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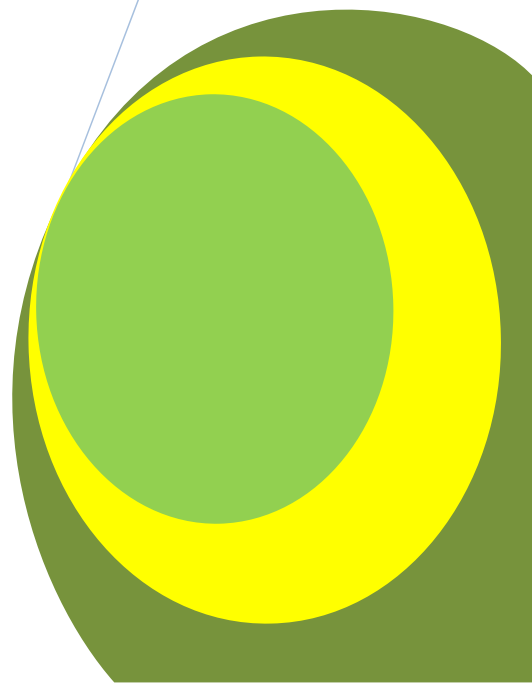
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## **Concentrations and Risk Evaluation of Selected Heavy Metals in Water and African Catfish *Clarias gariepinus* in River Kaduna, Nigeria**

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# Concentrations and Risk Evaluation of Selected Heavy Metals in Water and African Catfish *Clarias gariepinus* in River Kaduna, Nigeria

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## ABSTRACT

Freshwater is a vital medium by which fish for human consumption are cultured, thus, preserving its quality is essential. The presence and bioaccumulation pattern of some heavy metal concentrations in wild African Catfish, *Clarias gariepinus* (Burchell, 1822) muscles and water samples, collected from River Kaduna during the dry season month of December was assessed, to determine their concentrations, physico-chemical parameters, and risk evaluation of selected metals and their effects on fish quality. Analysis was carried out using standard analytical procedures and methods. Risk assessment for Fe, Pb, Ni, Cd, and Hg were based on average daily dose, hazard quotient, and cancer risk was also determined. Result showed that physico-chemical parameters, were within WHO recommended threshold limits, and mean concentrations of heavy metals followed the order Fe>Pb>Hg>Ni>Cd. Carcinogenic risk ( $CR_{ingt}$ ) via ingestion of fish muscles for Pb, Hg and Cd were higher than the acceptable limit ( $10^{-6}$ ). Anthropogenic activities, especially indiscriminate waste disposal were suggested as the main contributor to environmental pollution. Findings reveals possible health implications, thus constant surveillance was suggested to guide appropriate response.

**Key words:** River Kaduna, Heavy metals, Physico-chemical parameters, Risk Assessment.

## INTRODUCTION

With anthropogenic activities (rapid urbanization, industrialization, technological development) on the rise, there's a growing concern over the ecological effects of accumulation of heavy metals in the environment. As a result of these factors, over exploitation and pollution of an already strained freshwater resource have consequently, led to the deterioration of water quality, reduction of water quantity and a steep degradation of freshwater biodiversity habitats (Nevoh *et al.*, 2015, Hassan *et al.*, 2005). With rapid industrialization in recent years the release of toxic effluents into freshwater bodies has been on the rise, and these toxic elements of known or unknown toxicity have continuously polluted ecological habitats. Consequently, freshwater ecosystems ability to provide clean and reliable water sources, as well as maintain the natural water cycle and biological food web, and also the provision of food and recycling nutrients have been impaired (Hassan *et al.*, 2005). These actions have limited the amount of useable water available for biodiversity, and secondary effects on economic and social developments have also been on the increase (Jewitt, 2002). The toxic contamination of the aquatic ecosystems is cause primarily by heavy metals and/or metalloids, which are above natural background limits, and has become a problem of concern due to their toxicity, persistence, bioaccumulation affinity and their propensity to accumulate in vital human organs (Abubakar *et al.*, 2015; Obasohan *et al.*, 2006; Greaney, 2005).

Heavy metals is a term which applies to any group of metals or metalloids whose atomic weight is greater than 40, accumulates in food chains and can damage living tissues at low concentrations (EPA, 2000). Water which is essential to life, is mostly sourced through surface water for drinking and used as a culture media in Nigeria, and this plays an essential role in the socio-economy development of any country (Ishaku, 2011). However, freshwater resources in Nigeria, Kaduna State inclusive, are constantly being polluted by heavy metals through indiscriminate effluent discharge (Nevoh *et al.*, 2015, Ayotunde *et al.*, 2011, Nnaji *et al.*, 2007). River Kaduna in Kaduna State is one of the most important rivers in the State; however, it is prone to severally negative anthropogenic influences, such as industrial and domestic sewage discharges, agricultural runoffs, sand mining, and releases of chemicals from automobile mechanic workshops, abattoir wastes, refuse dumps, which all line up along the bank of the river. Also, the presence of the Kaduna Petrochemical Refinery which engages in effluent discharge further compounds the distress of the river (Nwaedozie, 1998). Thus, an investigation into the levels of selected heavy metals in the water and fish muscle of *Clarias gariepinus*, which populate the river, becomes

imperative, in order to establish its quality to be used as a culture media. Finally, health risk assessment through oral ingestion of fish muscles as human food was also evaluated.

## METHODOLOGY

### Study Area

The study area is located in Kaduna State, within the Guinea savannah vegetation belt of Nigeria. River Kaduna originates from the plateau hills of Jos and lies between longitude 7°24'0"E and 7°26'30"E and latitudes 10°28'30"N and 10°34'30"N (Fig. 1). It has major tributaries emptying into it among which are Kangimi, Romi and Rigasa Rivers (Amin, 2006). The State has a very long dry season, in the months of November through April, with a short wet season between the months of May and September. The mean annual rainfall ranges between 82 and 105mm, whilst average annual temperature ranges between 19.9°C – 32.4°C and relative humidity varies between 36.7% and 52.3% (NBS, 2012). Anthropogenic activities abound in the study area which include commercial, agricultural, industrial, automobile and proliferation of human and solid waste dumps.

### Sampling and sample treatment

4 samples of river water (250ml each) was collected during the dry season month of December from three sampling points (Upstream, Midstream and Downstream) which was established along River Kaduna after identifying the first effluent discharge source (point source) from the industries, in line with Nnaji *et al.* (2011). Sample point A (Upstream) was the first point source, followed by Sample point B (Midstream) and Sample point C (Downstream). Locations were established using a Global Positioning System (GPS) device. All samples were collected in 500 ml plastic bottles, which were pre-washed with 10% nitric acid (HNO<sub>3</sub>) and de-ionized water. Before sample collection, the bottles were immersed to about 20cm below the water surface to prevent contamination of heavy metals from air. The samples were then acidified with 2ml nitric acid to prevent precipitation of metals, reduce absorption of the analytes onto the walls of containers and to avoid microbial activity. The water samples were then immediately brought to the laboratory and stored at 4°C until analysis.

A total of twenty (20) wild fish samples of *C. gariepinus* species collected from River Kaduna were used in this study to investigate the concentration of heavy metals. All specimens when collected were placed immediately in polyethylene bags, put into isolated container of polystyrene icebox and then taken to the Multi-User Science Research Laboratory, Ahmadu Bello University, Zaria for analysis.

### Sample Analysis

Physical parameters (pH, Temperature, Dissolved Oxygen – DO, Turbidity, Biological Oxygen Demand – BOD, Total Dissolved Solids – TDS and Electrical Conductivity – EC) of river water sample was analysed using a Hach Sens-ION+ pH meter for pH, Hanna instrument (HI98129 Model) for temperature measurement, while turbidity was determined using 2100AN Hach model turbidity meter and Electrical Conductivity was measured using a digital conductivity meter (Hach Sens-Ion+ E7 Basic Conductivity Benchtop Meter Model). DO, BOD and TDS were determined according to APHA (1998) standard methods in the laboratory.

Heavy metal concentrations in river water samples were analysed according to digestion procedure methods modified by Zhang (2007). 100ml of water sample was measured and poured into a 250ml beaker, of which 5ml concentrated HNO<sub>3(aq)</sub> (Analar 98%) was added. Using a hotplate after adding few boiling chips mixture was heated gently and evaporated down to about 20ml. 5ml of HNO<sub>3</sub> was further added and heated for 10 minutes and then allowed to cool. The solution was quantitatively poured into a 100ml volumetric flask and marked up with distilled water.

Fish samples digestion procedure followed the wet digestion method modified by Manutsewee *et al.* (2007). Briefly, the fish was thawed and dissected and muscular tissues on the dorsal surface of each fish taken out and homogenized and about 4 grams of the surface of the homogenized muscles (without skin) of each specimen was taken and placed in a 300ml digestion tube. A digestion mixture containing 6.0ml of high purity HNO<sub>3</sub> plus 2ml of HCL (10M) and 4ml of H<sub>2</sub>O<sub>2</sub> (35%) was then added to each tube. The samples were at that point heated at 130°C by a heating digester with air condenser until a clear solution was obtained. After cooling, the samples were filtered through Whatman filter paper and the digested portion was diluted to a final volume of 50ml using distilled water. Blank reagents without fish samples were also digested using the same method.

### Analytic Technique

The analytical technique that was used in determining heavy metals levels in all samples was the Varian AA240 Fast Sequential Flame Atomic Absorption Spectrophotometer (AAS) (International Equipment Trading Ltd, USA) it is a standard laboratory analytical tool for metal analysis. AAS was used to determine Fe, Pb, Ni and Cd concentrations, while the Vapour Generation Accessory (Varian VGA 77) was used for Hg determination. All

samples tests were repeated three times and the mean taken as the actual concentration level of heavy metal in mg/l. Analysis quality was ensured through replicates, blank analysis, pre-digestion spikes and certified reference materials analysis.

### Health Risk Assessment

Humans are prone to be exposed to heavy metals through three main routes; viz. direct ingestion, inhalation (mouth and nose) and dermal absorption. Ingestion and dermal absorption by eating of aquatic organisms and swimming, respectively, are common routes which heavy metals gain entry into the human system (Wu *et al.*, 2009 and USEPA, 2005). However, only ingestion of aquatic organism (catfish consumption) was assessed in this study. The expressions for human health risk assessment were obtained from the USEPA – Risk Assessment Guidelines Superfund (RAGS) methodology (USEPA, 2005). The relationship was calculated using the following:

$$D_{ingt} = \frac{C_{fish} \times IR \times EF \times ED}{BW \times AT} \quad (\text{Eq. 1})$$

Where  $D_{ingt}$  = exposure to dose through fish ingestion ( $\mu\text{g/kg/day}$ );  $C_{fish}$  = concentration of the estimated metals in fish; IR = ingestion rate (L/day); EF = exposure frequency (days/year); ED = exposure duration (years); BW = average body weight (kg) and AT = averaging time (AT).

Potential non-carcinogenic risks for exposure to contaminants was also assessed, by comparing the calculated contaminant exposures of the exposure route with the reference dose (RfD) in order to calculate the Hazard Quotient (HQ) as shown in Eq. 2 (USEPA, 2005).

$$HQ_{ingt} = \frac{D_{ingt}}{RfD_{ingt}} \quad (\text{Eq. 2})$$

Where  $HQ_{ingt}$  = Hazard Quotient via ingestion (unit less) and  $RfD_{ingt}$  = oral reference dose ( $\mu\text{g/kg/day}$ ).  $RfD_{ingt}$  values were obtained from selected literatures (Liang *et al.*, 2011; Li and Zhang, 2010; Wu *et al.*, 2009).

The HQ is a numeric approximation of the systemic toxicity potential posed by a single element within a single exposure route. Thus, the total potential for non-carcinogenic effects posed by more than one element is evaluated by integrating computed HQs of each element and expressed as Hazard Index (HI) using Eq. 3 below (USEPA, 2005).

$$HI = \sum_{i=1}^n HQ_{ingt} \quad (\text{Eq. 3})$$

Where  $HQ_{ingt}$  = hazard index via ingestion (unit less). When HQ/HI exceeds unity, there's concern for potential human health risk caused by exposure to non-carcinogenic elements (USEPA, 2005).

Chronic daily intake (CDI) was evaluated using Eq. 4.

$$CDI_{ingt} = C_{fish} \times \frac{DI}{BW} \quad (\text{Eq. 4})$$

where  $C_{fish}$ , DI and BW represent the concentration of heavy metal in fish ( $\mu\text{g/kg}$ ), average daily intake and body weight, respectively. The parameters estimating exposure assessment of metals in the samples used in this study are tabled as follows:

**Table 1: Estimates of Exposure Parameters**

| Parameters                                     | Unit              | Values |          |
|------------------------------------------------|-------------------|--------|----------|
|                                                |                   | Adult  | Children |
| Concentration of metals in fish ( $C_{fish}$ ) | $\mu\text{g/L}$   |        |          |
| Injection Rate (IR)                            | L/day             | 2.2    | 1.8      |
| Exposure Frequency (EF)                        | Days/year         | 350    | 350      |
| Exposure Duration (ED)                         | year              | 70     | 6        |
| Average Body Weight (BW)                       | kg                | 70     | 15       |
| Average Time (AT)                              | days              | 25,550 | 2190     |
| Unit Conversion Factor                         | L/cm <sup>3</sup> | 0.001  | 0.001    |
| Fe                                             | (cm/h)            | 0.001  |          |
| Pb                                             |                   | 0.004  |          |
| Ni                                             |                   | 0.004  |          |
| Cd                                             |                   | 0.001  |          |
| Hg                                             |                   | 0.001  |          |

(Liang *et al.*, 2011; Wu *et al.*, 2009, USEPA, 2005)

Cancer Risk (CR) was also evaluated using Eq. 5.

$$CR_{ingt} = \frac{D_{ingt}}{SF_{ingt}} \quad (\text{Eq. 5})$$

where  $SF_{ingt}$  is the cancer slope factor. The  $SF_{ingt}$  for Hg is  $2.0 \mu\text{g/g/day}$  Cd is  $6.1 \times 10^3 \mu\text{g/g/day}$  and Pb is  $8.5 \mu\text{g/g/day}$  (Yu *et al.*, 2010; USEPA, 2005).

### Statistical Analysis

Analytical data were processed using IBM SPSS version 20 software. Where significant difference was observed between the concentrations, the means was separated using t-test analysis. Multivariate analyses were also performed on corresponding variables.

## RESULTS AND DISCUSSION

### Physico-chemical Parameters

The physico-chemical parameters of River Kaduna water samples are summarized in Table 2. pH values were within WHO threshold limit of 6.5-8.5, and these values has no significant effect on health, however, the choice of water for fish culture is not based purely on pH. The decrease in pH from the upstream to the downstream could be attributed to the presence of dissolved carbonates and bicarbonates, which are recognized to affect pH in surface water (Chapman, 1992). pH values obtained in this study are similar to results obtained by Abubakar *et al.* (2015) and Nwaedozie (1998), which is optimal when considering that values below 6.5 is acidic and could affect the digestive and lymphatic system due to acidosis (Nkansah *et al.* 2010).

Temperature values were between  $27.03 - 28.47^\circ\text{C}$ . Such values according to Nwaedozie (1998) are within aquaculture desirable limit ( $24.94^\circ\text{C} - 30.68^\circ\text{C}$ ), as temperature is the most important environmental variable since it affects metabolic activities, growth, feeding, reproduction, distribution and migratory behaviours of aquatic organisms (Kumar, 2004). Similar readings were reported by Oniye *et al.* (2002) when studying physico-chemical parameters in Zaria dam.

**Table 2: Physico-chemical characteristic of River Kaduna**

| Parameters                       | Upstream            | Midstream           | Downstream          | Mean                | WHO Limits |
|----------------------------------|---------------------|---------------------|---------------------|---------------------|------------|
| pH                               | $6.78 \pm 0.04^a$   | $6.69 \pm 0.03^b$   | $6.67 \pm 0.05^b$   | $6.71 \pm 0.06^b$   | 6.5 - 8.5  |
| Temperature ( $^\circ\text{C}$ ) | $28.47 \pm 0.08^a$  | $27.03 \pm 0.05^b$  | $27.31 \pm 0.03^b$  | $27.60 \pm 0.76^b$  | 30 - 36    |
| DO (mg/l)                        | $6.73 \pm 0.02^a$   | $5.9 \pm 0.04^b$    | $5.62 \pm 0.04^c$   | $6.08 \pm 0.58^b$   | 10         |
| Turbidity (NTU)                  | $56.5 \pm 0.53^a$   | $49.67 \pm 0.08^b$  | $55.5 \pm 0.53^a$   | $53.89 \pm 3.69^a$  | 5          |
| BOD (mg/l)                       | $2.33 \pm 0.05^a$   | $2.19 \pm 0.14^b$   | $2.25 \pm 0.09^a$   | $2.26 \pm 0.07^b$   | 20 - 40    |
| TDS (mg/l)                       | $80.39 \pm 0.47^a$  | $79.95 \pm 0.16^a$  | $78.82 \pm 0.96^b$  | $79.72 \pm 0.81^a$  | 500        |
| EC ( $\mu\text{S/cm}$ )          | $135.61 \pm 3.81^b$ | $136.61 \pm 0.78^a$ | $130.61 \pm 4.11^c$ | $134.28 \pm 3.22^a$ | 1000       |

Means with the same superscripts on same rows were not significantly different ( $p \geq 0.05$ ).

Dissolved Oxygen (DO) values in this study were higher than  $5 \text{mg/l}$ , which if below this concentration adversely affect aquatic life (Rao, 2005). Judging from the results in comparison with WHO standards, River Kaduna whose average DO level is  $6.08 \text{mg/l}$  is within the limits for ideal aquaculture. The decrease of DO values from the upstream to the downstream is attributed to the biology of freshwater bodies whose upper part have high amount of oxygen, due to steep or shallow rapids, and decreases downstream (Zeb *et al.*, 2008; Kumar, 2004).

Turbidity, an important variable relative to transport and bioavailability of contaminants varied between the sampling points, with an average NTU of 53.89. The values were far higher than WHO permissible limit of 5, and this may be as a result of waste discharge or earth-disturbing activities that occur near the rivers. Generally high turbidity value indicates a high concentration of total dissolved and suspended solids (Ladipo *et al.*, 2011); this is why total dissolved solids (TDS) obtained in this study were all very high, with a mean of  $79.72 \text{mg/l}$ , which is lower than the WHO standard indicative of portability ( $1000 - 1600 \text{mg/l}$ ).

Biological Oxygen Demand (BOD) values differed significantly in River Kaduna. The low BOD values obtained in the sample sites suggests low dissolved organic matter concentration from one location to another. This suggests periodic discharge of sewage containing varying amounts of substances in the different locations. The values obtained in this study were in many cases lower than the average values reported by Nnaji *et al.* (2011) in River Galma, also in Kaduna State.

Electrical conductivity values were relatively high in the three sampling locations with an average of 134.28 $\mu$ S/cm; this could be attributed to the drying of water bodies and salts, which accumulates through evaporation. Merz (2006) and Ladipo *et al.* (2011) also agree that during the drying phases EC concentrations can become high, which have an impact on aquatic biota.

### Heavy Metals in Water Samples

Mean metal concentration in water samples in River Kaduna as shown in Table 3, had mean Fe level above the WHO recommended value of 0.03mg/l. Iron is one of the most abundant metals in the Earth's crust, and due to the deposition of iron coagulants or the corrosion of steel and cast iron materials dumped into water bodies, it becomes present in water (WHO, 2012). Generally in Nigerian surface waters, there seem to be fairly high levels of Fe (Etim, 2012; Butu, 2013), for instance Butu (2013) found high concentrations of Fe (16.5 mg.l<sup>-1</sup>) in River Kubanni, Zaria, which is significantly higher than levels obtained in this study.

**Table 3: Heavy Metals in Water Samples of River Kaduna**

| Parameters | Upstream                     | Midstream                    | Downstream                   | Average                      | WHO Limits |
|------------|------------------------------|------------------------------|------------------------------|------------------------------|------------|
| Fe (mg/l)  | 4.15 $\pm$ 0.34 <sup>a</sup> | 4.03 $\pm$ 0.24 <sup>a</sup> | 3.98 $\pm$ 0.15 <sup>b</sup> | 4.05 $\pm$ 0.09 <sup>a</sup> | 0.03       |
| Pb (mg/l)  | 0.93 $\pm$ 0.02 <sup>a</sup> | 0.96 $\pm$ 0.01 <sup>a</sup> | 0.99 $\pm$ 0.02 <sup>a</sup> | 0.96 $\pm$ 0.03 <sup>a</sup> | 0.01       |
| Ni (mg/l)  | 0.28 $\pm$ 0.01 <sup>b</sup> | 0.38 $\pm$ 0.04 <sup>a</sup> | 0.39 $\pm$ 0.02 <sup>a</sup> | 0.35 $\pm$ 0.06 <sup>a</sup> | 0.02       |
| Cd (mg/l)  | 0.03 $\pm$ 0.00 <sup>a</sup> | 0.04 $\pm$ 0.00 <sup>a</sup> | 0.04 $\pm$ 0.01 <sup>a</sup> | 0.04 $\pm$ 0.01 <sup>a</sup> | 0.005      |
| Hg (mg/l)  | 0.62 $\pm$ 0.02 <sup>b</sup> | 0.89 $\pm$ 0.05 <sup>a</sup> | 0.91 $\pm$ 0.06 <sup>a</sup> | 0.81 $\pm$ 0.16 <sup>a</sup> | 0.5        |

Means with the same superscripts on same rows were not significantly different ( $p \geq 0.05$ ).

Pb levels are quite alarming with a high value of 0.99mg/l in the downstream, which has a WHO critical limit of 0.05mg/l. Excess Pb results in osteoporosis, lead poisoning, mottled teeth in children, kidney failure (Nephritis) and when in contact with other chemicals found in detergents could result in eutrophication of water tables (Ezeribe *et al.*, 2012).

Furthermore, access to safe water used as a culture media for fish farming is essential to health, a basic human right and a component of effective policy for health protection (Food and Agricultural Organization - FAO, 2012), thus, when Ni content (highest being 0.39mg/l in the downstream) in water samples in River Kaduna is over 1,600% above the WHO threshold limit of 0.02mg/l it becomes a crisis. For individuals who constantly consume matter from these water samples stand at risk of developing cancer (WHO, 2012).

Cadmium did not show any significant variation in the sampling points, however with a mean of 0.04mg/l it is significantly higher than WHO standard limit of 0.005mg/l. These values are discomfoting as high concentration of Cd in the liver, which is the principal organ responsible for detoxification, transportation and storage of toxic substances, makes it an active site for pathological effects induced by Cd contamination. Uzairu *et al.* (2009) concurs that Cadmium which accumulates in the kidney and liver causes kidney dysfunction and liver failure, interferes with the metabolism of Calcium and Phosphorus, causing painful bone diseases, in addition to being a teratogenic and carcinogenic agent.

Mercury, whose concentration levels were very high downstream River Kaduna (0.91mg/l), is largely emitted by both natural and anthropogenic activities in an inorganic form, predominantly metallic vapour, which is carried off to great distances by winds and eventually falls unto water bodies. This poses very serious health risks to the populace living within the area (Ibeto and Okoye, 2010). Clemente *et al.* (2009) states that in aquatic environments inorganic mercury is microbiologically transformed into lipophilic organic compound, methyl mercury, and this transformation makes mercury more prone to bio-magnifications in food chains and results in psychomotor retardation in children (Horsfall, 2001), autism (Lim *et al.*, 2008), and dysplasia of cerebral and cerebellar cortexes, neuronal ectopia and several other developmental disturbances (Zukowska and Biziuk, 2008).

## Heavy Metals in *C. gariepinus* Muscle Samples

With high iron levels causing discoloration and high turbidity of water, it is predictable that Fe values in *C. gariepinus* muscles is also very high (4.06mg/kg), as shown in Table 4; added to the fact that iron interactions in biological tissues, due to excess amount of iron, causes rapid increase in pulse rate and coagulation of blood in blood vessels, hypertension, and drowsiness (FAO, 2012).

Average Pb value was higher (0.84mg/kg) than the FAO limit for food – 0.3mg/kg, thus it is very substantial to cause considerable damage to the human body which could result to inducing oxidative damage to brain, heart, kidneys, and reproductive organs (El-Ghasham *et al.*, 2008).

Ni values obtained (0.19mg/kg) were significantly below the FAO fish food limit of 0.5 – 0.6 mg/kg, but lethal enough to cause gastrointestinal upset (vomiting, cramps, diarrhoea) and neurological symptoms (giddiness, headache, weariness). The value obtained were also similar to those obtained by Obasohan and Eguavoen (2008) who analysed heavy metals concentrations in the muscle of *Erpetoichthys calabaricus* from the Ogba River in Benin City and found Nickel levels to range between 0.08 to 0.79mg/kg.

Cadmium (Cd) whose food intake limit is put at 0.5mg/kg by the FAO was low in fish muscle samples captured from River Kaduna. With a value of 0.02mg/kg it is lower than concentrations reported in *Scomber scombrus* (2.2 – 2.4mg/kg) by Abubakar *et al.* (2015). When the results obtained here are placed parallel with *O. niloticus* and *Synodontis schall*, Cadmium levels in *C. gariepinus* compares positively, as Nnaji *et al.* (2007) reported levels of 0.012mg/kg and 0.006mg/kg, respectively.

Mercury concentrations from this study showed concentrations of 0.65mg/kg, which greatly exceeds that of the permissible food limit of 0.1mg.kg<sup>-1</sup>, and it is pertinent to note that concentrations as low as 0.25 mg.kg<sup>-1</sup> have been associated with a wide spectrum of adverse health effects including damage to the central nervous system (neurotoxicity) and kidney failure (Lim *et al.*, 2008).

## Health Risk Assessment

Health risks associated with aquatic food consumption often depends on the quantity that was consumed and an individual's weight. Reports from this study revealed that *C. gariepinus* muscles from River Kaduna containing Fe, Pb, Ni, Cd and Hg had hazard quotient ( $HQ_{ingt}$ ) values for both adults and children to be less than unity (Table 4), which suggests there's no potential health effects on the local population.

Chronic Daily Intake (CDI) for Fe, Pb, Ni, Cd and Hg for both adults and children were all less than 1 (Table 4). Thus, CDI indices for heavy metals were in the order: Hg>Pb>Cd>Ni>Fe. The CR values for Fe, Pb, Ni, Cd and Hg for both adults and children as shown in Table 4, were found to exceed the safe limit of cancer risk, as CR value greater than 1 in a million (10<sup>-6</sup>) is considered very significant by the USEPA (2005).

**Table 4: Health Risk, Chronic Daily Intake and Cancer Risk Assessment for Heavy Metals in *C. gariepinus* muscles taken via ingestion**

| Heavy Metals | Conc. (mg/kg)<br>in fish muscles | FAO Limits<br>(mg/kg) | RfD <sub>ing</sub><br>(µg/kg/day) | Adults               | Children             | Adults               | Children             | Adults               | Children             |
|--------------|----------------------------------|-----------------------|-----------------------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|
|              |                                  |                       |                                   | $HQ_{ing}$           | $HQ_{ing}$           | $CDI_{ing}$          | $CDI_{ing}$          | $CR_{ing}$           | $CR_{ing}$           |
| Fe           | 4.06 ± 0.30                      | 0.5                   | 700                               | $1.7 \times 10^{-4}$ | $6.7 \times 10^{-4}$ | $1.3 \times 10^{-1}$ | $4.9 \times 10^{-1}$ | –                    | –                    |
| Pb           | 0.84 ± 0.12                      | 0.3                   | 1.4                               | $1.8 \times 10^{-2}$ | $6.9 \times 10^{-2}$ | $2.6 \times 10^{-1}$ | $1.0 \times 10^{-1}$ | $2.9 \times 10^{-3}$ | $1.1 \times 10^{-2}$ |
| Ni           | 0.19 ± 0.30                      | 0.5 – 0.6             | 20                                | $2.9 \times 10^{-4}$ | $1.1 \times 10^{-3}$ | $5.9 \times 10^{-3}$ | $2.3 \times 10^{-2}$ | –                    | –                    |
| Cd           | 0.02 ± 0.30                      | 0.5                   | 0.5                               | $1.2 \times 10^{-3}$ | $4.6 \times 10^{-3}$ | $6.3 \times 10^{-4}$ | $2.4 \times 10^{-3}$ | $9.9 \times 10^{-8}$ | $3.8 \times 10^{-7}$ |
| Hg           | 0.65 ± 0.12                      | 0.1                   | 0.1                               | $1.9 \times 10^{-1}$ | $7.5 \times 10^{-1}$ | $2.0 \times 10^{-2}$ | $7.8 \times 10^{-2}$ | $9.7 \times 10^{-3}$ | $3.7 \times 10^{-2}$ |
| $HI_{ing}$   | -                                | -                     | -                                 | $2.2 \times 10^{-1}$ | $8.2 \times 10^{-1}$ | -                    | -                    | -                    | -                    |

## CONCLUSION

The study revealed very substantial heavy metal contamination in water samples and muscles samples of *C. gariepinus* obtained from River Kaduna, which has several discharge points of anthropogenic wastes and also from geologic processes. The study also established carcinogenic risks ( $CR_{ingt}$ ) for Hg and Pb ( $>10^{-6}$ ) through the ingestion of fish muscles from the river, however, Cd had no potential cancer risk in both adults and children. These findings contribute significantly to the understanding of the nexus water pollution and its inherent risks to public health in the context of a rapidly growing urban centre. Efforts should therefore be made by concerned local authorities by instituting control measures (both technical and non-technical) to minimize the impact risks on local residents and consumers of fishes from the river. In addition there's need to expand research in the area, to assess the level of contamination in river systems in the State, with the view of identifying precise health risks in different exposure groups within the State and Nigeria at large.

## CONFLICT OF INTERESTS

The authors declare that there is no conflict of interests regarding this paper publication.

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