Heavy Metals Analysis and Health Risk Assessment of Three Fish Species, Surface Water and Sediment Samples in Ogbaru Axis of River Niger, Anambra State, Nigeria

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Authors’ contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

ABSTRACT

Human activities on environmental resources have negatively affected floras and faunas in maintaining fair balance. In this research study, selected heavy metals (Al, As, Cd, Cr, Cu, Fe, Hg, Pb, Ni, Zn) concentration in three fish species (Clarias gariepinus, Heterotis niloticus and Anguilla labiate), surface water and sediment samples in Ogbaru axis of River Niger, Anambra State, Nigeria. We evaluated the samples using atomic absorption spectrophotometer (AAS). The result of heavy metals (Cu, Fe, Zn, Ni, Pb, Cd, Al, Cd) analysis in fish samples showed that Cr was detected in Clarias gariepinus and Anguilla labiate with a concentration of 0.001mg/kg in both species but was not detected in Heterotis niloticus. Hg and Al were not detected in Anguilla labiate but both metals were detected in the other fish species with a mean concentration of 0.311mg/kg and 0.001mg/kg respectively for Clarias gariepinus and 0.005mg/kg respectively for Heterotis niloticus. In decreasing order, the heavy metal concentration in Clarias gariepinus in increasing order of Cu > Fe > Ni > Hg > Pb > Zn > As > Cd > Al > Cr, while Heterotis niloticus followed the order Cu > Zn > Fe > Ni > Pb > Cd > Al > As > Hg > Cr, and Anguilla labiate followed the pattern of Cu > Fe > Zn > Ni > Pb > Cd > Cr > As > Hg > Al. For surface water, As (0.005mg/l), Cd (0.032 mg/l), Cr (0.099 mg/l), Cu (0.186 mg/l), Fe (2.308 mg/l), Hg (1.501 mg/l) and Pb (0.724 mg/l).
mg/l) showed high concentration for the raining season compared to dry season, as Al (0.246 mg/l), Ni (0.773 mg/l) and Zn (2.903 mg/l) were dominant during dry season, while sediment samples of Cr (0.112 mg/kg), Cu (0.029 mg/kg), Ni (0.945 mg/kg) and Pb (0.039 mg/kg) concentration in raining season were higher than dry season and vice versa for other As, Cd, Fe, Hg, Zn. Correlation matrices showed positive value showing that heavy metals were from a similar source with migration route and vice versa for negative correlation. Health and exposure risk assessment was conducted for carcinogenic and non-carcinogenic exposure in adults and children, where the cumulative cancer risk was within USEPA regulatory standard (1.0E-6 – 1.0E-04) and cumulative hazard index were above 1 for adults (2.02) and children (4.93), implying that children are at risk of having adverse health issues compared to adults. Therefore, there is a need for regulatory advocacy and special care to mitigate anthropogenic release and safeguard the environment.

Keywords: River Niger; fish species; surface water; sediment; heavy metal; hazard quotient.

1. INTRODUCTION

The influence of human activities has been known to cause immense environmental impact over a long period, which has made it difficult to contain pollution across environmental matrices especially in aquatic environment [1-3]. All over the world, water bodies are continuously overburdened with chemical effluents that have led to increase in heavy metals, pesticides, aromatic and aliphatic hydrocarbons, making it unfit for survival of aquatic organisms and inhibits water aesthetic [4-7]. Heavy metals are metallic chemical element with relatively high density that are toxic or poisonous at low concentrations to organisms [8].

According to USEPA [9], heavy metals are classified as nutritional metals example are chromium (iii), copper, cobalt, iron, manganese, molybdenum, selenium, zinc; non-essential metals are aluminum, arsenic, cadmium, lead, mercury, silver that is been debated by scientific critics [9,10]. Heavy metals in trace toxic amount can cause oxidative stress in relation to ecotoxicity in the aquatic organisms [11], as Woo et al. [12] infers that degradation of bacteria is possible in marine environment. Due to anthropogenic releases, sediment and water sources are influenced negatively across various environmental factors such as temperature, dissolved oxygen, pH, and conductivity that in-turns causes potential threat to aquatic organisms and mammals over a period [13,14].

Aquatic organisms ingest phytoplankton and dissolved food source in water with high metallic ions via ion-exchange across lipophilic membranes or adsorption on tissue or membrane surface, as such leads to increase metallic bioaccumulation, which thereafter is eaten by other aquatic mammals and humans [15-17]. Fish has over the decade been a major protein source for humans, which entails that peradventure these aquatic organisms or mammals have extreme concentration of heavy metals, after human consumption, it can lead to adverse health effect from high toxicity and chemical interaction with human organs and tissues [18]. Several studies have conducted heavy metal assessment across different aquatic organisms, which gives divergent inference in relation to anthropogenic pollutants [18-21].

The purpose of this study is the evaluation and health risk assessment of heavy metals in selected fish species, water and sediment from Ogbaru axis of River Niger, Ogbaru local government area, Anambra state, Nigeria.

2. MATERIALS AND METHODS

2.1 Study Area

The study area was Ogbaru axis of River Niger as shown in Fig. 1. Ogbaru local government area has an area of 453 km² in Anambra State, Nigeria, which is bounded to the north by Onitsha South local government area, in the west by the River Niger, in the south-east by Ihiala local government area, and in the east by Ekwusigo and Idemili South local government areas.

The River Niger in Ogbaru axis arises from a combination of two springs from Cameroun mountain, Cameroun and Guinea Highland, Guinea, that co-joins in Kogi State, Nigeria [22]. The water is discharged into diverse tributaries in the Niger Delta, which thereafter is deposited into the Atlantic Ocean. A closer investigation into the Rivers Niger shows that several commercial activities such as farming and fishing activities,
oil and gas exploration and solid mineral mining is abundant across a large expanse of river lines, as such the water volume fluctuates significantly as a result of natural and man-made influences that causes extreme flooding in Niger Delta, Nigeria [23].

2.2 Sample Collection and Preparation

Three sample regiments (fish, surface water and sediment) were collected across Ogbaru axis of the River Niger. Three species of fish samples: *Clarias gariepinus* (Cat fish), *Heterotis niloticus* (African arowana) and *Anguilla labiata* (African mottled eel) were bought from the local market close to the study area. The fish samples were of similar size, which was labelled accordingly, packaged in a polyethylene bag and transported to the laboratory for chemical evaluation.

The surface water and sediment samples were obtained via two seasons (wet and dry season), which was collected at different three (3) positions with a distance of five (5) meters and mixed to form a composite mixture, thereafter was packaged in a precleaned plastic container, labelled accordingly and subsequently sent to the laboratory for chemical evaluation [25].

2.3 Laboratory Analysis

2.3.1 Digestion of fish sample

Fish samples were dried at 105°C in a laboratory oven until they reach a constant weight. The dried samples were grounded using a porcelain mortar and pestle. As 5g of ground fish samples were weighed into Teflon crucible with 10ml of freshly prepared concentrated HCl/HNO₃.
(aqua-regia) in the rations of 3:1 added to each sample, thereafter allow the crucible was covered and allowed to solubilize. The samples in the crucibles were heated in the oven at a constant temperature of 150°C for 2 hours until the solution became clear and completely digested as the samples were cooled. 10ml of deionized water was added to each sample and filtered using Whatman filter paper into 250ml volumetric flask, and made up to 250 ml level with deionized water for metal determination of arsenic (As), mercury (Hg), lead (Pb), aluminum (Al), cadmium (Cd), nickel (Ni), copper (Cu), chromium (Cr), zinc (Zn) and iron (Fe) using Varian AA240 atomic absorption spectrophotometer.

2.3.2 Digestion of surface water samples

5 ml of 10 M concentrated HCl were added to 250 ml of surface water samples in 500 ml beaker, which was placed in water bath at 80°C and allowed to evaporate to 25ml. The concentrate was transferred to a 50 ml volumetric flask and diluted to mark with deionized water. Prior to analysis, the solution was filtered using Whatman filter paper as indicated by Izuchukwu et al. [26]. Similar metal determination was done accordingly to Braid et al. [25] procedure.

2.3.3 Digestion of sediment samples

Sediment samples were dried at 105°C in a laboratory oven for 1 hour, thereafter the sediment was ground into fine powder using pestle and mortar. 5g of sediment sample were weighed into a 250ml beaker as 50ml deionized water, 0.5ml of concentrated HNO₃ and 5ml of concentrated HCl was added accordingly. The beaker was thereafter placed on a hot plate in a fume cupboard for digestion to prevent chemical spillage and allowed to evaporate to 15ml. The beaker were removed and allowed to cool to room temperature, as the digestate were filtered into a 50ml volumetric flask and made up to 50ml mark with deionized water, then metal determination was conducted as done for water samples.

2.4 Data Analysis

Microsoft Excel 2019 data analysis was utilized for determination of correlation matrix, which evaluates the strength and direction of a linear relationship between two variables (or metal ions of interest). Correlation coefficient of value greater than 0.71 is accepted for correlation matrix at significance level of 0.05 [27].

2.4.1 Health risk assessment

Cancer risk (CR) and Hazard Quotient (HQ) are indices developed by USEPA risk assessment models for evaluation of carcinogenic and non-carcinogenic health risk in adults and children in relation to fish, surface water and sediment samples in Ogbaru axis of river Niger. Exposure route were employed which is Fish (dietary ingestion), surface water (dermal and ingestion) and Sediment (dermal, accidental ingestion and inhalation) [28, 29]. The formulas are shown below:

\[
CR_{\text{ingestion}} = \frac{C \times EF \times ED \times I Rx \times RBA^* \times 10^{-6} \times CSF}{BW \times AT} \quad (1)
\]

\[
HQ_{\text{ingestion}} = \frac{C \times EF \times ED \times I Rx \times RBA^* \times 10^{-6}}{BW \times AT \times RFD} \quad (2)
\]

\[
CR_{\text{dermal}} = \frac{C \times EF \times ED \times SAx \times AF \times Kp^* \times 10^{-6} \times CSF}{BW \times AT \times GIABS^*} \quad (3)
\]

\[
HQ_{\text{dermal}} = \frac{C \times EF \times ED \times SAx \times AF \times GIABS^* \times Kp^* \times 10^{-6}}{BW \times AT \times RFD} \quad (4)
\]

\[
CR_{\text{inhalation}} = \frac{C \times EF \times ED \times ET \times 10^{6} \times IUR}{AT \times PEF \times VF} \quad (5)
\]

\[
HQ_{\text{inhalation}} = \frac{C \times EF \times ED \times ET \times 10^{6}}{AT \times PEF \times VF \times RIC^*} \quad (6)
\]

Where C is the concentration of heavy metal in sample; EF is exposure frequency; ED is exposure duration; I R x is ingestion rate of sample; SA is skin surface area; RBA*: relative bioavailability for sediment calculation only; AF: adherence factor; Kp: dermal permeability constant for sediment calculation only; GIABS is gastrointestinal absorption factor for sediment calculation only; ET is inhalation exposure time; AT: average time; BW is body weight; PEF is particulate emission factor; VF is volatilization factor.
3. RESULTS

3.1 Heavy Metal Concentration in Fish Samples

Table 3 and Fig. 2 shows the concentration of heavy metals in different fish species assessed in Ogbaru axis of River Niger. The highest concentration of aluminum (Al) was indicated in *Clarias gariepinus* followed by *Heterotis niloticus* with the concentration of 0.019mg/kg and 0.005mg/kg respectively, as Ismaniza et al. [5] observed a concentration range of 15.39 – 320.6 mg/kg for aluminum that was attributed to industrial waste, erosion, dissolution of minerals and salts, atmospheric dust pollution and rain [34]. Highest concentration of arsenic (As) was seen in *Clarias gariepinus* having 0.093mg/kg while the lowest concentration of 0.002mg/kg was found in *Anguilla labiate* which was lower than those reported in Zrnčić et al., [35] study ranging between 0.021 – 0.048 μg/g for *Cyprinus carpio*. Ashraf et al., [1] observed a concentration of 0.87 mg/kg for *Hampala macrolepidota* from a tin mining catchment area.
Table 3. Mean concentration of heavy metals in fish species

| Heavy metal (mg/kg) | Clarias gariepinus (Cat fish) | Heterotis niloticus (African Arowana) | Anguilla labiate (African mottled eel) |
|---------------------|-------------------------------|---------------------------------------|----------------------------------------|
| Al                  | 0.019±0.027                   | 0.005±0.002                           | 0.000±0.000                            |
| As                  | 0.093±0.004                   | 0.003±0.002                           | 0.002±0.002                            |
| Cd                  | 0.022±0.004                   | 0.020±0.004                           | 0.028±0.001                            |
| Cr                  | 0.001±0.002                   | 0.000±0.000                           | 0.001±0.002                            |
| Cu                  | 2.161±0.033                   | 2.197±0.007                           | 10.560±0.306                           |
| Fe                  | 1.755±0.028                   | 1.234±0.006                           | 1.927±0.022                            |
| Hg                  | 0.311±0.00058                 | 0.00067±0.001                         | 0.000±0.000                            |
| Ni                  | 0.419±0.009                   | 0.514±0.004                           | 0.322±0.006                            |
| Pb                  | 0.276±0.003                   | 0.394±0.1                             | 0.299±0.061                            |
| Zn                  | 0.245±0.04                    | 1.242±0.03                            | 0.556±0.008                            |

Presented values shown as mean ± SD

Chromium (Cr) concentration was 0.001 mg/kg in Clarias gariepinus and Anguilla labiate. The mean concentration of Cu ranged 2.16 mg/kg – 10.56mg/kg as the highest value was found in Anguilla labiate with the lowest in Clarias gariepinus, which was far below Cu in Ikema and Egiebor [36] assessment in fish sample having 0.03mg/kg. Mercury concentration was highest in Clarias gariepinus having 0.311mg/kg, which is lower than commission of the European communities [37] guideline of 0.5mg/kg. The mean lead concentration of Heterotis niloticus had highest concentration of 0.394mg/kg followed by Anguilla labiate with a concentration of 0.299mg/kg and the least value of 0.276mm/kg in Clarias gariepinus, which was below FAO/WHO limit of 0.4mg/kg for fish species [38].

The concentrations of Cadmium ranged between 0.020mg/kg - 0.028mg/kg. The highest concentration was measured in the muscles of Anguilla labiate while the lowest was recorded from Heterotis niloticus. For zinc, the value recorded ranged between 0.245mg/kg - 1.242mg/kg for all three fish species. The highest concentration of nickel (0.514 mg/kg) was measured in Heterotis niloticus while the lowest concentration of 0.322mg/kg was detected in Anguilla labiate. The highest concentration of iron (Fe) was predominant in Anguilla labiate having 1.93mg/kg, while the lowest value of 1.23mg/kg was recorded in Heterotis niloticus.

3.1.1 Heavy metal concentrations in surface water and sediment samples

Table 4 and Fig. 3 shows the concentration of heavy metals in surface water (mg/l) and sediments (mg/kg) in seasonal variations (raining and dry seasons). For water samples, As, Cd, Cr, Cu, Fe, Hg and Pb showed high concentration for raining season in comparison to...
dry season, as Al, Ni and Zn were dominant during dry season respectively. Using percentage stark column arrangement (Fig. 3i), we can see that Al and Zn was 100% at dry season, while As. was 100% at raining season; Cu and Pb had 96% for raining season and 4% for dry season. For sediment samples (Fig. 3ii), Cr, Cu, Ni and Pb concentration in raining season were higher than dry season, and vice versa for dry season that is As, Cd, Fe, Hg, Zn were dominant, although As were similar in concentration for both season at 0.001 mg/kg. A view at Fig. 3ii shows that As, Fe and Zn had 50%, 46% and 45% cumulative concentration for raining season as Al and Hg had 10% and 19% for raining season, while 90% and 81% for dry season respectively.

3.1.2 Correlation matrix of fish, surface water and sediment samples

Pearson correlation was conducted for the heavy metal concentration in fish samples in relation to water and sediment as presented in Table 5. The correlation coefficient was significant at $p \leq 0.05$ in most cases with presence of positive and negative correlation. A review of the three fish samples depicts that they had similar correlation matrices across all metal substrates in water and sediment samples attributed to bioaccumulation and bio-speciation of heavy metals and other pollutants in tandem to seasonal variation [39-42].

A strong correlation indicates that metals across both fish and water/sediments have common pollution source and similar migration behavior, while if there is medium or weak correlation, it depicts that there is slight or no influence associated between the fish and water/sediment samples [43, 44]. In view of this correlating regression, positive values show that they are from similar or mutual source and reaction mode, while negative is associated to different polluting or interacting source and biochemical interaction taken place no associated to water and sediment samples [44-46].

Table 4. The concentrations of heavy metals in surface water and sediment samples

| Heavy metal | water$^a$ (mg/l) | water$^b$ (mg/l) | Sediment$^a$ (mg/kg) | sediment$^b$ (mg/kg) |
|-------------|------------------|------------------|----------------------|----------------------|
| Al          | 0.000±0.000      | 0.246±0.058      | 0.160±0.018          | 1.458±0.892          |
| As          | 0.005±0.003      | 0.000±0.000      | 0.0006±0.0009        | 0.001±0.003          |
| Cd          | 0.032±0.026      | 0.270±0.190      | 0.316±0.059          | 0.788±0.131          |
| Cr          | 0.099±0.084      | 0.039±0.023      | 0.112±0.052          | 0.030±0.023          |
| Cu          | 0.186±0.167      | 0.007±0.011      | 0.029±0.042          | 0.022±0.033          |
| Fe          | 2.308±0.823      | 0.180±0.063      | 2.371±0.216          | 2.653±0.918          |
| Hg          | 1.501±1.093      | 0.195±0.017      | 0.150±0.035          | 0.614±0.302          |
| Ni          | 0.254±0.067      | 0.773±0.464      | 0.945±0.189          | 0.781±0.134          |
| Pb          | 0.724±0.789      | 0.023±0.014      | 0.039±0.024          | 0.002±0.003          |
| Zn          | 0.000±0.000      | 2.903±1.263      | 0.766±1.016          | 0.931±1.397          |

a: raining season, b: dry season; Presented values shown as mean ± SD

Fig. 3. Percentage stark column of water and sediment samples
Table 6 represents correlation conducted for water and sediment samples during wet and dry season. We can see therefore that there was presence of positive and negative correlation across all heavy metals accessed. Al correlated with Cd (0.961) and Cr (-0.71) strongly, with As correlating with Cu (0.993), Hg (0.952), Ni (-0.911), Pb (0.976) and Zn (-0.772), vertical correlation of Cd and Cr produced medium and weak correlation, while Cu, Fe, Hg, Ni, Pb correlated strongly, medium and weak accordingly, as there were presence of negative and positive correlation signifying all metal components were not from the same source and biochemical interaction mode between water and sediment samples [47-50].

3.1.3 Health risk assessment of fish, surface water and sediment samples

3.1.3.1 Cancer risk

The result of carcinogenic risk assessment was conducted heavy metals (Al, As, Cd, Cr (III), Cr (VI), Cu, Fe, Hg, Ni, Pb, Zn) in fish samples, surface water and sediment in Ogbaru axis of River Niger as presented in Table 7 and 8 across different exposure pathways in adults and children. Using USEPA reference range of 1.00E-06 – 1.00E-04 [51], one can see that both children and adults were within and above the range, which entails that there will be no associated cancer issues across different exposure pathways. The total exposure pathway (total CR) for adults is Al, Cr (III), Cu, Fe, Hg, Zn (0.00E+00), As (2.30E-05), Cd (1.74E-05), Cr (VI) 1.12E-06, Ni (1.72E-04), Pb (1.33E-06), while children is Al, Cr (III), Cu, Fe, Hg, Zn (0.00E+00), As (9.90E-06), Cd (2.14E-05), Cr (VI) (1.68E-06), Ni (7.83E-05), Pb (5.96E-07). The cumulative cancer risk for adults is 2.15E-04, while children is 1.12E-04, which entails that there is likelihood that children will encounter cancer health risk compared to adults even though the value is within USEPA reference range [32].

3.1.3.2 Hazard quotient (HQ)

The result of heavy metals (Al, As, Cd, Cr (III), Cr (VI), Cu, Fe, Hg, Ni, Pb, Zn) in Ogbaru axis of River Niger is presented in Table 9 and 10. A review of hazard quotient evaluated for all exposure pathways in fish, surface water and sediment shows that HQ were less than 1 for adults, while for children were less than 1 except for fish dietary exposure (Anguilla labiate) in Cu having 2.09. The total exposure pathway (total HQ) of heavy metals for adult is Al (1.26E-05), As (1.19E-01), Cd (2.82E-02), Cr (III) (1.61E-06), Cr (VI) (3.01E-04), Cu (1.36E+00), Fe (2.59E-03), Hg (3.82E-01), Ni (2.30E-02), Pb (1.01E-01), Zn (2.57E-03), which shows that Cu is greater than 1 and vice versa for others heavy metals. For children, the total HQ is Al (4.39E-05), As (2.60E-01), Cd (1.11E-01), Cr (III) (8.93E-06), Cr (VI) (4.45E-03) Cu (2.96E+00), Fe (5.89E-03), Hg (1.30E+00), Ni (5.42E-02) Pb (2.37E-01) Zn (6.36E-03), which shows that Cu and Hg were greater than 1 and less than 1 for other heavy metals. Therefore, we can see that the cumulative hazard quotient for adults is 2.02, while children is 4.93 implying children are extremely at risk in tandem to adults.

4. DISCUSSION

Heavy metals in diverse concentration are released from a host of natural and anthropogenic source that pose negative environmental and health-based risk over a period of time [52,53]. According to Vu et al. [54], anthropogenic activities lead to the release of heavy metals that a readily mobile in surface water, which thereafter suspend and deposit them on sediment fine grains. As these anthropogenic metals reach high threshold, aquatic organism is impacted negatively via bioactivity and mobile bio-accessibility from contaminated sediment finegrains and water body [55,56]. In this study, heavy metal concentration varied over fish, surface water and sediment samples, thus implies that biochemical transformation and geochemical interaction has great impact to floras and faunas in relation to humans [57-59].

According to WHO [60], arsenic (As) is found in diet, mostly in fish and shells, which exist as less toxic organic form in comparison to inorganic form, as such limited data has suggested that natural and anthropogenic source could impact on the concentration depending on the location. Arsenic in high concentration is known to cause short- and long-term health risks such as tissue and organ cancer, dermal lesion and vascular diseases, although arsenic exposure in humans are excreted via urine or sweat as organic acids in minute concentration [60-63].

Aluminum (Al) and iron (Fe) are known to exist in water and sediment as combined component of carbonates, sulphates, chlorides, oxides that are easily absorbed in tissues and bones of aquatic
Table 5. Correlation matrix between fish samples in relation to water and sediment

| C. garipinus and water | Al   | As   | Cd   | Cr    | Cu   | Fe   | Hg   | Ni    | Pb    | Zn   |
|------------------------|------|------|------|-------|------|------|------|-------|-------|------|
| Al                     | -0.574 | 0.954 | -0.181 | -0.576 | 0.797 | 0.906 | 0.260 | -0.671 | 0.747 |
| As                     | -0.481 | -0.792 | -0.702 | 0.999 | -0.952 | -0.173 | -0.940 | 0.992 | -0.970 |
| Cd                     | 0.994 | -0.573 | 0.121 | -0.783 | 0.941 | 0.739 | 0.536 | -0.862 | 0.911 |
| Cr                     | -0.197 | -0.765 | -0.909 | -0.700 | 0.449 | -0.580 | 0.903 | -0.608 | 0.519 |
| Cu                     | -0.505 | 0.999 | -0.595 | -0.747 | -0.952 | -0.176 | -0.939 | 0.993 | -0.970 |
| Fe                     | -0.979 | 0.292 | -0.951 | 0.393 | 0.318 | 0.467 | 0.790 | -0.983 | 0.997 |
| Hg                     | -0.625 | -0.383 | -0.537 | 0.888 | -0.358 | 0.771 | -0.173 | -0.294 | 0.395 |
| Ni                     | 0.970 | -0.252 | 0.937 | -0.431 | -0.278 | -0.999 | -0.797 | -0.890 | 0.836 |
| Pb                     | -0.818 | -0.111 | -0.750 | 0.725 | -0.084 | 0.918 | 0.961 | -0.934 | -0.990 |
| Zn                     | 0.999 | -0.475 | 0.993 | -0.204 | -0.499 | -0.980 | -0.630 | 0.971 | -0.822 |

| H. niloticus and water | Al   | As   | Cd   | Cr    | Cu   | Fe   | Hg   | Ni    | Pb    | Zn   |
|------------------------|------|------|------|-------|------|------|------|-------|-------|------|
| Al                     | -0.580 | 0.956 | -0.166 | -0.582 | 0.723 | 0.990 | 0.183 | -0.648 | -0.267 |
| As                     | -0.925 | -0.793 | -0.707 | 0.999 | -0.982 | -0.688 | -0.907 | 0.996 | 0.940 |
| Cd                     | 0.988 | -0.898 | 0.130 | -0.794 | 0.893 | 0.988 | 0.462 | -0.842 | -0.537 |
| Cr                     | -0.139 | 0.506 | -0.076 | -0.705 | 0.562 | -0.026 | 0.939 | -0.644 | -0.906 |
| Cu                     | -0.548 | 0.188 | -0.600 | -0.752 | -0.983 | -0.69 | -0.906 | 0.997 | 0.939 |
| Fe                     | -0.864 | 0.991 | -0.830 | 0.618 | 0.053 | 0.8123 | 0.812 | -0.995 | -0.859 |
| Hg                     | -0.412 | 0.728 | -0.352 | 0.960 | -0.537 | 0.814 | 0.318 | -0.748 | -0.399 |
| Ni                     | 0.874 | -0.993 | 0.841 | -0.602 | -0.072 | -0.999 | -0.802 | -0.867 | -0.996 |
| Pb                     | -0.891 | 0.997 | -0.860 | 0.574 | 0.107 | 0.998 | 0.781 | -0.999 | 0.907 |
| Zn                     | 0.912 | -0.999 | 0.884 | -0.533 | -0.156 | -0.995 | -0.749 | 0.996 | -0.999 |

| A. labiate and water | Al   | As   | Cd   | Cr    | Cu   | Fe   | Hg   | Ni    | Pb    | Zn   |
|----------------------|------|------|------|-------|------|------|------|-------|-------|------|
| Al                   | -0.803 | -0.788 | -0.702 | 0.999 | -0.923 | -0.689 | -0.959 | 0.993 | -0.899 |
| As                   | 0.999 | -0.792 | 0.115 | -0.789 | 0.965 | 0.989 | 0.581 | -0.854 | 0.978 |
| Cd                   | -0.129 | 0.694 | -0.111 | -0.702 | 0.373 | -0.032 | 0.876 | -0.616 | 0.318 |
| Cr                   | -0.513 | -0.100 | -0.528 | -0.785 | 0.340 | -0.923 | -0.69 | -0.959 | 0.994 | -0.899 |
| Cu                   | -0.982 | 0.902 | -0.978 | 0.315 | 0.340 | 0.915 | 0.775 | -0.961 | 0.998 |
| Fe                   | -0.395 | 0.865 | -0.378 | 0.962 | -0.586 | 0.565 | 0.455 | -0.768 | 0.937 |
| Hg                   | 0.993 | -0.869 | 0.990 | -0.247 | -0.406 | -0.997 | -0.503 | -0.92 | 0.736 |
| Ni                   | -0.799 | 0.999 | -0.788 | 0.699 | -0.107 | 0.899 | 0.868 | -0.865 | 0.943 |
| Pb                   | 0.984 | -0.897 | 0.980 | -0.305 | -0.349 | -0.999 | -0.554 | 0.998 | -0.894 |

Correlation significant at p ≤ 0.05
**Table 6. Correlation matrices of water and sediment**

|       | Al    | As    | Cd    | Cr    | Cu    | Fe    | Hg    | Ni    | Pb    | Zn    |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Al    | 1     |       |       |       |       |       |       |       |       |       |
| As    | -0.367| 1     |       |       |       |       |       |       |       |       |
| Cd    | 0.961 | -0.567| 1     |       |       |       |       |       |       |       |
| Cr    | -0.710| 0.533 | -0.652| 1     |       |       |       |       |       |       |
| Cu    | -0.442| 0.993 | -0.644| 0.524 | 1     |       |       |       |       |       |
| Fe    | 0.333 | 0.472 | 0.278 | 0.395 | 0.368 | 1     |       |       |       |       |
| Hg    | -0.14 | 0.952 | -0.390| 0.248 | 0.943 | 0.426 | 1     |       |       |       |
| Ni    | 0.296 | -0.911| 0.547 | -0.200| -0.930| -0.168| -0.962| 1     |       |       |
| Pb    | -0.497| 0.976 | -0.699| 0.499 | 0.994 | 0.268 | 0.929 | -0.949| 1     |       |
| Zn    | 0.018 | -0.772| 0.121 | -0.617| -0.700| -0.914| -0.679| 0.482 | -0.619| 1     |

*Correlation significant at p ≤ 0.05*

**Table 7. Cancer risk (CR) of heavy metal exposure matrix in adults**

|             | Dietary Ingestion | Ingestion | Surface water Exposure pathways | Ingestion | Dermal | Sediment Exposure pathways | Ingestion | Dermal | Inhalation | Total CR |
|-------------|-------------------|-----------|--------------------------------|-----------|--------|----------------------------|-----------|--------|------------|----------|
| C. garpinus | 2.18E-05          | 5.30E-08  | 1.47E-06                       | 1.02E-06  | 2.55E-06| 8.64E-08                   | 2.15E-07  | 2.07E-08| 5.15E-08  | 1.46E-07 |
| H. niloticus| 5.30E-08          | 1.47E-06  | 2.15E-07                       | 2.07E-08  | 5.15E-08| 1.46E-07                   | 1.46E-07  | 2.07E-08| 5.15E-08  | 1.46E-07 |
| A. labiate  | 2.18E-05          | 5.30E-08  | 1.47E-06                       | 1.02E-06  | 2.55E-06| 8.64E-08                   | 2.15E-07  | 2.07E-08| 5.15E-08  | 1.46E-07 |
| Cr (III)    | 2.18E-05          | 5.30E-08  | 1.47E-06                       | 1.02E-06  | 2.55E-06| 8.64E-08                   | 2.15E-07  | 2.07E-08| 5.15E-08  | 1.46E-07 |
| Cr (VI)     | 2.18E-05          | 5.30E-08  | 1.47E-06                       | 1.02E-06  | 2.55E-06| 8.64E-08                   | 2.15E-07  | 2.07E-08| 5.15E-08  | 1.46E-07 |
| Cu           | 2.18E-05          | 5.30E-08  | 1.47E-06                       | 1.02E-06  | 2.55E-06| 8.64E-08                   | 2.15E-07  | 2.07E-08| 5.15E-08  | 1.46E-07 |
| Fe           | 2.18E-05          | 5.30E-08  | 1.47E-06                       | 1.02E-06  | 2.55E-06| 8.64E-08                   | 2.15E-07  | 2.07E-08| 5.15E-08  | 1.46E-07 |
| Hg           | 2.18E-05          | 5.30E-08  | 1.47E-06                       | 1.02E-06  | 2.55E-06| 8.64E-08                   | 2.15E-07  | 2.07E-08| 5.15E-08  | 1.46E-07 |
| Ni           | 2.18E-05          | 5.30E-08  | 1.47E-06                       | 1.02E-06  | 2.55E-06| 8.64E-08                   | 2.15E-07  | 2.07E-08| 5.15E-08  | 1.46E-07 |
| Pb           | 2.18E-05          | 5.30E-08  | 1.47E-06                       | 1.02E-06  | 2.55E-06| 8.64E-08                   | 2.15E-07  | 2.07E-08| 5.15E-08  | 1.46E-07 |
| Zn           | 2.18E-05          | 5.30E-08  | 1.47E-06                       | 1.02E-06  | 2.55E-06| 8.64E-08                   | 2.15E-07  | 2.07E-08| 5.15E-08  | 1.46E-07 |
| ∑ HM         | 7.72E-05          | 6.87E-05  | 4.32E-05                       | 4.24E-05  | 2.07E-05| 3.42E-06                   | 1.67E-05  | 1.46E-06| 2.98E-06  | 5.42E-07 |

*No data – Analytical data unavailable; No CSF – reference value unavailable; Total CR: total cancer risk; ∑ HM: sum total of heavy metals*
Table 8. Cancer risk (CR) of heavy metal exposure matrix in children

| Fish Exposure pathway | Surface water Exposure pathways | Sediment Exposure pathways | Total CR |
|-----------------------|---------------------------------|---------------------------|----------|
|                       | Ingestion                       | Dermal                    | Inhalation |
|                       | C. garipinus                    | H. niloticus              | A. labiate |
|                       | Water*                          | Water*                    | Water*    | Water* |
|                       | Sediment a                      | Sediment b                | Sediment a | Sediment b |
|                       | Sediment a                      | Sediment b                | Sediment a | Sediment b |
|                       | Sediment a                      | Sediment b                | Sediment a | Sediment b |
| Pb                    | No CSF                          | No CSF                    | No CSF     | No CSF   |
| Cu                    | 9.34E-06                        | 3.01E-07                  | 2.01E-07   | 9.14E-09 |
| Cr (III)              | 9.14E-06                        | 2.87E-08                  | 3.77E-08   | 7.89E-07 |
| Cr (VI)               | 3.56E-06                        | 3.94E-09                  | 9.85E-09   | 2.94E-09 |
| Al                    | 3.31E-05                        | 2.94E-05                  | 1.67E-08   | 3.83E-06 |
| HM: sum total of heavy metals |

No data – Analytical data unavailable; No CSF; No IUR – reference value unavailable; Total CR: total cancer risk; Σ HM: sum total of heavy metals

Table 9. Hazard quotient (HQ) of heavy metal exposure matrix in adults

| Fish Exposure pathway | Surface water Exposure pathways | Sediment Exposure pathways | Total HQ |
|-----------------------|---------------------------------|---------------------------|---------|
|                       | Ingestion                       | Dermal                    | Inhalation |
|                       | C. garipinus                    | H. niloticus              | A. labiate |
|                       | Water*                          | Water*                    | Water*    | Water* |
|                       | Sediment a                      | Sediment b                | Sediment a | Sediment b |
|                       | Sediment a                      | Sediment b                | Sediment a | Sediment b |
|                       | Sediment a                      | Sediment b                | Sediment a | Sediment b |
| Pb                    | 9.14E-06                        | 3.01E-07                  | 2.01E-07   | 9.14E-09 |
| Cu                    | 9.14E-06                        | 3.01E-07                  | 2.01E-07   | 9.14E-09 |
| Cr (III)              | 9.14E-06                        | 3.01E-07                  | 2.01E-07   | 9.14E-09 |
| Cr (VI)               | 3.56E-06                        | 3.94E-09                  | 9.85E-09   | 2.94E-09 |
| Al                    | 3.31E-05                        | 2.94E-05                  | 1.67E-08   | 3.83E-06 |
| HM: sum total of heavy metals |

No data: Analytical data unavailable; Total HQ: total hazard quotient; Σ HM: sum total of heavy metals
Table 10. Hazard quotient (HQ) of heavy metal exposure matrix in children

| Fish Exposure pathway | Surface water Exposure pathways | Sediment Exposure pathways | Total HQ |
|-----------------------|---------------------------------|---------------------------|---------|
|                       | Dietary Ingestion               | Ingestion                 | Dermal  | Inhalation |
|                       | C. garipinus                    |                           |         |            |
|                       | Al                              | 1.51E-05                  | 3.96E-06 | No Data    | 1.59E+00 |
|                       | As                              | 2.46E-01                  | 7.92E-03 | 5.28E-03   | 6.47E+00 |
|                       | Cd                              | 1.74E-02                  | 1.58E-02 | 2.22E-02   | 1.66E+00 |
|                       | Cr (III)                        | 5.28E-07                  | No Data  | 5.28E-07   | 8.21E+00 |
|                       | Cr (VI)                         | 2.64E-04                  | No Data  | 2.64E-04   | 5.28E+00 |
|                       | Cu                              | 4.28E-01                  | 4.35E-01 | 2.09E+00   | 2.64E+00 |
|                       | Fe                              | 1.98E-03                  | 1.40E-03 | 2.18E-03   | 5.28E+00 |
|                       | Hg                              | 8.21E-01                  | 2.64E-03 | No Data    | 5.28E+00 |
|                       | Ni                              | 1.66E-02                  | 2.04E-02 | 1.28E-02   | 2.64E+00 |
|                       | Pb                              | 6.25E-02                  | 8.92E-02 | 6.77E-02   | 2.64E+00 |
|                       | Zn                              | 6.47E-04                  | 3.28E-03 | 1.47E-03   | 2.64E+00 |
|                       | Σ HM                            | 1.59E+00                  | 5.76E-01 | 2.20E+00   | 5.28E+00 |

No data – Analytical data unavailable; Total HQ: total hazard quotient; Σ HM: sum total of heavy metals

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organisms and humans also. Similarly, they both impact water quality such as color, turbidity, hardness, conductivity and dissolved oxygen [64,65]. There is little indication that aluminum and iron have health implication, but hypothetically, it has been said that extreme \textit{aluminum exposure leads to Alzheimer diseases in humans} [66].

Iron (Fe) is an essential element in human nutrition, which estimated daily requirement depends on age, sex, physiological status and iron bioavailability [60].

Cadmium (Cd) and zinc (Zn) in high concentration is an indication of pollution from each other, as they are released into the environment from several industrial activities such as steel, plastics, fertilizer that get absorbed and/or assimilated by aquatic organism and agricultural plants. Zinc impacts taste at minimum concentration of 4mg/l (as sulphate, carbonate and chloride).

In humans, cadmium and zinc accumulate in kidney after exposure leading to cytotoxicity induced tumors in urinary tract and development of hyperplasia and subsequently neoplasia [67,68,69].

Cadmium (III) and (VI) are known valence group of chromium that are prevalent different in biochemical interaction in human body [70]. Chromium (III) is a vital source of nutrient that exist in food source, although chromium (VI) is known to be carcinogenic via different exposure route (inhalation, oral and dermal). A national toxicology program (NTP) study shows that chromium (VI) is reduced to chromium (III) in human stomach and gastrointestinal tract in a dose-response interaction at very low concentration, but at high concentration can lead to tumor and cancer in organs and tissues in humans [71].

Copper (Cu) and lead (Pb) are released into the environment from natural and anthropogenic sources, as its solubility is initiated by pH dominant anions (sulphate, nitrate, phosphate, chloride, carbonate) that impacts water quality (temperature, taste, color, dissolved oxygen) over a period of time [72,73]. Short-term exposure of copper leads to gastrointestinal irritation (diarrhea), which is concentration dependent, as long-term effect can lead to metabolic homeostasis and trigger Wilson disease in gene carriers [60].

Exposure to lead has been known to cause neurodevelopmental issues, cardiovascular diseases, impaired renal function and fertility, hypertension, as lead in blood is known to cause blood cell-tumor and systolic blood pressure [38,65,74]. In children, lead decreases intelligence quotient (IQ) point by at least two (2) point and increase systolic blood pressure by about 3 mmHg [75].

Mercury exist as organic and inorganic forms in aquatic environment as inorganic mercury exposure in human causes genotoxic health activities (tissue and organ tumor) as oral exposure above recommended guideline of 0.0006mg/l result in hemorrhagic gastritis in stomach and intestinal tissue and kidney damage [63,76-79].

Nickel exist predominantly in food source as water and sediment exposure is a minor contributor to adult and children over a period of time. Although presence of steel industries can lead to increase nickel pollution from industrial effluents, which impacts the aquatic and land environment. High concentration of nickel causes dermal allergies (dermatitis) [80].

The correlative review as shown in Table 5 and 6 shows that diverse activities such as industrial effluents and emission, agricultural land use, sanitary landfill, mining activities, fishing and water-land transport has negative influence on surface water and sediment, which in turn leads to exposure to floras and faunas over a period of time [30,31]. As the aforementioned activities takes place, it leads to the release of chemical toxins in high concentration that has the potential to cause immense health risk to a population, which leads to carcinogenesis, mutagenesis and non-carcinogenesis (adverse health effect) [51].

5. CONCLUSION

The study evaluated significant concentration of heavy metals in three fish species, surface water...
and sediment samples from Ogbaru axis of River Niger. However, the concentration was low or moderate within set WHO standard, as correlation showed positive and negative regression indicating that they were from similar source and vice-versa thus lead to bioaccumulation and increased toxicity in fish samples. Cancer risk and hazard quotient showed that fish dietary exposure is a major contributor compared to surface water and sediment exposure for both adults and children respectively. Children are more prone to have adverse health effect from consumption of fish samples exposed to low or moderate heavy metal concentration in comparison to adults. Based on this results, one can draw that fish samples were immensely impacted by anthropogenic activities that are released into the River Niger that span over a wide distance. Therefore, the following recommendations is advocated, which are further evaluation of pollutants in microscale and nanoscale is advocated to derive required information on the exposure medium of environmental matrices to human, regulatory action and proactive attention should be enforced on environmental polluters involved in diverse activities, and regular public health check on the level of heavy metals among the populace in the communities that border the study area should be employed in order to safeguard health and wellbeing.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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