

## Assessing Carcinogenic and other Health Risks Associated with Consuming a Food Fish, *Labeo pseudocoubie*, from the Niger-Benue/Imo River Systems, Nigeria

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### Abstract

Carcinogenic and other health risks associated with consuming a food fish, *Labeo pseudocoubie* from the Niger-Benue/Imo River systems was assessed using bioaccumulation of poisonous metals and health indices. Three hundred fish samples of *Labeo pseudocoubie* were collected from five stations along the Niger-Benue/Imo River Systems of Nigeria to investigate the bioaccumulation of metal, non-carcinogenic and carcinogenic human health risks. The metal concentrations (As, Pb, Cd, Ni, Zn, Hg, Ba, Fe, V, Cu and Cr) were analyzed using the X-ray Fluorescence (XRF) Spectrometer. The non-carcinogenic (estimated daily intake, chronic daily intake and target hazard quotient) and carcinogenic human health risks were calculated for metal concentrations in the fish. The data revealed that the mean bioaccumulation for five (5) metals in *L. pseudocoubie* from most stations were higher than the permissible limits. The non-carcinogenic human health risk revealed that majority of the metals had values above the daily reference dose for both males and females; while the target hazard quotient revealed that very few metals (3) had concentrations above the level at which obvious health impact may be observed. Furthermore, the carcinogenic human health assessment revealed that nickel and arsenic in all stations, except for arsenic in Station 3, were above the range for relatively negligible cancer risk for both males and females. It is therefore recommended that fish consumers along the Niger-Benue/Imo River Systems should exercise serious caution when consuming fish in these areas due to the possible adverse effects that could ensue.

**Keywords:** Target cancer risk; Target hazard quotient; Cyprinids

### Introduction

The greatest challenge of the modern society is to find ways to sustain activities that ensure economic development at levels that promote human health and environmental protection. These economic development activities introduce pollutants from industrial, agricultural and domestic wastes which eventually find their way into the aquatic ecosystem directly or indirectly [1,2].

Heavy metals are non-biodegradable, persistent and are known components of wastes from various anthropogenic activities [2]. The aquatic ecosystem is very vulnerable to heavy metal contamination which may accumulate in the food chain and cause ecological damage, sometimes disrupting sustainable food supply and causing serious health threats to humans due to biomagnifications over time [3]. Acute and chronic effects on human and non-human components of the environment include: skin cancer, ulcerations, stunted growth, heart and liver damage, paralysis, anaemia, brain damage, cancer, and sometimes death [4].

Fishes are consumed worldwide as they serve as a source of healthy protein with increased health benefits. In Nigeria, fish consumption makes up 55% of the protein intake of its populace [1,5,6]. However, these fishes have been shown to accumulate significant amounts of various pollutants in fatty tissues or selectively bound to muscle tissue. This bioaccumulation (up to 1 million times) may occur even when extremely low concentrations of these pollutants are available in the water and sediment, giving rise to concentrations high enough to pose health risks to fish consumers [3,7,8].

Assessment of human health risks associated with food (fish) consumption is now of great benefit to prevent adversity due to toxicants

especially heavy metal bioaccumulation such as the Minamata disease of Japan which resulted in several deaths due to inorganic mercury in fish [9,10].

This study therefore aims to investigate the metal accumulation in fish, and non-carcinogenic and carcinogenic human health risks using the fish *Labeo pseudocoubie* from the Niger-Benue/Imo River Systems of Nigeria.

### Material and Methods

#### Study area

The Niger-Benue/Imo River Systems (Figure 1) have great economic importance to dweller along its course and the country as a whole. It serves as a source for drinking, bathing, washing, fishing, navigation, irrigation, construction raw materials, hydropower generation and many other uses. Over 260 species of fish have been recorded in these systems where *Labeo sps* are part of the top ten catches [1,11].

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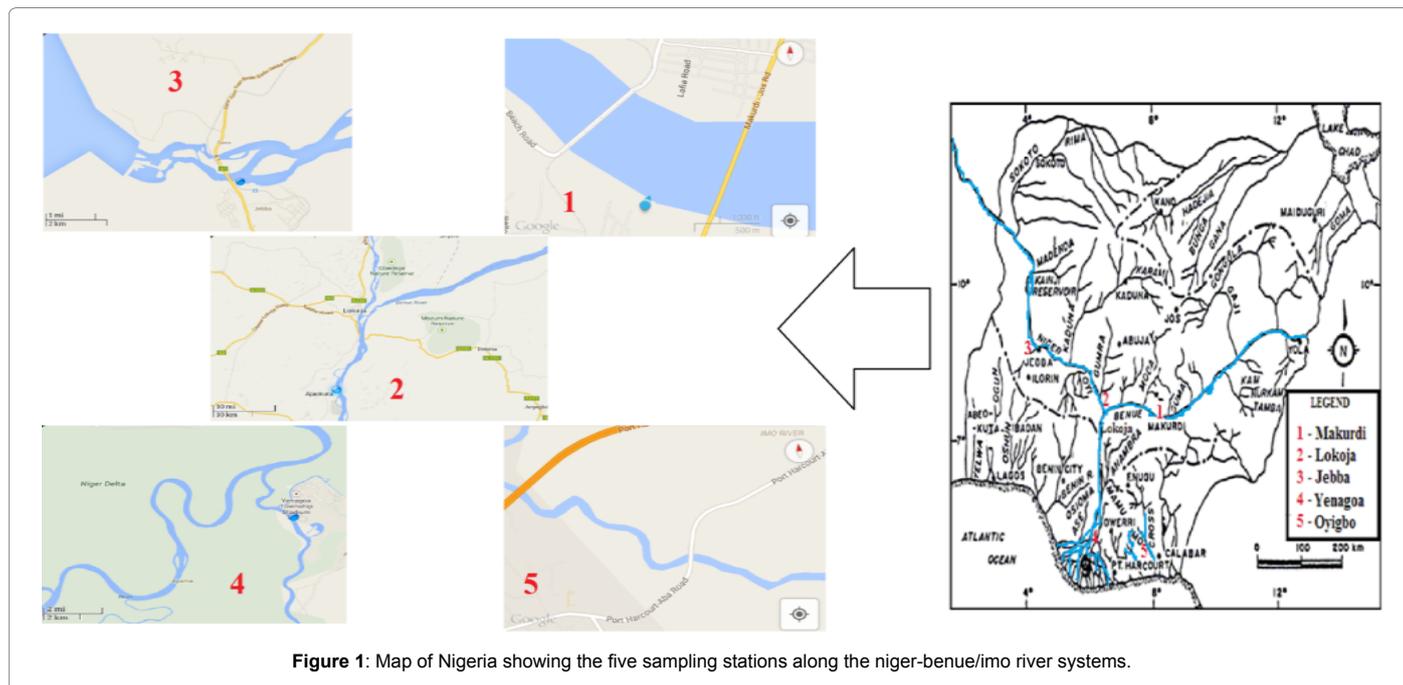


Figure 1: Map of Nigeria showing the five sampling stations along the niger-benue/imo river systems.

Major activities along the river systems (plate 1a and b) include hydropower generation, iron and steel mining, paper mill, agricultural activities, dredging, fishing, oil mining, municipal and industrial effluent discharges, open defaecation, engine boat and ship transportation, sale of petroleum products, oil spills, flooding, etc.

**Sampling locations:** Five sampling stations were selected along the river systems as representatives of the entire water bodies

- Station 1: Makurdi – River Benue (7°45'22.38" N/8°32'19.78" E)
- Station 2: Lokoja – Confluence Point (7°34'06.25" N/6°41'38.32" E)
- Station 3: Jebba – River Niger (9°7'43.03" N/4°49'9.87" E)
- Station 4: Yenagoa – River Nun (4°54'48.20" N/6°16'0.22" E)
- Station 5: Oyiibo – Imo River (4°53'11.65" N/7°7'32.23" E)

**Fish sample collection:** Ten fish samples of *Labeo pseudocoubie* were collected bimonthly from each of the five sampling locations from May 2015 to March 2016. The fish samples were placed in an ice chest and transported to the laboratory where they were immediately processed for analysis.

**Fish processing and analysis (ISO 18227):** The whole fish samples were placed in foil plates and covered before being heating it in an oven at 100°C until dryness was achieved. This was done to replicate the various forms of heating implemented by indigenes most of the time before consumption. The dried fish samples were milled using a mixer (Mixer Mill MM 400) and 4.5 g of the samples were weighed. An additional 0.45 g of a binder mix (Hochstwx HWC) was added to each of the pre-weighed fish samples and compressed into pellets using a compressing apparatus (Spectro Hydraulic Press 360) before placing them in the X-ray Fluorescence (XRF) sample compartment for analysis of the eleven (11) metals of interest. The energy dispersive XRF spectrophotometry (SPECTRO XEPOS) was used to run elemental analysis by turning on the X-LabPro version 5.1 Software. A primary fine focus beam provided by the X-ray tube with a molybdenum anode was automatically mono-chromatised and directed to the sample at a glancing angle less than the critical angle. The tube was operated at 50

kV and 30 mA and the fluorescent X-rays derived from the sample were detected with a solid state lithium-drifted silicon detector of 20 mm<sup>2</sup> front area, cooled with helium gas [12]. After 21 min the elemental analysis result was obtained and the value for the metals of interest recorded in mg/kg. The metals of interest are: Arsenic (As), Lead (Pb), Nickel (Ni), Zinc (Zn), Cadmium (Cd), Chromium (Cr), Barium (Ba), Mercury (Hg), Iron (Fe), Vanadium (V), and Copper (Cu).

This method of analysis was used due to its high compatibility level with green chemistry which aims to reduce the use of chemicals and possible pollution of the environment accruing from analytical purposes.

**Human health risk assessment:** The values of fish metal bioaccumulation and constants were used to calculate the estimated daily intake of metals (EDI), chronic daily intake for the metals (CDI), target hazard quotients (THQ), and target cancer risk (TCR) separately for adult male and female individuals using constants in Tables 1 and 2.

**Estimated daily intake:** The estimated daily intake (EDI) was determined using the following equation

$$EDI \text{ (kg / day)} = \frac{C_{\text{metal}} \times IFR}{BW \times 0.01}$$

Where:

- $C_{\text{metal}}$  = metal concentration in fish (mg/kg);
- IFR = Ingestion rate for fish (kg/day); and
- BW = Body weight (kg).

**Non-carcinogenic health effects:** Non-Carcinogenic Fish Ingestion Equation

$$CDI = \frac{C \times IRF \times 0.01 \times EF \times ED}{RfD \times ATn \times BW}$$

Where:

- CDI = Chronic daily intake for the toxicant (mg/kg-day);
- C = Concentration of heavy metal in fish (mg/kg);

BW=Body Weight (kg);

ED=Exposure Duration (average life expectancy);

EF=Exposure frequency (365 days/year);

IR =Ingestion Rate Fish (kg/day);

ATn=Averaging Time for non-carcinogens (ED × EF); and

RfD=Reference Dose of individual metal (mg/kg/day).

The equation for calculating the Target Hazard Quotient (non-carcinogenic hazard) is:

$$THQ = \frac{CDI}{RfD}$$

Where:

CDI=chronic daily intake for the toxicant (mg/kg-day); and

RfD=chronic reference dose for the toxicant (mg/kg-day).

**Carcinogenic health effects:** Among the eleven metals analysed, only Arsenic and Nickel are confirmed “Class A” human carcinogen through the oral route of exposure. The basic equation for calculating Target Cancer Risk (lifetime cancer risk) is:

$$TCR=CDI \times SF$$

Where:

TCR=a unit less probability of an individual developing cancer over a lifetime;

CDI=chronic daily intake or dose (mg/kg-day); and

SF=slope factor (mg/kg-day).

### Quality control

The equipment was previously calibrated and calibration verification was run on the equipment to ensure optimal performance and recovery before sample analysis commenced. Blank sample of the binder mix was also analyzed alongside samples and used to correct for any form of contamination. A quality control (Certified Reference Material by IAEA) sample was also analyzed just after the blank analysis and at the end of the analysis with elemental recovery between 90-110%. Duplicate analysis was also carried out for every 10 samples

Metals	Reference dose (mg/kg/day)	Cancer slope factor (mg/kg/day)
As	0.003	1.5
Pb	0.001	-
Cd	0.001	-
Ni	0.02	1.7
Zn	0.3	-
Hg	0.001	-
Ba	0.2	-
Fe	0.7	-
V	0.001	-
Cu	0.04	-
Cr	0.003	-

Table 1: Metal reference dose and cancer slope factor.

Sex	Body weight (kg)	Fish ingestion rate (kg)	Life expectancy (years)	Average life expectancy (years)
Male	70	0.10	53	54.5
Female	65	0.10	56	54.5

Table 2: Constants for calculation of health hazard risk for Nigeria.

or a batch of sample and relative percentage difference (RPD) for each duplicate sample was less than ± 10%.

### Statistical analysis

The data were subjected to analysis of variance (ANOVA) which was followed by the Honestly Significant Difference (Tukey-HSD) post hoc test (defined at p<0.05).

## Results and Discussion

### Bioaccumulation of metals in the fish

The data for metal bioaccumulation in fish with FAO limit is presented in Table 3. The combined data across each sampling station revealed that Station 4 had higher total metal load in fish while Station 3 had the least, followed by Stations 5, 1 and 2. However, the difference was not statistically significant (P=0.82).

**Station 1:** Fish metal concentration for Pb, Cd, Fe, and Cr were above the FAO limits. The high levels of: iron may be linked to the naturally high deposits of iron in the sediment and soil, and the dredging activities, lead can be associated with the Lead-Zinc deposits occurring abundantly together with Barite in the Benue trough sediment and its mining for use in the oil industry is very common [13]; cadmium can be traced to its association with weathering of rocks, cement factories, pesticides and fertilizers, iron, and zinc extraction [14]; chromium can be linked to cement factories, asbestos roofs and weathering of rocks [15,16]. The aforementioned natural occurrences and anthropogenic activities are common in Station 1 (Makurdi) and are linked to the sediment which the study fish feeds on occasionally.

**Station 2:** The bioaccumulation of metals revealed that As, Pb, Cd, Fe, and Cr was above the FAO limit. These high levels of: arsenic can be linked to smelting by-products from steel and iron industries [17] lead may be due to paint from old structures from the Colonial days with Station 2 (Lokoja) serving as headquarters; cadmium can be traced to its association with weathering of rocks, cement factories, and iron extraction [14]; iron may be linked to the natural deposits and mining of iron ore in the sediment and soil, chromium may be linked to cement factories, asbestos roofs and weathering of rocks [15,16]. These are common occurrences in the area and the area is also the confluence point for the Niger and Benue Rivers. This means that contaminants may be easily transported from both rivers and deposited in this area due to the high flow rate and turbulence which allows for easy settling out of particulate matter (Figure 2).

**Station 3:** The bioaccumulation of metals revealed that Pb, Cd, Fe and Cr were above the FAO limit. These high levels of: lead may be due to paint from old structures from the Colonial days when the area was the hub of industrial activities (as train coaches and rails can be seen abandoned and rotting away) and the natural lead and feldspar deposits; cadmium can be traced to its association with weathering of rocks, and iron and limestone deposits [14]; iron may be linked to the natural deposits of iron, lead and copper ores in the region [18,19]; chromium may also be linked to asbestos roofs and weathering of rocks [15,16,18]. These are common occurrences in the area which is known to have loose easily erodible soil type (commonly called Ku soil by locals). This means that pollutants may be easily eroded and washed into the river along with municipal runoffs [18].

**Station 4:** Arsenic, Pb, Cd, Zn, Hg, Fe and Cr in fish were above the FAO limit. Crude oil activities in the area may be linked to the excessive bioaccumulation levels of As, Pb, Cd, Hg, and Cr which are known pollutants of the industry [1,20]. However, Zn and Fe can be traced to

activities in the area (Niger Delta) such as use of fertilizers, preservatives for wood, sewage, municipal runoffs, erosion of roofing sheets due to acid rain and other metallurgical activities. Furthermore, this station has a direct link to the Niger-Benue River Systems, increasing the possibility of most of the pollutants being transported directly from those rivers down to the Niger Delta (station 4).

**Station 5:** Arsenic, Pb, Cd, Zn, Fe and Cr in fish were above the FAO limit. Crude oil activities in the area may be linked to the excessive bioaccumulation levels of As, Pb, Cd, and Cr which are known pollutants of the industry (1,19). Zn and Fe can be also be linked to activities in the area (Niger Delta) such as use of fertilizers, preservatives for wood, sewage, municipal runoffs, erosion of roofing sheets due to acid rain and other metallurgical activities [3].

### Human health risk

**Non-carcinogenic health risk:** The data for non-carcinogenic health risk (Estimated Daily Intake, Chronic Daily Intake and Target Hazard Quotient) for all stations are presented in Table 4.

**a) Station 1:** The Estimated Daily Intake (EDI) for both males and females, revealed that out of all the metals analyzed, only Hg and Ba had values below the RfD provided by USEPA. This indicates that all the other metals had concentrations above the stipulated amount for oral daily intake for each of the metals.

Chronic Daily Intake (CDI) for both sexes revealed that only Ni, Zn, Hg, Ba, Fe and Cu had values below the RfD, meaning that

Stations	Metals in fish (mg/kg)										
	As	Pb	Cd	Ni	Zn	Hg	Ba	Fe	Cu	Cr	V
1	1.23 <sup>a,b</sup>	2.73 <sup>a,b</sup>	0.12 <sup>a,b</sup>	1.97 <sup>a,b</sup>	15.97 <sup>a,b</sup>	0.00 <sup>a,b</sup>	0.13 <sup>a,b</sup>	129.93 <sup>a</sup>	12.71 <sup>a,b</sup>	1.09 <sup>a,b</sup>	2.97 <sup>a,b</sup>
2	1.52 <sup>a,b</sup>	3.32 <sup>a,b</sup>	0.09 <sup>a,b</sup>	2.63 <sup>a,b</sup>	14.98 <sup>a,b</sup>	0.00 <sup>a,b</sup>	0.09 <sup>a,b</sup>	177.85 <sup>a</sup>	14.98 <sup>a,b</sup>	3.77 <sup>a,b</sup>	2.65 <sup>a,b</sup>
3	0.01 <sup>a,b</sup>	1.45 <sup>a,b</sup>	0.06 <sup>a,b</sup>	1.31 <sup>a,b</sup>	22.89 <sup>a,b</sup>	0.00 <sup>a,b</sup>	0.05 <sup>a,b</sup>	104.78 <sup>a</sup>	0.75 <sup>a,b</sup>	0.75 <sup>a,b</sup>	0.86 <sup>a,b</sup>
4	1.44 <sup>a,b</sup>	0.82 <sup>a,b</sup>	3.28 <sup>a,b</sup>	1.97 <sup>a,b</sup>	125.85 <sup>a,b</sup>	0.07 <sup>a,b</sup>	17.41 <sup>a,b</sup>	202.36 <sup>a</sup>	12.52 <sup>a,b</sup>	3.82 <sup>a,b</sup>	1.12 <sup>a,b</sup>
5	1.72 <sup>a,b</sup>	1.16 <sup>a,b</sup>	1.64 <sup>a,b</sup>	2.76 <sup>a,b</sup>	127.07 <sup>a,b</sup>	0.05 <sup>a,b</sup>	21.03 <sup>a,b</sup>	160.82 <sup>a</sup>	16.72 <sup>a,b</sup>	2.74 <sup>a,b</sup>	2.44 <sup>a,b</sup>
Mean	1.18 <sup>a,b</sup>	1.90 <sup>a,b</sup>	1.04 <sup>a,b</sup>	2.13 <sup>a,b</sup>	61.35 <sup>a,b</sup>	0.02 <sup>a,b</sup>	7.74 <sup>a,b</sup>	155.15 <sup>a</sup>	11.54 <sup>a,b</sup>	2.43 <sup>a,b</sup>	2.01 <sup>a,b</sup>
SD	0.68	1.07	1.42	0.59	59.51	0.03	10.56	38.57	6.27	1.45	0.95
FAO(1993)	1.4	0.5	0.05	80	40	0.05	-	100	30	0.15	-

Table 3: Bioaccumulation of metals in fish from the niger-benue/Imo river systems.



Figure 2: Some activities along the niger-benue/Imo river systems.

		Non-carcinogenic human health indices (mg/kg/day)										
Stations		As	Pb	Cd	Ni	Zn	Hg	Ba	Fe	V	Cu	Cr
<b>Station 1</b>												
Male	EDI	0.176	0.39	0.017	0.281	2.281	0	0.019	18.561	0.425	1.816	0.156
	CDI	0.006	0.004	0.002	0.001	0.001	0	0	0.003	0.044	0.005	0.005
	THQ	2.008	0.401	1.763	0.072	0.003	0	0	0.004	0.437	0.117	1.779
Female	EDI	0.189	0.42	0.018	0.303	2.457	0	0.02	19.989	0.457	1.955	0.168
	CDI	0.006	0.004	0.002	0.001	0.001	0	0	0.003	0.044	0.005	0.005
	THQ	2.046	0.409	1.797	0.074	0.003	0	0	0.004	0.445	0.119	1.813
<b>Station 2</b>												
Male	EDI	0.217	0.474	0.013	0.376	2.14	0	0.013	25.407	0.378	2.14	0.539
	CDI	0.007	0.005	0.001	0.002	0.001	0	0	0.004	0.039	0.006	0.018
	THQ	2.481	0.488	1.322	0.097	0.002	0	0	0.005	0.389	0.138	6.153
Female	EDI	0.234	0.511	0.014	0.405	2.305	0	0.014	27.362	0.408	2.305	0.58
	CDI	0.008	0.005	0.001	0.002	0.001	0	0	0.004	0.04	0.006	0.019
	THQ	2.529	0.497	1.348	0.098	0.002	0	0	0.005	0.397	0.14	6.272
<b>Station 3</b>												
Male	EDI	0.001	0.207	0.009	0.187	3.27	0	0.007	14.969	0.123	0.107	0.107
	CDI	0	0.002	0.001	0.001	0.001	0	0	0.002	0.013	0	0.004
	THQ	0.016	0.213	0.881	0.048	0.004	0	0	0.003	0.126	0.007	1.224
Female	EDI	0.002	0.223	0.009	0.202	3.522	0	0.008	16.12	0.132	0.115	0.115
	CDI	0	0.002	0.001	0.001	0.001	0	0	0.002	0.013	0	0.004
	THQ	0.017	0.217	0.898	0.049	0.004	0	0	0.003	0.129	0.007	1.248
<b>Station 4</b>												
Male	EDI	0.206	0.117	0.469	0.281	17.979	0.01	2.487	28.909	0.16	1.789	0.546
	CDI	0.007	0.001	0.048	0.001	0.006	0.01	0.001	0.004	0.016	0.005	0.019
	THQ	2.35	0.12	48.183	0.072	0.021	1.028	0.006	0.006	0.165	0.115	6.235
Female	EDI	0.222	0.126	0.505	0.303	19.362	0.011	2.678	31.132	0.172	1.926	0.588
	CDI	0.007	0.001	0.049	0.001	0.006	0.01	0.001	0.004	0.017	0.005	0.019
	THQ	2.396	0.123	49.11	0.074	0.021	1.048	0.007	0.006	0.168	0.117	6.355
<b>Station 5</b>												
Male	EDI	0.246	0.166	0.234	0.394	18.153	0.007	3.004	22.974	0.349	2.389	0.391
	CDI	0.008	0.002	0.024	0.002	0.006	0.007	0.002	0.003	0.036	0.006	0.013
	THQ	2.807	0.17	24.092	0.101	0.021	0.735	0.008	0.005	0.358	0.154	4.472
Female	EDI	0.265	0.178	0.252	0.425	19.549	0.008	3.235	24.742	0.375	2.572	0.422
	CDI	0.009	0.002	0.025	0.002	0.006	0.007	0.002	0.003	0.037	0.006	0.014
	THQ	2.861	0.174	24.555	0.103	0.021	0.749	0.008	0.005	0.365	0.156	4.558

**Table 4:** Non-carcinogenic human health risks from fish consumption in the niger-benue/imo river systems.

the concentration of the other five metals in the fish were above the stipulated limit for oral route intake of each metal for a one year duration (Figure 3).

Target Hazard Quotient (THQ) for both sexes revealed that only As, Cd and Cr had values >1, indicating that their individual concentration was at a level where exposure could cause obvious adverse effects.

**b) Station 2:** The EDI for both males and females revealed that out of all the metals analyzed for, only Hg and Ba had values below the RfD provided by USEPA. This means that all the other metals had concentrations above the stipulated amount for oral daily intake for each of the metals.

The CDI index for both sexes revealed that only Cd, Ni, Zn, Hg, Ba, Fe and Cu had values below the RfD, indicating that the concentration of the other four metals in the fish were above the stated limit for oral intake of each metal over a period of one year.

The THQ (for both sexes) revealed that only As, Cd and Cr had values >1, implying that exposure to these metals through fish consumption could result in evident adverse effects.

**c) Station 3:** The EDI index for all the metals revealed that only As, Hg and Ba had values below the RfD provided by USEPA, which shows that all the other metals had concentrations above the stipulated amount for oral daily intake for each of the metals for both sexes.

The CDI index (male and female) revealed that only As, Cd, Ni, Zn, Hg, Ba, Fe and Cu had values below the RfD, which means that the concentration of the other three metals in the fish were above the amount for a one year exposure via the oral route.

The THQ for both males and females showed that only Cr had values >1, which means that the concentration of this metal was at a level where exposure through fish consumption could result in observable adverse effects.

**d) Station 4:** The EDI index for both males and females revealed that all the metals had concentrations above the stated amount for oral daily intake for each of the metals.

The CDI index (for both sexes) revealed that only Pb, Ni, Zn, Ba, Fe and Cu had values below the RfD, while the concentration of the other five metals in the fish were above the specified dose for a one year oral intake of these metals.



Figure 3: Some activities along the niger-benue/imo river systems.

The THQ (for males and females) indicated that only As, Cd, Hg and Cr had values  $>1$ , meaning that exposure to these metals through fish consumption may produce significant adverse effects.

**e) Station 5:** The EDI index (both sexes) revealed that all the metals had concentrations above the specified amount for oral daily intake for each of the metals.

The CDI index for males and females revealed that only Ni, Zn, Ba, Fe and Cu had values below the RfD, while the concentration of the other six metals in the fish were above the stated dose for a 365 days oral exposure to these metals.

The THQ (for both sexes) showed that only As, Cd and Cr had values above 1, meaning that exposure to these metals through fish consumption may result in evident adverse effects.

**Target carcinogenic risk:** The data for target carcinogenic risk for all stations is presented in Figures 4a (males) and 4b (females). The acceptable level for TCR ranges from  $10^{-4}$  to  $10^{-6}$  which implies that when the calculated value for TCR is at  $10^{-6}$  for individual toxic metals, relatively negligible cancer risk exists [21].

**a) Arsenic:** In this study, TCR revealed that Arsenic values were 0.000 to 0.013 ( $10^{-4}$  to  $0.13 \times 10^{-3}$ ) for both males and females. The highest life time cancer risk was recorded in Station 5 ( $0.13 \times 10^{-3}$ ) for both males and females indicating that consumption of *L. pseudocoubie* in this area would result in an excess of 13 cancer cases per 1,000

people. While the least life time cancer risk was recorded in Station 3 at less than 1 cancer case per 10,000 people for both males and females.

Station 1 had a risk level of  $0.09 \times 10^{-3}$  for males and females, indicating an excess of 9 cancer cases per 1,000 people for both sexes; while Stations 2 and 4 had a life time cancer risk of  $0.11 \times 10^{-3}$  for males and females which would result in an excess of 11 cancer cases per 1,000 people.

**b) Nickel:** The male TCR data for Nickel ranged from 0.002 to 0.003 ( $0.02 \times 10^{-3}$  to  $0.03 \times 10^{-3}$ ). The highest life time cancer risk was recorded in Stations 2 and 5, indicating that consumption of *Labeo pseudocoubie* in this area would result in an excess of 3 cancer cases per 1,000 males; while stations 1, 3, and 4 had the least life time cancer risk of  $0.02 \times 10^{-3}$  resulting in an excess of 2 cancer cases per 1,000 males.

TCR data for Nickel ranged from 0.002 to 0.004 ( $0.02 \times 10^{-3}$  to  $0.04 \times 10^{-3}$ ) for females. The highest life time cancer risk was recorded in Station 5 ( $0.04 \times 10^{-3}$ ) indicating that consumption of *Labeo pseudocoubie* in this area would result in an excess of 4 cancer cases per 1,000 females. While the least life time cancer risk ( $0.02 \times 10^{-3}$ ) was recorded in Station 3, resulting in an excess of 2 cancer cases per 1,000 males and females. Other stations had a risk level of  $0.03 \times 10^{-3}$  which would result in an excess of 3 cancer cases per 1,000 females.

The TCR values for arsenic only in Station 3 was within the range for relatively negligible cancer risk for both males and females [21]. The findings of this study agree with most findings where TCR values of  $<1$  was recorded in various fishes [2,22].

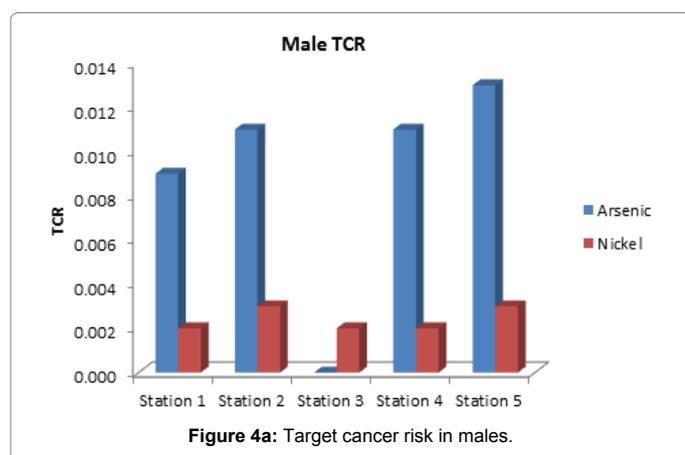


Figure 4a: Target cancer risk in males.

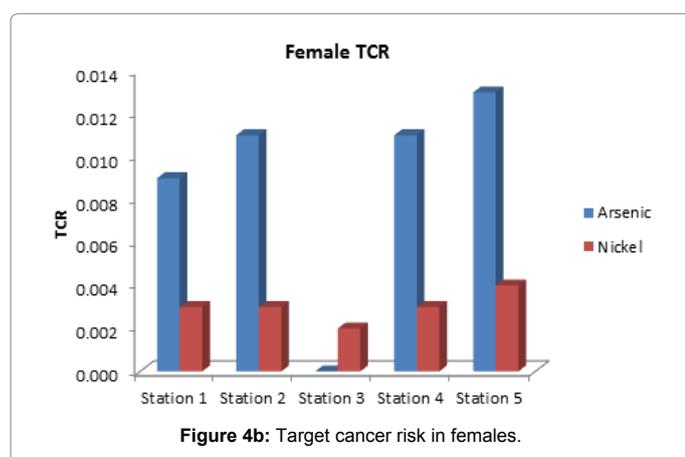


Figure 4b: Target cancer risk in females.

## Conclusion

Bioaccumulation of some metals in *L. pseudocoubie* from all five stations along the Niger-Benue/Imo River Systems was higher than the permissible limits by FAO [11].

The non-carcinogenic human health risk revealed that most (>6 metals) of the metals had values above the reference dose for both daily and yearly exposures for both males and females; while the target hazard quotient revealed that fewer metals (<4) had concentrations above the level at which obvious health impact on consumers can occur. The carcinogenic human health risk also revealed that nickel and arsenic in all stations, except for only arsenic in Station 3, were above the range for relatively negligible cancer risk for both males and females indicating massive environmental perturbations from anthropogenic activities which have resulted in pollution of the environment.

It is therefore recommended that fish consumers along the Niger-Benue/Imo River Systems should exercise serious caution when consuming fish in these areas due to the possible adverse effects that could ensue [23-29].

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