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TARGET CANCER RISK AND OTHER POTENTIAL HUMAN HEALTH RISK ASSESSMENTS OF HEAVY METALS INTAKE VIA CONSUMPTION OF CATFISH (CLARIA BUTHUPOGON) COLLECTED FROM RIVER OLUWA AND RIVER OWENA, SOUTHWESTERN NIGERIA

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ABSTRACT

Concentrations of Fe, Cu, Mn, Cr, Zn, Hg, Pb, Cd, Ni, Ni and V, were determined in catfish (Clarias buthupogon) collected from River Oluwa and River Owena in the dry and rainy seasons. Analysis was done using the AAS using GBC Avanta PM. Average Estimated Daily Intake (EDI) of Fe, Cu, Mn, and Zn were lower than the Dietary Daily Intake for an adult recommended by the Institute of Medicine, Food and Nutrition Board. Average EDIs of Cr (0.8566 mg/kg/day), Pb (0.5371 mg/kg/day), V (0.0480 mg/kg/day), Cd (0.1796 mg/kg/day), Ni (0.4014 mg/kg/day) were higher than the recommended Average Daily Intake of the metals. All Hazard Index (Hi) values calculated are greater than 1, which shows high non-carcinogenic risk exposure with significant risk to consumers. Target Cancer Risk (TCR) values of Pb and Cd calculated are within the safe limit of TCR 0.000001 and 0.0001 suggested by USEPA. TCR values of Cr and Ni are unacceptable because they exceeded the safe limit of TCR 0.0001 suggested by USEPA. This shows that there is a potential cancer risk by continuous exposure to high concentration of Cr and Ni from consuming catfish collected from Rivers Oluwa and Owena (dry and rainy seasons).

Keywords: Catfish, non-carcinogenic, cancer-risk, hazard index, target hazard quotient

I. INTRODUCTION

Fish contains high-quality proteins, vitamins, and essential omega-3 fatty acids. It is also a good dietary source of cardioprotective docosahexaenoic fatty acid and eicosapentaenoic fatty acid [1]. Therefore, regular fish consumption equivalent to at least 1–2 servings per week is recommended to prevent diet-related chronic diseases. The recommended fish consumption is at least two times a week (quantities of approx. 300 g). The mean consumption of an adult living in Europe is 24.4 kg of fish or seafood per year [2].. The process of metal accumulation in the organisms is strongly affected by the habitat of the organism [3], [4]. Bottom sediments are known to act as a sink for heavy metals introduced to the marine environment [5]. Therefore, benthic organisms, which occupy the bottom layer of the water column, tend to accumulate the highest levels of heavy metals in comparison to pelagic organisms [6], [7].The most prevalent means of livelihood at the samplings points of River Oluwa and River Owena is fishing with trap sets, cast nets, hooks, and lines [8]. Fish species in the rivers at the sampling points are Clarias garienpinus, Clarias buthopogon, Tilapia zillii, Oreochromis niloticus, and Mormyrus rume. Besides this natural source, Catfish is the main species of fish farmed in the Southern part of Nigeria. Tilapia and carp are also produced and consumed, but they have not gained much popularity.

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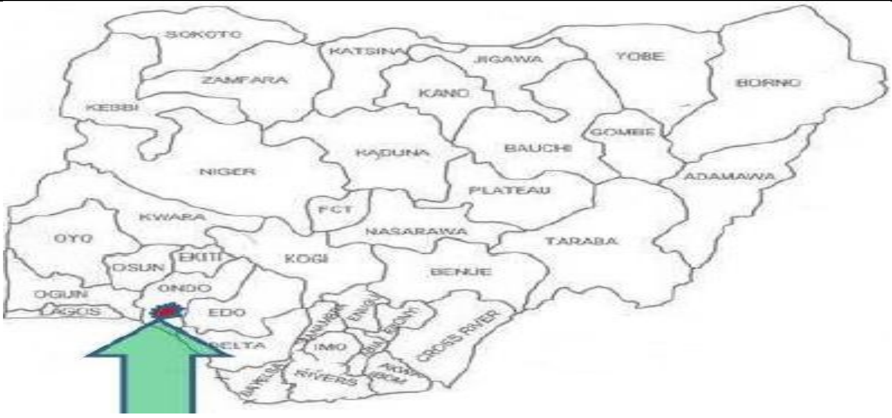

Fig. 2: Map of Nigeria showing sampling points

Clarias buthupogon is catfish that belongs to the species of Clarias which is characterized by having an elongated, body, lively, and have the ability to live for long periods out of water [9]. (Akinloye and Olubanjo, 2017). Indices of weight and volumetric occurrences indicated that Clarias buthupogon eats aquatic insects, crustaceans, oligochaetes, mollusks, and animal and plant debris [10].

Fig. 1: Picture of Clarias buthupogon

Catfish is the major fish cultured in Nigeria because it is found all over the Country, eaten by most tribes, resistant to harsh environmental conditions, commands a good price, tasty, and can be kept alive for days during marketing. Estimates put the current production output of catfish in the Country at over 253,898 metric tonnes per year [11].

The health risk assessment of heavy metals to human health through the consumption of Tilapia and catfish has been reported [12]. It was shown that there is evidence of health risks to consumers. Assessment of heavy metals contamination and human health risk in Clarias gariepinus [Burchell, 1822] collected from Jabi Lake, Abuja, Nigeria was carried out [13]. The Hazard Index (HI) values revealed no adverse health risk. Ighariemu et al. [14] studied the levels of some heavy metals in three different species of catfishes in Ikoli Creek, Bayelsa State, Nigeria. They concluded that there was probable risk of cancer for the populace that consumed fishes caught at Ikoli creek. Bioaccumulation of Heavy Metals by Clarias gariepinus (African Catfish) in Asa River, Ilorin, Kwara State, has been investigated [15]. It was found that the bioaccumulation level of heavy metals in selected organs and tissues of African catfish in Asa River, Ilorin, Kwara State, Nigeria was very high and the level of accumulation of heavy metals increased downstream. Health risk assessment of heavy metals in fish (Chrysichthys nigrodigitatus) from Two Lagoons in Southwestern Nigeria was carried out [16]. It was reported that the Total Hazard Quotient (THQ) for all metals (THQ) had no adverse health effects from the consumption of fish. However, the Target Cancer Risk (TR) due to Pb and Ni exposure through fish consumption may increase the probability of developing cancer in the future. Human health risk assessment of some heavy metals in a rural spring, Southeastern Nigeria has been carried out. Health risk assessment for all the sites indicated that there is no particularly dangerous single heavy metal, but their cumulative effect, indicated by the hazard index (HI) calls for concern. Hazard Index (HI) for all the stations highly exceeded threshold value.

Reports of the effects of high concentrations of heavy metals in catfish (Clarias buthugon) in Nigeria are limited.

Researches carried out showed that fish in rivers bio-accumulate heavy metals to a large extent that can cause health consequences [17], [18], [19]. Therefore, this study assessed the risk of heavy metals in Catfish (Clarias buthugon) against possible health hazards because fish consumption has increased tremendously across Nigeria, especially in the Western part of the country. Okitipupa and Owena communities depend mainly on fishing as their main occupation. These communities also consume fish to a large extent.

II. METHODOLOGY

Study Sites:

River Owena is at Latitude 6°33' 53" N and Longitude 5º 8' 52" E in Ondo State in the Southwestern part of Nigeria [20].

River Oluwa lies between Latitude 7°2' 00" N and Longitude 4º 31' 30" E from Osun State through Ondo State before discharging into the Atlantic Ocean at Ayetoro in the Southwestern part of Nigeria [21], [22].

Sample Collection

Catfish (Clarias buthupogon) was collected from River Oluwa at Okitipupa and River Owena at Owena, Kilometer 10, Akure – Ondo Road, Western Nigeria. Samples were taken to the laboratory on the day of collection and preserved

Heavy Metal Determination

25mls digest of the samples was analyzed in the AAS using GBC Avanta PM ver 2.02. Blank samples were run to avoid contamination during the analysis [7], [23], [24], [25]. The tissues were placed in watch glasses and oven-dried at 105 °C until the weight is constant and later cooled in the desiccators. A representative sample (2.5g) of the plant was accurately weighed and was subjected to nitric, perchloric and sulphuric acid digestion (wet oxidation). Digestion was carried out with nitric, perchloric and sulphuric acid mixture in ratio 10:4:1 at a rate of 5 mL/per 0.5 g of sample and were placed on a hot plate at 100˚C temperature. Digestion was continued until the liquor becomes clear. All the digested liquors were filtered and diluted to 25 mL with distilled water of the element in the sample solution times 20 as additional factor in µg/g dry weight.

Health Risk Evaluation Methods

Estimated Daily Intake (EDI)

The EDI of an adult, of each heavy metal was calculated using the following equation [16], [25].

EDI ($mg\ kg^{-1}\ day^{-1}$) = (EF X ED X FIR X C) / (WAB X ATn)

Where EF = Exposure frequency = 365 days in a year

ED = Exposure duration = 30 years for an adult

FIR = Fish Ingestion Rate = 19.5 g per person per day

C= Concentration of the metal in fish (mg/kg)

WAB = Average body weight (kg), (60 kg for adults)

ATn = Average exposure time for non-carcinogens (365 days

year-1 × ED)

Target Hazard Quotient (THQ) [16], [26] .

This shows the estimate of the non-carcinogenic risk level due to heavy metal exposure.

To determine the human health risk from consuming metal contaminated fish, the THQ was calculated using the equation given below:

$THQ = ((EF \times ED \times FIR \times C)/(RfD \times WAB \times ATn)) \times 10^{-3}$

RfD is the oral reference dose as shown in Table 1 to Table 4.

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If the THQ is less than 1, the exposed population is unlikely to experience obvious adverse effects. If the THQ is equal to or higher than 1, there is a potential health risk, and related interventions and protective measurements should be taken (Kawser, et al., 2015).

Hazard Index (HI)

The hazard index (HI) is expressed as the sum of the target hazard quotients (THQ).

$HI = THQ_1 + THQ_2 + THQ_3 \ldots\ldots THQ_n$

The effect of Hazard Index (HI) of the summed metals in humans could be synergistic [16].

HI values less than 1 (HI<1) implies minimal non-carcinogenic risk exposure with no significant health risk to consumers. HI values greater than or equal to 1 (HI<=1) should trigger public health concern.

Target Cancer Risk (TCR) [27], [28], [29].

TCR is used to estimate the carcinogenic risks as shown in the following equation.

$TCR = ((EF \times ED \times FIR \times C \times CSForal)/(WAB \times AT)) \times 10^{-3}$

Where, AT is the averaging time, carcinogens (365 days/year for 70years). CSForal = Cancer slope factor as shown in Table 1.

In general, the excess cancer risk lower than 1 X 10^{-6} (0.000001) are considered to be negligible, cancer risk above 1 X 10^{-4} (0.0001) are considered unacceptable and risks lying between 1 X 10^{-6} and 1 X 10^{-4} are generally considered an acceptable range [30].

III. RESULTS AND DISCUSSION

Table 1: Estimated Target Cancer Risk (TCR) of individual metals from consumption of catfish (Clarias buthupogon) from River Oluwa (Dry season)

Metal	EF (days in a year)	ED (years)	FIR (g /person/day)	C (ppm)	WAB (kg)	Atn (days-1 xED)	EDI (mg kg-1 day -1)	RfD-oral (mg-1 da-1)	THQ	HI	AT	CSForal (kg/day/mg)	TCR
Fe	365	30	19.5	88.90	60	10950	28.8925	0.7	0.0413	1.5	365		
Cu	365	30	19.5	2.00	60	10950	0.6500	0.04	0.0163		365		
Mn	365	30	19.5	7.10	60	10950	2.3075	0.1	0.0231		365		
Cr	365	30	19.5	0.86	60	10950	0.2795	0.0003	0.9317		365	0.5	0.00014
Zn	365	30	19.5	62.50	60	10950	20.3125	0.3	0.0677		365		
Hg	365	30	19.5	0.00	60	10950	0	0.0003	0		365		
Pb	365	30	19.5	1.72	60	10950	0.5590	0.004	0.1398		365	0.009	5.03E-06
Cd	365	30	19.5	0.80	60	10950	0.2600	0.001	0.26		365	0.38	9.88E-05
Ni	365	30	19.5	0.62	60	10950	0.2015	0.05	0.004		365	0.91	0.000183

V	365	30	19.5	0.16	60	10950	0.0520	0.007	0.0074		365		

EF = Exposure Frequency, ED = Exposure Duration, FIR = Fish Ingestion Rate, WAB = Average Body Weight, ATn = Average Exposure Time for non-carcinogens, THQ = Target Hazard Quotients, EDI = Estimated Daily Intake, RfD= Reference Dose, CSForal = Cancer Slope Factor by oral ingestion, HI = Hazard Index, AT – Average Time.

Table 2: Estimated Target Cancer Risk (TR) of individual metals from consumption of catfish (Clarias buthupogon) from River Oluwa (Rainy season)

Metal	EF (days in a year)	ED (years)	FIR (g /person/ day)	C (ppm)	WAB (kg)	Atn (days-1 xED)	EDI (mg kg-1 day -1)	RfD-oral (mg-1 da-1)	THQ	HI	AT	CSForal (kg/day/ mg)	TR
Fe	365	30	19.5	58.8	60	10950	19.1133	0.7	0.0273	4.1	365		
Cu	365	30	19.5	0.86	60	10950	0.2795	0.04	0.007		365		
Mn	365	30	19.5	3.14	60	10950	1.0205	0.1	0.0102		365		
Cr	365	30	19.5	3.51	60	10950	1.1408	0.0003	3.8025		365	0.5	0.00057
Zn	365	30	19.5	12.3	60	10950	4.004	0.3	0.0133		365		
Hg	365	30	19.5	0.00	60	10950	0	0.0003	0		365		
Pb	365	30	19.5	1.7	60	10950	0.5525	0.004	0.1381		365	0.009	4.97E-06
Cd	365	30	19.5	0.39	60	10950	0.12675	0.001	0.1268		365	0.38	4.82E-05
Ni	365	30	19.5	1.88	60	10950	0.611	0.05	0.0122		365	0.91	0.000556
V	365	30	19.5	0.18	60	10950	0.05883	0.007	0.0084		365		

Table 3: Estimated Target Cancer Risk (TR) for individual metals from consumption of catfish (Clarias buthupogon) from River Owena (Dry season

Metal	EF (days in a year)	ED (years)	FIR (g /person/day)	C (ppm)	WAB (kg)	Atn (days-1 xED)	EDI (mg kg-1 day -1)	RfD-oral (mg-1 da-1)	THQ	HI	AT	CSForal (kg/day/ mg)	TR
Fe	365	30	19.5	62.1	60	10950	20.1923	0.7	0.0288	3.5	365		

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Cu	365	30	19.5	1.71	60	10950	0.5558	0.04	0.0139		365		
Mn	365	30	19.5	5.37	60	10950	1.7453	0.1	0.0175		365		
Cr	365	30	19.5	2.81	60	10950	0.9133	0.0003	3.0442		365	0.5	0.000457
Zn	365	30	19.5	35.9	60	10950	11.6513	0.3	0.0388		365		
Hg	365	30	19.5	0.00	60	10950	0	0.0003	0		365		
Pb	365	30	19.5	1.67	60	10950	0.5428	0.004	0.1357		365	0.009	4.88E-06
Cd	365	30	19.5	0.77	60	10950	0.2503	0.001	0.2503		365	0.38	9.51E-05
Ni	365	30	19.5	1.20	60	10950	0.3900	0.05	0.0078		365	0.91	0.000355
V	365	30	19.5	0.13	60	10950	0.0423	0.007	0.006		365		

Table 4: Estimated Target Cancer Risk (TR) for individual metals from consumption of catfish(Clarias buthupogon) from River Owena (Rainy season)

Metal	EF (days in a year)	ED (years)	FIR (g /person/day)	C (ppm)	WAB (kg)	Atn (days-1 xED)	EDI (mg kg-1 day -1)	RfD-oral (mg-1 da-1)	THQ	HI	AT	CSForal (kg/day/ mg)	TR
Fe	365	30	19.5	49.8	60	10950	16.1720	0.7	0.0231	3	365		
Cu	365	30	19.5	0.52	60	10950	0.1690	0.04	0.0042		365		
Mn	365	30	19.5	2.21	60	10950	0.7183	0.1	0.0072		365		
Cr	365	30	19.5	2.54	60	10950	0.8255	0.0003	2.7517		365	0.5	0.000413
Zn	365	30	19.5	12.7	60	10950	4.1243	0.3	0.0137		365		
Hg	365	30	19.5	0.00	60	10950	0	0.0003	0		365		
Pb	365	30	19.5	1.52	60	10950	0.4940	0.004	0.1235		365	0.009	4.45E-06
Cd	365	30	19.5	0.25	60	10950	0.0813	0.001	0.0813		365	0.38	3.09E-05
Ni	365	30	19.5	1.24	60	109	0.403	0.05	0.00		36	0.91	0.0003

						50	0		81		5		67
V	365	30	19.5	0.12	60	109 50	0.039 0	0.00 7	0.00 56		36 5		

Comparison of Concentration of heavy metals in catfish (Clarias buthupogon) with standards

The Pearson correlation coefficient of heavy metals in catfish (Claris buthupogon) at River Oluwa and River Owena in the dry and rainy seasons carried out using SPSS 25.0 showed that Mn and Cu ($r = 0.988^*$, $p < 0.05$), Mn and Zn ($r = 0.974^*$, $p < 0.05$), Mn and Cd ($r = 0.960^*$, $p < 0.05$), Cr and Ni ($r = 0.950^*$, $p < 0.05$) exhibited positively significant correlation. The positive correlation between the metals could be attributed to discharges from non-specific sources of heavy metals input into River Oluwa and River Owena. The heavy metals were probably introduced from several sources.

EDIs of the metals were presented in Tables 1 – 4. Average EDI of Fe obtained was 21.0925 mg/kg/day in the dry and rainy seasons. These are lower than the Tolerable Upper Intake Level of 45 mg/kg/day for adult [31]. The values are slightly above the range of 16 mg/kg/day and 18 mg/kg/day recommended as the median dietary intake for adult. Anemia is the most easily identifiable indicator of functional iron deficiency. Average EDI of Cr obtained was 0.8566 mg/kg/day in the dry and rainy seasons which is higher than the Recommended Adequate Intake of 0.035 mg/kg/day for adult men. Chromium VI is a well established human carcinogen, mutagen, and clastogen, but chromium III compounds are not [31], [33]. Cu had the average EDI value of 0.4135 mg/kg/day is this study. This is lower than the Tolerable Upper Intake Level of 10 mg/kg/day for adult. Mn had the average EDI value of 1.2400 mg/kg/day is this study which is lower than the Tolerable Upper Intake Level of 11 mg/kg/day for an adult. Zn had the average EDI value of 10.0230 mg/kg/day, which is lower than the Tolerable Upper Intake Level of 40 mg/kg/day for an adult. The average EDI of Pb was 0.5371 mg/kg/day. This is higher than the recommended Average Daily Intake of 0.2100 mg/kg/day. High concentration of lead in the body can cause kidney and brain problems, anemia, weakness, fetal developmental errors and infertility [32]. Vanadium had an average EDI of 0.0480 mg/kg/day which is higher than recommended Average Daily Intake of 0.006 mg/kg/day – 0.180 mg/kg/day.

The mean EDI of Cd was 0.1796 mg/kg/day which is higher than the recommended Average Daily Intake of the recommended Average Daily Intake of 0.06 mg/kg/day. High ingestion of cadmium can regulate gene expression and enzyme activity, damage the DNA by generating free radicals, inducing oxidative stress and induce cell proliferation. Nickel had average EDI of 0.4014 mg/kg/day which is higher than recommended Average Daily Intake of 0.074 mg/kg/day – 0.100 mg/kg/day. The risk of adverse effects resulting from excess intakes of nickel from food and supplements appears to be very low at the highest intakes (Institute of Medicine, Food and Nutrition Board, 2001).

The order of Average EDI of the heavy metals: River Oluwa – Dry Season (5.3515 mg/kg/day) > River Owena – Dry Season (3.6283 mg/kg/day) > River Oluwa – Rainy Season (2.6907 mg/kg/day) > River Owena – Rainy Season (2.3026 mg/kg/day). This indicates that ingestion of heavy metals by people in consumption of catfish (Clarias buthupogon) is higher around River Oluwa than River Owena and ingestion of heavy metals by people in consumption of catfish (Clarias buthupogon) is higher in the dry season that in the rainy season.

THQ values are shown in Table 1 to Table 4. The highest THQ value in catfish at River Oluwa in the Dry Season is 0.932 in Cr. This shows that the exposed population is unlikely to experience non-carcinogenic adverse health effect due to heavy metal exposure from the consumption of catfish (Clarias buthupogon). THQ values in catfish taken from River Oluwa in the Rainy season were less than 1 except in Cr (3.803). This THQ in Cr shows that the population around River Oluwa will likely experience non-carcinogenic adverse health effect due to Cr exposure from the consumption of catfish (Clarias buthupogon) collected from River Oluwa in the Rainy season. THQ values in catfish (Clarias buthupogon) collected from River Owena in the Dry season were also less than 1 in the metals except in Cr (3.0442). This also indicates that the population around River Owena will likely experience non-carcinogenic adverse health effect due to Cr exposure from the consumption of catfish (Clarias buthupogon) collected from River Owena in the Dry season. THQ values in catfish (Clarias buthupogon) taken from River Owena in the Rainy season were also less than 1 in the metals except in Cr (2.7517). This also indicates that the population around River Oluwa will likely experience non-carcinogenic

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adverse health effect due to Cr exposure from the consumption of catfish (Clarias buthupogon) collected from River Owena in the Rainy season. HI values are shown in Table 1 to Table 4. HI value calculated for the heavy metals in catfish taken from River Oluwa in the Dry season is 1.4912. The value HI calculated for the heavy metals in catfish taken from River Oluwa in the Rainy Season is 4.1458. HI calculated for the heavy metals in catfish taken from River Owena in the Dry season is 3.5430, while that of the Rainy season is 3.0183. All Hi values calculated are greater than 1, which implies high non-carcinogenic risk exposure with significant risk to consumers of catfish (Clarias buthupogon) taken from River Oluwa and River Owena. These calculated HI values should be a great health concern to the public. Target Cancer Risk (TCR) values are shown in Table 1 to Table 4. In Catfish (Clarias buthupogon) collected from River Oluwa (Dry season and Rainy season) and River Owena (Dry season and Rainy season), TCR values of Pb and Cd are within the acceptable TCR range (between 0.000001 and 0.0001) as suggested by USEPA [30]. This implies that exposure to Pb and Cd through consumption of catfish (Clarias buthupogon) may not increase the probability of developing cancer in the future. TCR values of Cr and Ni are unacceptable because they exceeded the safe limit of TCR 0.0001 suggested by USEPA [30]. This implies that there is a potential cancer risk by continuous exposure to high concentration of Cr and Ni from consuming catfish collected from River Oluwa (Dry season and Rainy season) and River Owena (Dry season and Rainy season). Therefore, there is a need for periodic biomonitoring of River Oluwa and River Owena and increase public awareness on the health implications.

IV. CONCLUSION

Average EDIs of Fe, Cu, Mn, and Zn were lower than the recommended Dietary Daily Intake for an adult, while the Average EDIs of Cr, Pb, V, Cd and Ni were higher than the recommended Average Daily Intake of the metals. Ingestion of heavy metals by people in consumption of catfish (Clarias buthupogon) is higher around River Oluwa than River Owena and higher in the dry season that in the rainy season.

Values of THQ obtained indicate that the population around River Oluwa will unlikely experience non-carcinogenic adverse health effect due to heavy metal exposure from the consumption of catfish (Clarias buthupogon) collected from River Oluwa in the dry season, while the population around River Oluwa will likely experience non-carcinogenic adverse health effect due to Cr exposure from the consumption of catfish (Clarias buthupogon) collected from River Oluwa in the Rainy season. The population around River Owena will likely experience non-carcinogenic adverse health effect due to Cr exposure from the consumption of catfish (Clarias buthupogon) collected from River Owena in the Dry season and Rainy season. Therefore, related interventions and protective measurements should be taken to protect the population around River Oluwa and River Owena.

There is a potential cancer risk by continuous exposure to high concentration of Cr and Ni from consuming catfish collected from River Oluwa (Dry season and Rainy season) and River Owena (Dry season and Rainy season). Therefore, there is a need for periodic biomonitoring of River Oluwa and River Owena and increase public awareness on the health implications among the people living around River Oluwa and River Owena.

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