents an estimation of the daily exposure of a contaminant to which the human population may be continually exposed over a lifetime without an appreciable risk of harmful effects. Values of Pb, Cd and Ni in this study were above recommended limits of the FAO/WHO but may not pose human health risk in view of the fact that their EDI values were less than their respective RFD values but regular monitoring is necessary to detect increases in metal accumulation. [41] found that values of estimated daily intakes (EDI) of Zn, Cd, Pb and Ni in muscles of fish in their study were well below their corresponding permissible tolerable daily intake and concluded that fish were safe for human consumption. The Target hazard quotient (THQ) for the metals in the current study showed that Cr > Pb > Cd > Cu > Ni with all the values < 1 suggesting minimal risk of non carcinogenic consequence but Cr showed higher potential health risk than other metals. THQ > 1 has been said to indicate potentials of non carcinogenic risk to human exposures [42, 43, 44] particularly with increase in metal exposure. The THQ of metals in this study (<1) agrees with the findings of [45] and [46] but disagreed with the findings of [47] who reported >1 THQ for Pb, Cr, and Hg in fish from the coast of India. The Hazard index (HI) of all the metals was also calculated in view of the fact that more than one metal can often be bio-accumulated in fish tissue as observed in this study. Such metals could have interactive or synergistic effects. The HI value (0.64) observed in this study was also < 1suggesting minimal risk exposure of no significant health risk to consumers of *Sarotherodon melanotheron* obtained from the study area. Studies have reported that HI should not be > 1 in order to ease public health concern [48, 49]. The HI of this study agrees with the findings of [40] who also reported values of <1. The percentage contribution of each heavy metal in the hazard index as thus: Cr (46.4%), Pb (37.8%), Cd (9.8%), Cu (3.6%) and Ni (2.5%). The target carcinogenic risk (TR) was calculated for only Ni whose CPSo (carcinogenic potency slope, oral (mg/kg bw-day^{-1}) was available and the value obtained was 2.63 x 10^{-3}. This value indicates a moderate condition compared to the range issued by [50]. This value is not absolute but gives an upper limit likelihood that an exposed person may have cancer once in life [50].

V. Conclusion

The study therefore concluded that heavy metal bioaccumulation over time is imminent in biota particularly fish obtained from Azuabie creek looking at studies carried out in the area. The health risk assessment indices (EDI, THQ, HI and TR) evaluated for this study showed minimal to moderate risk levels with respect to human exposure vis-à-vis consumption of *Sarotherodon* melanotheron from the study area. This may minimize public health concerns but regular monitoring is strongly recommended.

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