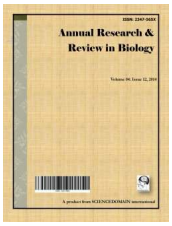

Annual Research & Review in Biology

16(5): 1-14, 2017; Article no.ARRB.34920
ISSN: 2347-565X, NLM ID: 101632869

Comparative Analysis of Contaminability between *Clarias gariepinus* and *Tilapia mariae*

Isibor Patrick Omoregie[1*] and Imoobe Tunde Ohiokhioya Thadeus[2]

[1]Department of Biological Sciences, College of Science and Technology, Covenant University, Canaanland, Ota, Ogun State, Nigeria.
[2]Department of Animal and Environmental Biology, Faculty of Life Sciences, University of Benin, Benin City, P.M.B. 1154, Nigeria.

Authors' contributions

This work was carried out in collaboration between both authors. Author IPO conducted the research, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author ITOT designed and supervised the study. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/ARRB/2017/34920
Editor(s):
(1) Nema Abdelhameed Mohamed, Department of Zoology, Alexandria University, Alexandria, Egypt.
(2) George Perry, Dean and Professor of Biology, University of Texas at San Antonio, USA.
Reviewers:
(1) Isa Baba Koki, Northwest University Kano, Nigeria.
(2) K. Venkatesha Raju, Bangalore University Bangalore, India.
Complete Peer review History: http://www.sciencedomain.org/review-history/20885

Original Research Article

Received 19th June 2017
Accepted 3rd August 2017
Published 9th September 2017

ABSTRACT

Water, *Clarias gariepinus* and *Tilapia mariae* samples were collected from four (4) stations across the length of the Osse River between the periods of April, 2013 to September, 2014. Heavy metals (Iron, manganese, nickel and lead) and total hydrocarbons in water and fish tissues (gills, intestine and muscles) were tested using Atomic Absorption Spectrophotometer (Varian Techron Spectr AA – 10 Model; serial number 902 1318) and Agilent 6890N Gas Chromatograph - Flame Ionization Detector instrument (Model 6890) respectively. Much higher concentrations of all the contaminants (except lead) were detected in the intestine of *Clarias gariepinus* than the intestine of *Tilapia mariae.* This can be attributed to the fact that *Clarias gariepinus*- a demersal fish (bottom feeder) as opposed to *Tilapia mariae* (pelagic fish), must have been exposed to considerably high concentrations of heavy metals and total hydrocarbons (THCs) in the bottom of the river through foraging. The sequence of heavy metals and total hydrocarbons was the same in both fish species: Fe > Mn > THC > Pb > Ni as against the sequence in water: Fe > THC > Mn > Pb > Ni. The trend of

**Corresponding author: E-mail: patrick.isibor@covenantuniversity.edu.ng*

the heavy metals and total hydrocarbons among the analyzed matrices was: *Clarias gariepinus* > *Tilapia mariae* > water. Despite the health risks (mainly of iron and manganese) observed in both species, no ecological risk was observed in the aqueous phase. This can be attributed to the significant bioaccumulation factors which are functions of their thresholds of essentiality. Results showed that *Clarias gariepinus* posed a higher level of health risk than *Tilapia mariae*. Furthermore, given that manganese alone contaminated the muscle of *T. mariae* while iron and manganese were the contaminants in the muscle of *C. gariepinus*, it is safer to consume the *T. mariae* than the *C. gariepinus*; particularly during the dry season.

Keywords: Clarias gariepinus; Tilapia mariae; contaminability; bioaccumulation; health risk; ecological risk.

1. INTRODUCTION

The Osse River serves as a major source of water for domestic uses to the inhabitants of Gelegele community in Ovia North East local Government, Edo State, Nigeria. The river also serves as a source of fish protein and income generation i.e. the fishermen sell the fishes; mainly *Clarias gariepinus* (Burchell, 1822) and *Tilapia mariae* (Boulenger, 1899) to the market women and consumers within and outside nearby communities.

Despite the domestic, nutritional and economic significances of the river, anthropogenic activities such as oil exploration i.e. gas flaring, transportation of crude oil etc.; agricultural practices, laundering, logging etc. take place without regards to the likely devastating ecological consequences. Some of the by-products of the prevalent activities around the Osse River include heavy metals and hydrocarbons. These pollutants are released into the river, incorporated into the aquatic food chain and their concentrations are biomagnified from one trophic level to the apex; up the pyramid of biomasses through alimentation. This causes disruption of the delicate aquatic ecological equilibrium; culminating in several eco-physiological hazards such as decreased biodiversity of aquatic organisms, structural lesions, functional disturbances in aquatic fauna etc. [1]. Fishes are the most susceptible group of aquatic fauna to oil spill; due to the vulnerability of their niche. This is due to the fact that in the river, they are at the top of the food chain; hence they have high tendency to concentrate toxicants from organisms at lower trophic levels. Note-worthy is the fact that fish, apart from being a good source of digestible protein, vitamins, minerals and polyunsaturated fatty acids, could also be source of heavy metals and hydrocarbons to man. This is due to the fact that fish may concentrate large amounts of heavy metals and hydrocarbons from crude oil polluted water [2]. Accumulation rates of toxicants in fishes is a function of many factors which include fish age, fish size, concentration of toxicants, duration of exposure, route of uptake, physiological roles of subject organs, ambience physico-chemistry, swimming and feeding habits. Previous evidences showed that *Clarias gariepinus* (Burchell, 1822) and *Tilapia mariae* (Boulenger, 1899) have different accumulation tendencies of heavy metals and total hydrocarbons [3-5]. Seasonality has also been previously reported as a factor which plays key role in bioavailability of heavy metals and total hydrocarbons [2]. Higher concentrations of heavy metals in environmental matrices during the dry season than rainy seasons have been frequently reported in previous literatures [6-8]. However, some cases of higher concentrations during the rainy seasons were observed in Warri River, Delta State, Nigeria by Olomukoro and Egborge [9] and in Ikpoba River, Edo State, Nigeria by Olomukoro and Igbinosun [10].

Omoigberale and Ogbeibu [11] reported that the level of manganese in water at the Gelegele section of the river was higher than the regulatory limits within the period of July, 2000 to June, 2002. Oguzie and Ehigiator [12] later (July to September, 2007) observed a drop in the level of manganese at the same location below the established standard.

Despite the predominant unregulated anthropogenic activities around Osse River which might affect the palatability of the fish and shellfish, fishing for consumption remained the predominant activity. This necessitates assessment of the contaminabilities of *C. gariepinus* and *T. mariae* of the river. Thus, this study was aimed at comparing the levels of Iron, manganese, nickel, lead and total hydrocarbons in *Clarias gariepinus* and *Tilapia*

mariae of the river; with a view to assessing their fitness for consumption.

2. MATERIALS AND METHODS

2.1 Study Area

The investigation was carried out on Osse River (5°16'40'' E and 5°23'20'' E; 6°2'0'' N and 6°14'0'' N), in Ovia North-East local Government Area of Edo State; within the tropical rainforest belt of Southern Nigeria (Fig. 1).

The River is a link between Benin River and Ughoton stream; it transverses from Nikorowa, through Ekehuan and Gelegele to Iziedema communities. The river is an oligotrophic [13] fresh lotic water with a thick aquatic vegetation cover along the bank. The river is the major source of domestic water supply to the inhabitants of Gelegele and other communities located around.

The climate of the study area is a humid tropical climate; characterized by two different seasons, which are the wet and dry seasons. The wet season occurs between April and October; with a break in August and an average rainfall of 1,704 mm; with a range of 1,562 – 1,867 mm. The dry season on the other hand lasts from November to March with a cold harmattan spell which occurs between December and January. The average temperature is 25 ºC (77 F) during the rainy seasons and about 28 ºC (82 F) during the dry season; with a mean daily temperature ranging from 23 ºC minimum during the rainy season to 30 ºC maximum during the dry season.

Four (4) stations were chosen at locations of distinct anthropogenic activities. Station 1 (control) was located upstream at Nikorowa (06º 13.432 ^{l}N, 05º 20.426^{l} E). Negligible activities were observed at the location. Station 2 was located at the Ekehuan section (06 º 11.398^{l}N, 05 º 21.781^{l}E). Unregulated crude oil exploration activities took place at this location. Other predominant activities include laundering, fishing, and transportation of diesel in vessels. Station 3 was located at the Gelegele section (06 º 09.323^{l}N, 05 º 20.584^{l}E). This station

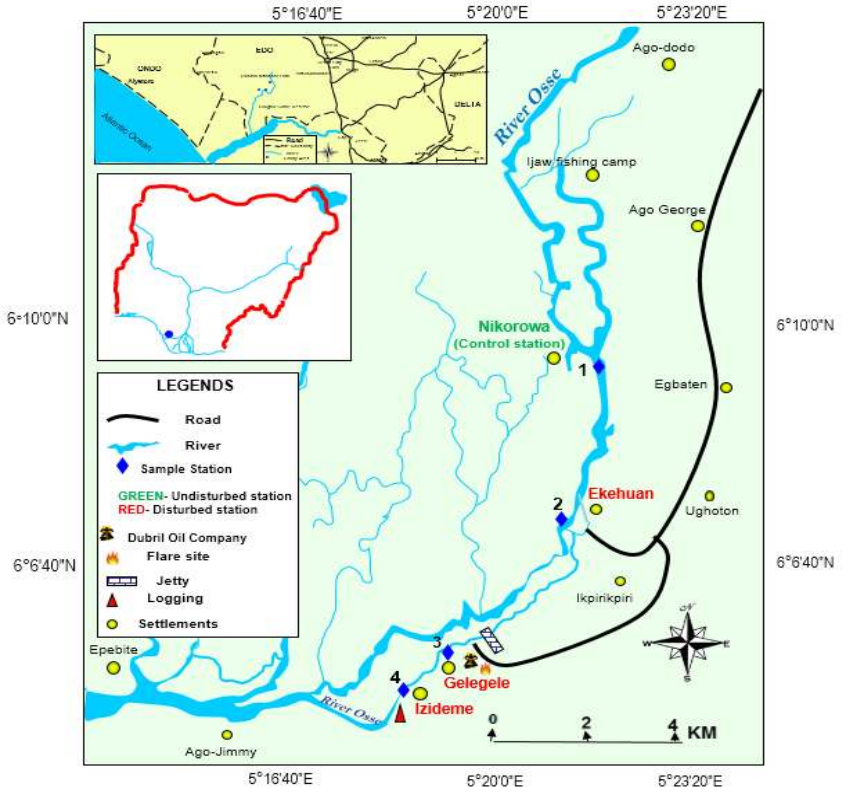

Fig. 1. Map of study area showing sampled stations

constantly received effluents from an Oil Company called Dubril Oil Company. Station 4 was located at the Iziedema section (06 º 08.936 I N, 05 º 19.939 I E). The predominant activities noticed around this location were logging and other agricultural activities.

2.2 Sample Collection and Analysis

2.2.1 Water samples

Water samples were collected at all stations using 150 mL glass bottles with lid and were labelled appropriately, preserved in iced coolers and transported immediately to the laboratory for analysis of heavy metals and total hydrocarbons. This was done on monthly basis for 18 months.

2.2.1.1 Heavy metals in water

Water samples were digested using 10 mL of concentrated H_2SO_4 as recommended by ICARDA [14]. The sample was then filtered through Whatman filtered paper 42 and aspirated directly into an Atomic Absorption Spectrometer (Varian Techron Spectr AA – 10 Model; serial number 902 1318) connected to a printer (HP Deskjet 2400); for the quantitative determination of all trace metals. The blanks were prepared accordingly. For quality assurance purposes the AAS was calibrated for each metal by dissolving 1 gram analar grade metal salt in 1 L of distilled water. Standard and corresponding blanks were run with each set of experimental digest. The detection limits of iron (0.5 mg/L), manganese (0.5 mg/L), nickel (0.5 mg/L), and lead (0.03 mg/L) were carefully observed. To ascertain quality control and standardization measures, all laboratory procedures were repeated at least 3 times and mean values were compared with standard values supplied by FEPA [15].

2.2.1.2 Total hydrocarbons (THC) in water

A beaker was properly rinsed with distilled deionized water and 100 mL of water sample was poured in it. 50 mL of dichloromethane was added to the water sample. The mixture was properly shaken and allowed to settle [16]. Separation and detection of compounds in water samples were carried out using Agilent 6890N Gas Chromatograph - Flame Ionization Detector (GC-FID) instrument according to recommendations of LAWI [17]; which were slightly modified by Cortes et al. [18]. 3 µL of concentrated samples was eluted from the column and was injected into Gas Chromatography (GC) vial. The blank dichloromethane was injected into the micro-syringe of GC to clean the syringe (3 times) before subjecting to sample to analysis. The micro-syringe was further rinsed with the samples. Then the samples were injected into the column for separation of compounds in the sample. After separation the compounds were passed through a flame ionization detector (FID). The amount of THC was ascertained at a particular chromatogram in mg/L for water samples.

2.2.2 Fish samples

Cast nets, hand nets, baskets and baited hooks were used to capture fish from the river. Fish age and size are major factors which influence accumulation of toxicants. On this basis, the morphometrics of both specimens were ascertained to be of minimal variance; *Clarias gariepinus* was 12.8- 24.7 cm (standard length), 6- 12 cm (body depth), 118.3 – 218.5 g (weight) and *Tilapia mariae* was 5.9- 19.8 cm (standard length), 9.2- 19.5 cm (body depth), 125. 5 – 237.9 g (weight). The weights were measured using electronic weight balance (model pl440 w) and other morphometrics such as body depth and standard length were measured using a metre rule. Fish specimens were preserved in sterile polythene bags with ice, kept in clean plastic coolers and transported to the laboratory for further identification. They were rinsed with distilled water to remove dirt. Fish samples were identified using standard references [16,19]. Fish age was determined using the count of annuli on the otoliths [20]. On monthly basis, 6 representatives; each of *Clarias gariepinus* and *Tilapia mariae* were dissected using sterile blades. The gills, intestine and muscles of the fish were removed and kept preserved in freezer at –10 ^{o}C pending further analysis.

2.2.2.1 Heavy metals in fish tissues

Ten (10) grams of wet weight fish tissue was placed in silica flasks covered with a glass plate, 20 mL of HNO3: HClO4 (5:1) mixture was added. Digestion process was carried out by heating the mixture at 105 ℃ for about 24 hours according to Turkmen [21]. The extract was made up to 25 mL with HNO3 (70%) and diluted with deionized water. For quality assurance, reagent blanks were processed simultaneously in triplicates. Each residue was filtered into volumetric flasks with the aid of a Whatman filter paper 42. The solution was tested for metals (iron, manganese, nickel, and lead) concentrations using a Perkin Elmer 3110 model Atomic Absorption

Spectrophotometer (ASS) and recorded in mg/kg; wet weights [22]. To determine metal concentration, the ASS was calibrated for each metal by dissolving 1 gram analar grade metal salt in 1 L of distilled water. Standard and corresponding blanks were run with each set of experimental digest. The detection limits of iron (0.5 µg/g), manganese (0.5 µg/g), nickel (0.05 µg/g), and lead (0.03 µg/g) were carefully observed.

The actual concentration of metal was calculated thus:

> Actual concentration of metal (mg/ kg wet weight) = RD X Dilution factor [23].

Where RD = ASS reading of digest

$$\text{Dilution factor} = \frac{\text{Volume of digest used}}{\text{Weight of sample digested}}$$

2.2.2.2 Total hydrocarbons (THC) in fish tissues

Ten (10) g wet weight shrimp tissue was placed in a 100 mL beaker containing 60 mL extraction mixture (acetone and dichloromethane; 1:1). The content was properly agitated while heated for about 10 minutes at 70℃; as demonstrated by Schwab et al. [24]. The extract was decanted into a clean round bottom flask. 5 grams of sodium sulfate was added to remove water. The extract was further concentrated to 3 mL by heating at 20℃ [24]. Silica gel column (combination of 2 g wool and 30 g chromatography silica gel) was prepared and 1.5 mL of the concentrated extract was pipetted

Plate 1. Some representatives of *C. gariepinus* and *T. mariae* captured from the river

and dropped on the silica gel column. Then 40 mL HPLC-hexane was added to remove any organic contaminant. The silica gel columns were loaded into a Gas chromatography with flame ionization detector (GC-FID) system 6890; series model G1530. 1 µL portion of the sample was injected and analyzed for total hydrocarbons. The carrier gas was purified nitrogen, kept at a flow rate of 5 mL per minute. The operating temperature program was heated to 60℃ for 2 minutes and was gradually increased at a rate of 10℃ per minute, up to 300℃. The procedure was maintained for about 10 minutes [25]. The oven was kept at 60℃, injector at 250℃ and detector at 300℃. The minimum detection limit for total petroleum hydrocarbons was 0.1 µg/kg wet weight. For quality assurance, all tissue analysis results were cross checked using standard reference materials for biological samples, provided by FEPA [14]. The concentrations of THC in the tissues of the fish was expressed in mg/ kg wet weight.

2.3 Data Analysis

The obtained water and specimen data were analyzed using the SPSS package (version 19.0) and the descriptive statistics were expressed as mean ± standard deviation and range; using one way analysis of variance (ANOVA) to test for the significant difference among the groups at probability level of 0.05. Furthermore, the Duncan Multiple Range (DMR) test was employed in ascertaining the actual locations of the significant differences.

2.3.1 Bioaccumulation assessments

The Bioaccumulation Factors (BAF) and Biota-sediment Accumulation Factors of the parameters in *Clarias gariepinus* and *Tilapia mariae* were calculated using the following methods;

$$BAF = \frac{CF\ (mg/kg)}{CW\ (mg/kg)}$$

Where BAF represents bioaccumulation factor, CF represents concentration of toxicants in fish tissues and CW represents concentration of toxicants in water.

A bioaccumulation factor greater than 1 indicated a hydrophobic or lipophilic contaminant i.e. it has high lipid affinities and will concentrate in tissues with high lipid content instead of an aqueous environment like the cytosol. It is an expression of the tendency of a contaminant to bioaccumulate.

2.3.2 Risk characterization

Risk characterization is the link between risk assessment and risk management. However, a risk characterization is incomplete without numerical expressions of risks; alongside comprehensive analysis interpreting and qualifying the values. A risk assessment index greater than 1 indicates a threat to human health or the environment.

2.3.2.1 Health risk assessment

Health risk assessment gives a quantitative knowledge of risk each contaminant poses to the health of the consumers of the fish. For the purpose of this research, different methods were employed in calculating the health risk indices (HRI) of the carcinogenic component of crude oil (total hydrocarbons) and the non-carcinogenic components (heavy metals).

2.3.2.2 Health risk index of heavy metals (non-carcinogens)

Health Risk Index for heavy metals was calculated thus;

$$\text{Health Risk Index (HRI)} = \frac{\text{Daily intake of metal (DIM)}}{\text{Reference oral dose (ROD)}}$$

$$\text{While Daily intake of metals (DIM)} = \frac{\text{M X CF X Daily intake of fish}}{\text{Average body weight}}$$

Where M was the metal concentration in fish tissue (mg/kg), CF is Conversion factor = 0.085. 60 kg was adopted as the average body weight of the consumers of the fish. Daily intake of fish was estimated as the fish consumption rate in Nigeria= 48 g/person/day [26].

2.3.2.3 Health risk index of total hydrocarbons (carcinogens)

The health risk index of total hydrocarbons was calculated thus;

$$HRI = \frac{C \times IR \times EF \times ED}{BW \times AT} \times SF \times ADAF$$

Where

C = concentration of carcinogen in fish tissues (mg/kg)

IR = intake rate of fish; which is 8.9 kg/person/year [26].
BW = average body weight of exposed individuals used was 65 kg as recommended by Oguntona [27].
EF= exposure frequency; how many times the individuals are exposed to these carcinogens in a year. The adopted value is 365 days/ year.
ED = Exposure Duration; which is the adopted value of the average life expectancy of Nigerians; which is 52.62 years in 2014 [28].
AT = length of time over which the average dose was calculated; which is 365 days X 52.62 years
SF = Slope factor; which is 2.0 (mg/kg-day)$^{-1}$
ADAF = Age-dependent adjustment factor. The adopted value is 1.

2.3.2.4 Ecological risk assessment

Concentrations of chemicals above permissible limits in the aquatic environment elicit high levels of ecological risks. These risks have to be numerically evaluated for quantification and interpretation. Ecological risk assessment was therefore calculated thus;

$$\text{Risk Quotient (RQ)} = \frac{\text{Environmental concentration (mg/kg)}}{\text{Recommended limit (mg/kg)}}$$

3. RESULTS AND DISCUSSION

The physico-chemistry of an aquatic environment is the background factor that influences the kinetics of heavy metals and total hydrocarbons. All the parameters in water of Osse River; except manganese were lower than FEPA regulatory limit (Table 1). The mean concentrations of manganese in water at Stations 3 (0.97 mg/L) and 4 (1.26 mg/L) were very much higher than the concentrations at Stations 1 (0.02 mg/L), 2 (0.24 mg/L) and FEPA regulatory limit (0.5 mg/L). The concentrations of lead in the water of Stations 3 and 4 were also significantly higher than Stations 1 and 2 ($P < 0.001$). This result is at variance with the observations of Omoigberale and Ogbeibu [11]; and Oguzie and Ehigiator [12]. The periodic variability in the levels of manganese can be attributed to varying anthropogenic activities. Manganese is a constituent of mucopolysaccharides essential for healthy joints and bones [8]. It is also essential for regulation of red blood cells, the reproductive cycle in vertebrates and it is a constituent of a number of metalloenzymes that occupy key roles in metabolism [29,30]. Due to the high essentiality of manganese, there is little risk of exposure except at extremely high concentrations. The concentrations of manganese observed at the Stations were not high enough to be of eco-toxicological significance. The significantly high concentration of total hydrocarbons (THC) observed at Station 2 (3.19 mg/L) than other stations ($P< 0.001$) is a reflection of the severe oil exploration activities at the location.

The gills of *Clarias gariepinus* and *Tilapia mariae* accumulated the highest mean concentrations of iron, followed by their muscles, then their intestines. The specific order of iron accumulation among the tissues was: gills of catfish > gills and muscle of tilapia > muscle of catfish > intestines of both species ($P< 0.001$). It was only in the gills of both species THC was beyond FEPA limits while other tissues were lower in THC.

Concentrations of Fe (281.8±42.3 and 153.8±21.7 mg/kg), Mn (24.1±5.1 and 12.9 ±2.2 mg/kg), and THCs (3.5±0.5 and 2.5 ±0.3 mg/kg) detected in the gills of the *C. gariepinus* and *T. mariae* respectively were higher than the established limits (Table 2). Only Mn (10.5 ± 2.7 and 6.4±1.1 mg/kg) contaminated the intestine of the *C. gariepinus* and *T. mariae* respectively. Fe (116.8±18.7 mg/kg) and Mn (21.5±2.5 mg/kg) contaminated the muscles of *C. gariepinus* while only Mn (13± 1.4 mg/kg) contaminated the muscles of *T. mariae.* A high correlation was apparent between the contamination of the fish tissues and the water samples (Table 1). Results imply that the anthropogenic activities have significantly disrupted the aquatic ecological equilibrium and it is prognostic of severe environmental degradation if the unregulated activities at the river persist.

It is noteworthy that the intestine of *Clarias gariepinus* accumulated higher concentrations of all the parameters analyzed (except lead) than the intestine of the *Tilapia mariae.* This can be attributed to the difference in the feeding habits of the fishes i.e. *Clarias gariepinus*, being a demersal fish (bottom feeder) must have accumulated higher concentrations of the heavy metals and THC from the repository sediments, in its intestinal tissues through alimentation process than *T. mariae*. Intestine of *T. mariae* is expected to accumulate less due to its pelagic (surface) nature of feeding. Furthermore, the

spatio-temporal graphs showed the fluctuations in the parameters across the fish tissues over the period of study at a glance.

The gills of both fish species accumulated the highest concentrations of iron throughout the period of study; particularly in September, October and November, 2013 (Fig. 2). Higher concentrations of iron were recorded during wet season than during the dry season. This might be due to higher influx of the trace metals from surface runoff during rainy season. Relatively higher concentrations of iron in the gills can be attributed to essentiality of the metal in respiration process as a core constituent of haemoglobin. Affinity of iron for the gills of the fishes conforms to the earlier findings of Eneji et al. [5]. Manganese was also more accumulated in the gills of both species than any other tissue (Fig. 3). This is partly because the gills is naturally endowed with physiological and anatomical properties which must have maximized the absorption efficiency of the heavy metals and THC from the aqueous phase.

Outstandingly high concentrations of heavy metals and THC observed in the gills than other tissues can be attributed to the fact that the gills is constantly involved in physiological functions such as respiration, ion regulation and

Table 1. Summary of heavy metals and THC in water of the Osse River

Parameter	Station 1	Station 2	Station 3	Station 4	P value	FEPA [15]
	Mean±S.E (range)	Mean±S.E (range)	Mean±S.E (range)	Mean±S.E (range)		
Fe (mg/L)	0.45±0.16^{B} (0- 2.4)	1.71±0.25^{A} (0- 3.5)	1.44±0.19^{A} (0- 2.9)	1.3±0.27^{A} (0.2- 5.4)	P<0.001	20
Mn (mg/L)	0.02±0.01^{B} (0- 0.1)	0.24±0.06^{B} (0- 0.7)	0.97±0.22^{A} (0- 2.3)	1.26±0.34^{A} (0- 3.7)	P<0.001	0.5
Ni (mg/L)	0.01±0.03^{C} (0- 0.4)	0.03±0.07^{B} (0- 1.1)	0.01±0.05^{B} (0- 0.9)	0.2±0.06^{A} (0-0.7)	P<0.05	0.1
Pb (mg/L)	0.01±0.003^{B} (0- 0.1)	0.08±0.1^{B} (0- 0.2)	0.83±0.24^{A} (0- 2.7)	0.83±0.26^{A} (0- 2.7)	P<0.001	<1
THC (mg/L)	0.02±0.01^{D} (0- 0.1)	3.19±0.6^{A} (0- 10.5)	0.77±0.2^{B} (0-1.89)	1.26±0.28^{C} (0- 3.2)	P<0.001	10

Note: Values with the same superscript have no significant difference
N= number of sample replicates. P > 0.05 means there is no significant difference, P < 0.05 means there is significant difference, P < 0.01 means there is much significant difference, and P < 0.001 means there is very much significant difference

Table 2. Summary of heavy metals and THC in fishes (mg/kg wt. weight)

Fish species	Tissue	Fe	Mn	Ni	Pb	THC
Clarias gariepinus	Gills	281.8±42.3^{A} (21-658)	24.1±5.1^{A} (1.7-62.3)	0.2±0.02^{A} (0-0.1)	1.1±0.2^{A} (0-3)	3.5±0.5^{A} (0.6-8.2)
	Intestine	66.1±7.8^{D} (15.5-153)	10.5±2.7^{B} (1.1-37.4)	0.1±0.02^{C} (0-0.6)	0.2±0.03^{B} (0-0.4)	1.6±0.2^{C} (0.3-3.5)
	Muscle	116.8±18.7^{C} (15.8-242.4)	21.5±2.5^{A} (1.3-35.1)	0.2±0.09^{E} (0-1.6)	0.1±0.03^{B} (0-0.4)	0.6±0.2^{D} (0.2-2.3)
Tilapia mariae	Gills	153.8±21.7^{B} (22-374)	12.9±2.2^{B} (1.51-34.05)	0.4±0.1^{B} (0.1-0.9)	1.7±0.3^{A} (0-3.7)	2.5±0.3^{B} (0.4-5.2)
	Intestine	50.4±5.4^{D} (15-80)	6.4±1.1^{C} (1-15)	0.1±0.1^{D} (0.01-0.8)	0.3±0.1^{B} (0-0.8)	1.5±0.2^{C} (0.1-2.7)
	Muscle	74±10^{B} (20-193)	13±1.4^{B} (1.3-23.5)	0.4±0.03^{F} (0.01-0.45)	0.4±0.1^{B} (0-1.3)	0.3±0.1^{D} (0-1.3)
P- Value		P<0.001	P<0.01	P<0.01	P<0.001	P<0.001
FEPA limits [15]		100	1	0.5	2	2

Note: Values with the same superscript have no significant difference N= number of sample replicates. P > 0.05 means there is no significant difference, P < 0.05 means there is significant difference, P < 0.01 means there is much significant difference, and P < 0.001 means there is very much significant difference

osmoregulation which entail active interactions with extraneous chemicals. Concentrations of nickel was higher in the tissues of *T. mariae* than in *Clarias gariepinus*, except for outstandingly high concentration of nickel recorded in the muscle of *C. gariepinus* in November, 2013 (Fig. 4).

Fairly higher level of lead was also observed in the *T. mariae* than the *C. gariepinus* (Fig. 5). Some considerable levels of total hydrocarbons were accumulated in the gills, followed by muscles in both species; particularly in the middle of each year (Fig. 6).

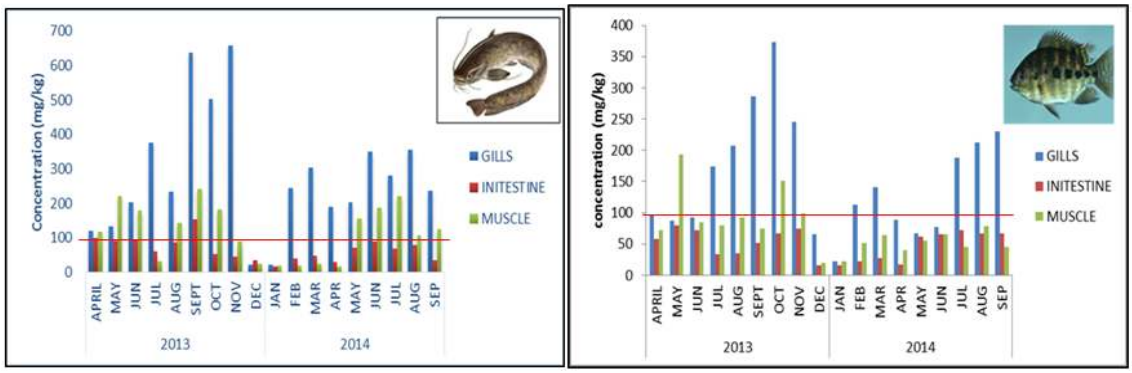

Fig. 2. Tissue and temporal variation of iron in *Clarias gariepinus* and *Tilapia mariae*
Note: Horizontal line indicates the FEPA limit (100 mg/kg) for iron in fish [15]

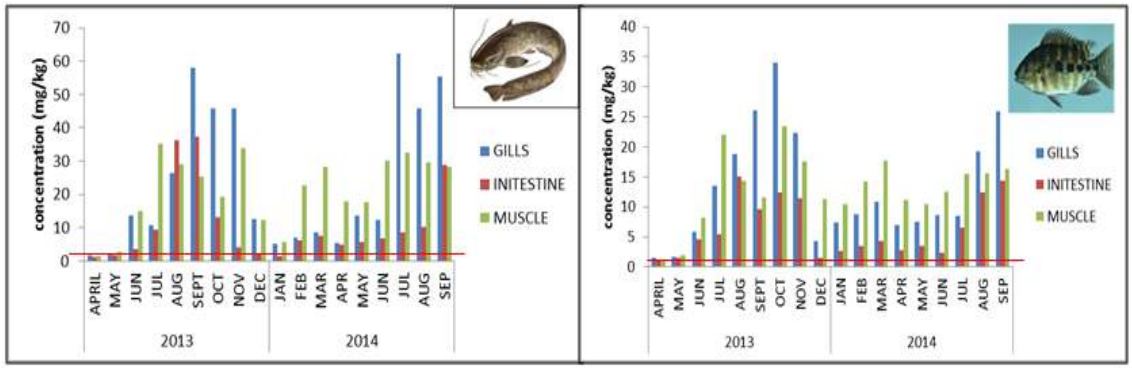

Fig. 3. Tissue and temporal variation of manganese in *Tilapia mariae*
Note: Horizontal line indicates the FEPA limit (1 mg/kg) for manganese in fish [15]

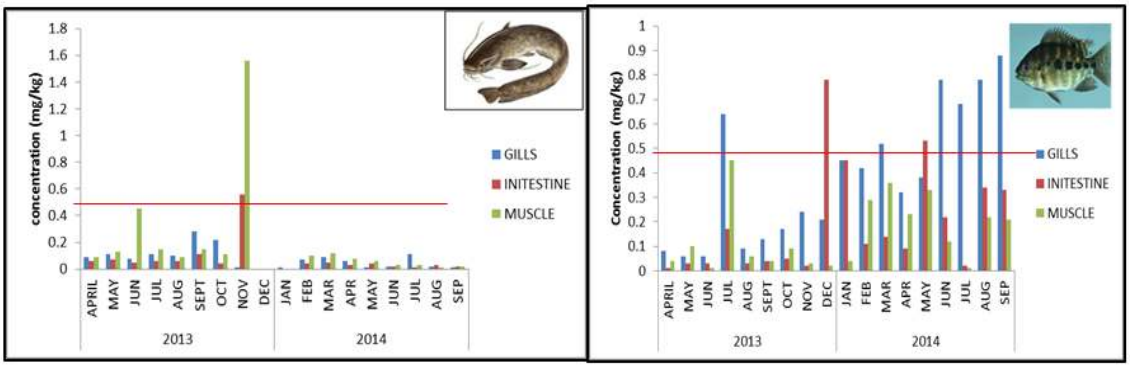

Fig. 4. Tissue and temporal variation of nickel in *Clarias gariepinus* and *Tilapia mariae*
Note: Horizontal line indicates the FEPA limit (0.5 mg/kg) for nickel in fish [15]

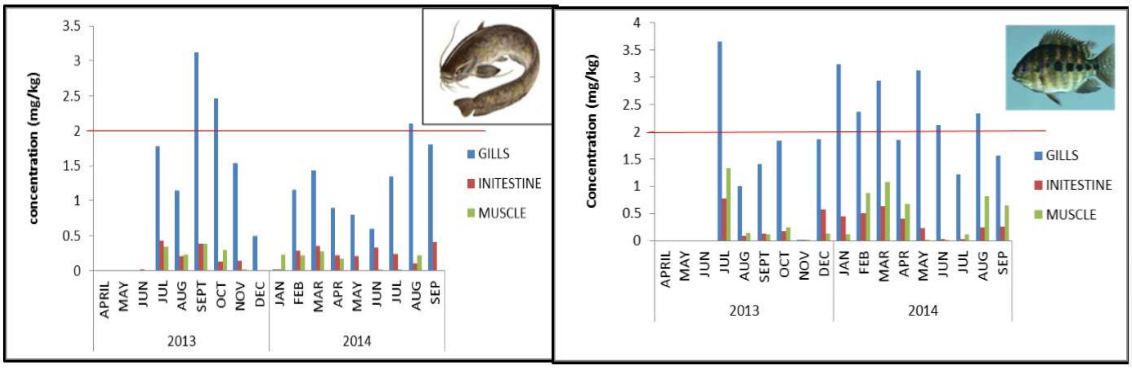

Fig. 5. Tissue and temporal variation of lead in *Clarias gariepinus* and *Tilapia mariae*
Note: Horizontal line indicates the FEPA limit (2 mg/kg) for lead in fish [15]

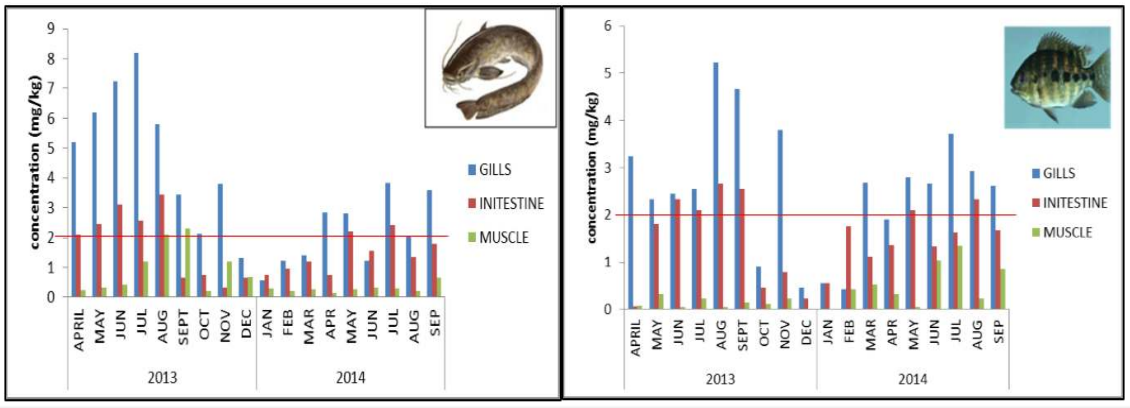

Fig. 6. Tissue and temporal variation of total hydrocarbons in *Tilapia mariae*
Note: Horizontal line indicates the FEPA limit (2 mg/kg) for THC in fish [15].

Higher concentrations of the heavy metals and THC were observed during the rainy season than the dry season. This conforms to the observations of Eneji [4], Olomukoro and Egborge [9]; and Olomukoro and Igbinosun [10]. These observations are however at variance with the findings of Ehaise and Anyasi [7]; and Ogbeibu et al. [31]. Results showed very similar accumulation patterns between *Clarias gariepinus* and *Tilapia mariae*. However, *C. gariepinus* exhibited higher accumulation capacity than *T. mariae*. This observation is at variance with the findings of Eneji et al. [5].

Results showed that iron, manganese, nickel and total hydrocarbons pose significant health risks to the consumers of *Clarias gariepinus* while only iron, manganese and total hydrocarbons were of significant health risk indices in *Tilapia mariae* (Fig. 7). Impermissible dietary levels of iron may elicit many implications in man; such as multi-system organ failures, coma, convulsion and ultimately death [32,33].

Excess manganese is liable to elicit poor cognitive performance in school children and neurological disorders similar to Parkinson's disease [34]. Total hydrocarbons are often associated with carcinogenic, mutagenic and immune-suppressive conditions in man [35]. Results showed that *Clarias gariepinus* posed a higher level of health risk than *Tilapia mariae* (Fig. 7). However, despite the risk levels observed in both species, no ecological risk was observed in the aqueous phase (Fig. 8). This can be attributed to the significant bioaccumulation factors of the heavy metals and THC in the tissues of both fish species [23]; particularly distinctively high bioaccumulations factors of iron and manganese which can be attributed to their thresholds of essentiality (Fig. 9).

A rather "anomalous order" of accumulation of heavy metals and THC among the tissues analyzed was detected thus: gills > muscles > intestine. This is at variance with the normal order: gills > intestine > muscles [3,4]. Under normal circumstances, the gills, followed by the intestine are expected to accumulate heavy metals and THC higher than the muscles due to the fact that the gills is more metabolically active than the muscles.

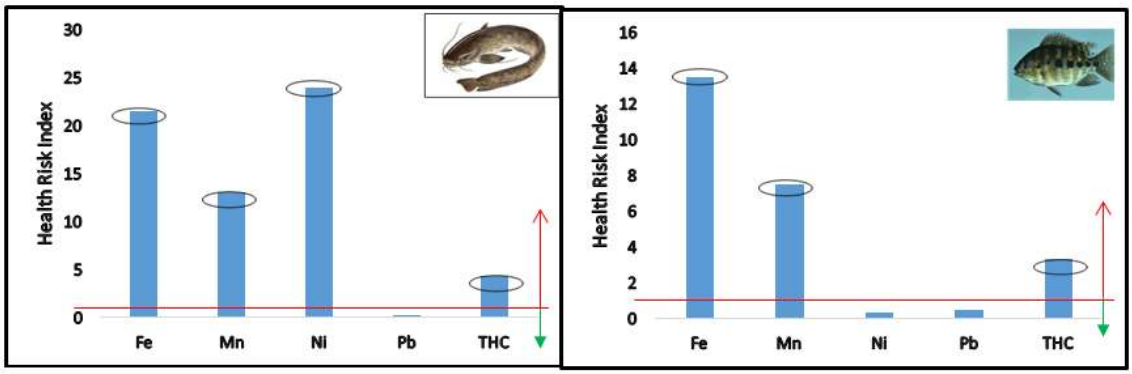

Fig. 7. Health risk indices in *Clarias gariepinus* in *Tilapia mariae*

Note: Red horizontal line= significant risk margin, red vertical arrow= significant range, green arrow= insignificant range, encircled bars= significant risks

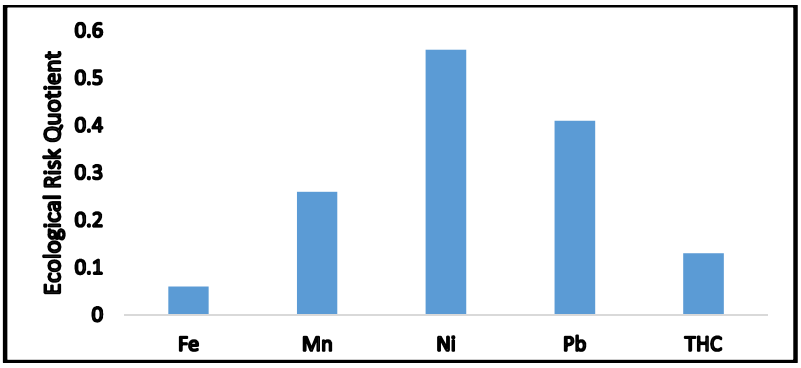

Fig. 8. Ecological risk indices of pollutants

Note: The significant level (1) is beyond the range of graph; hence not indicated

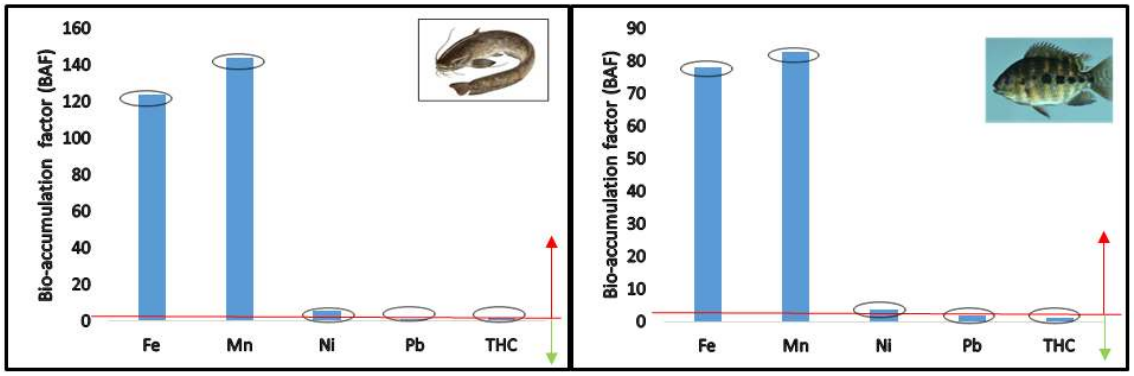

Fig. 9. Bioaccumulation factor (BAF) in *Clarias gariepinus* and *Tilapia mariae*

It is noteworthy that the muscle tissue of *Clarias gariepinus* and *Tilapia mariae* of Osse River overtook the position of the intestine (second position) in the accumulation order. The muscle tissues are the major edible parts of the fish and constitutes the major part of its body weight [36]; hence holds the nutritional and economic values. Contamination of muscle tissues of both fish species investigated being unusually higher than the intestine is an imperative beckon for attention. This unusual order, hereby termed critical or anomalous order was earlier observed in silver catfish (*Chrysichthys nigrodigitatus*) and *Tilapia nilotica* of Okumeshi River, Delta State, Nigeria [37]. It was also observed in *Chrysichthys nigrodigitatus* and *Tilapia zilli* of Badagry creek, Lagos, Nigeria [38].

4. CONCLUSION

Given that manganese alone contaminated the muscle of *T. mariae* while iron and manganese were the contaminants in the muscle of *C. gariepinus*, the *T. mariae* is safer for consumption than the *C. gariepinus*. It is also safer to capture the fish during the dry season than the wet season. We recommend a further in-depth research on the actual impacts of the heavy metals and total hydrocarbons in the fish species on the health of the consumers.

ACKNOWLEDGEMENT

We appreciate the Covenant University Centre for Research, Innovation and Discovery (CUCRID) for the financial support.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Jezierska B, Witeska M. The metal uptake and accumulation in fish living in polluted waters. Twardowska, I. et al. (eds.). Soil and Water Pollution Monitoring, Protection and Remediation. 2006;3(69):107-114.
2. Mansour SA, Sidky MM. Ecotoxicological studies. 3: Heavy metals contaminating water and fish from Fayoum Governorate, Egypt. Food Chem. 2002;78:15-22.
3. Akan JC, Salwa M, Yikala BS, Chellube ZM. Study on the distribution of heavy metals in different tissues of fishes from River Benue in Vinikilang, Adamawa State. British Journal of Applied Science & Technology. 2012;2(4):311-333.
4. Eneji SI. Spatial and temporal variation in the heavy metals loading of River Benue in Makurdi metropolitan area, Ph. D. Thesis, Department of Chemistry University of Agriculture Makurdi, Nigeria. 2010;95.
5. Eneji SI, Rufus SA, Annune PA. Bioaccumulation of heavy metals in fish (*Tilapia zilli* and *Claria gariepinus*) organs from River Benue, North-Central Nigeria. Pak. J. Anal. Environ. Chem. 2011; 12(1&2):25-31.
6. Li P, Qian H, Howard KWF, Wu J, Lyu X. Anthropogenic pollution and variability of manganese in alluvial sediments of the Yellow River, Ningxia, northwest China. Environmental Monitoring and Assessment. 2014;186(3):1385-1398.
7. Ehaise FO, Anyasi CC. Influence of breweries effluent discharge on the microbiological and physico-chemical quality of Ikpoba River, Nigeria. Biotechnology. 2005;4(10):1062–1065.
8. Kadiri MO. Seasonal trend in the chemical limnology of a shallow Nigeria man-made lake. Acta. Hydrobiol. 2000;42(1&2):29–40.
9. Olomukoro JO, Egborge ABM. Hydrobiological studies on Warri River, Nigeria. Part II: Seasonal trend in the physico-chemical limnology. Trop. Freshwat. Biol. 2004;13:9–23.
10. Olomukoro JO, Igbinosun O. Acute toxicity of brewery effluent on Chironomus travalensis (Dipteran larvae). Journal of Aquatic Sciences. 2004;19(1):23–26.
11. Omoigberale MO, Ogbeibu AE. Environmental impacts of oil exploration and production on the macrobenthic invertebrate Fauna of Osse River, Southern Nigeria. Research Journal of Environmental Sciences. 2010;4:101-114.
12. Oguzie FA, Ehigiator FAR. Concentration of heavy metals in three African Prawn (Crustacea: Palaemonidae) from Osse river in Edo State, Nigeria. J. Agric. Sc. Env. 2011;11(1):104- 113.
13. Imoobe TOT, Adeyinka ML. Zooplankton-based assessment of the trophic state of a

tropical forest river in Nigeria. Arch. Biol. Sci. Belgrade. 2009;61(4):733-740.

14. International Center for Agricultural Research in the Dry Areas (ICARDA). Methods of Soil, Plant and Water Analysis: A manual for the West Asia and North Africa regions (3rd Edition). 2013;244.
15. Federal Environmental Protection Agency (FEPA). Guidelines and Standards for Environmental pollution control in Nigeria. 2003;420.
16. Idodo-Umeh G. Freshwater fishes of Nigeria (Taxonomy, Ecological notes, Diet and Utilization). Idodo Umeh Publishers Limited. 2003;408.
17. Laboratory Analytical Work Instruction (LAWI). The Determination of Total Petroleum Hydrocarbon in Soil/Sediment/ Sludge in Gas Chromatography. Published by Fugro (Nig.) Ltd. 2011;3:9.2.
18. Cortes JE, Suspes A, Roa S, Gonzalez C, Castro HE. Total petroleum hydrocarbon by Gas Chromatography in Colombian waters and soil American J. Environ. Sci. 2012;8(4):396-402.
19. Olaosebikan BD, Raji A. Field guide to Nigerian freshwater fishes. Federal College of Freshwater Fisheries Technology. 1998;202.
20. Garling DL, Ashley K. Determining the age of fish. Extension Bulletin (E-1774). 2002; 2.
21. Turkmen G. Seasonal variation in heavy metals in Shrimps Penaeus kerathurus (Forskal, 1775) from Izmir Bay. J. Amin. Vet. Adv. 2012;11(15):2839.
22. Van Loon JC. Analytical atomic spectroscopy. Selected methods. Academic Press, New York. 1980;337.
23. Olaifa FE, Olaifa AK, Adelaja AA, Owolabi, AG. Heavy metal contamination of *Clarias gariepinus* from lake and fish farm in Ibadan, Nigeria. Afr. J. Biomed. Res. 2004; 7:145–148.
24. Schwab AP, Su J, Wetzel S, Pekare S, Banks MK. Extraction of petroleum hydrocarbons from soil by mechanical shaking. Environmental Science and Technology. 1993;33:1940-1945.
25. American Petroleum Institute. (API). API Recommended Practice for Analysis of oil field water. APR – RP – 45, API Dallas Texas; 1968.
26. Food and Agricultural Organization (FAO). Fishery Profile: The Federal Republic of Nigeria. 2007;24.
27. Oguntona, T. Green leafy vegetables. In: Osagie, A.U. and O.U. Eka (Eds.). Nutritional Quality of Plant Foods. Post-Harvest Research Unit, Department of Biochemistry, University of Benin, Benin City, Nigeria. 1998;120-133.
28. Central Intelligence Agency (CIA). World Factbook. 2016;17.
29. Burnell JN. The biochemistry of manganese in plants. In: Graham RD, Hannam RJ, Uren NC, eds. Manganese in soils and plants. Dordrecht, Kluwer Publishers. 1988;408.
30. Woolhouse HW. Toxicity and tolerance in the responses of plants to metals. In: Lange OC, Nobel PS, Osmond CB, Ziegler H, eds. Encyclopedia of plant physiology II. New York, NY, Springer-Verlag. 1983;300.
31. Ogbeibu AE, Oriabure PA, Oboh IP, Edogun IS. The effects of brewery effluent discharge on the water quality and sediment of the Ikpoba River, Benin City, Nigeria. Journal of Aquatic Sciences. 2014; 29(1A):43-58.
32. Chang TP, Rangan C. Iron poisoning: A literature-based review of epidemiology, diagnosis, and management. Pediatr Emerg Care. 2011;27:978-85.
33. Manoguerra AS, Erdman AR, Booze LL, Christianson G, Wax PM, Scharman EJ. Iron ingestion: An evidence-based consensus guideline for out-of-hospital management. Clin Toxicol (Phila). 2005; 43:553-70.
34. Agency for Toxic Substances and Disease Registry (ATSDR). Public health statement for zinc: Public service. Department of Health and Human Services. 2005;42.
35. Agency for Toxic Substances and Disease Registry (ATSDR). Toxicological profile for polyaromatic hydrocarbons (PAH) in Goldstein, B.D. et al., (2011). The Gulf Oil Spill. New England Journal of Medicine. 2010;364(14):1334-1348.
36. Fabbri E, Capuzzo A, Moon TW. The role of circulating catecholamines in the regulation of fish metabolism: An overview, Comp. Biochemical Physiology C Pharmacology Toxicology Endocrinology 1998;1(20):177-192.

37. Ekeanyanwu CR, Ogbuinyi CA, Etienajirhevwe OF. Trace metals distribution in fish tissues, bottom sediments and water from Okumeshi River in Delta State, Nigeria. Ethiopian Journal of Environmental Studies and Management. 2010;3(3):12-17.

38. Aderinola OJ, Kusemiju V, Clarke, EO, Anetekhai, MA, Adu AA. Bio-accumulation of heavy metals in silver catfish-*Chrysichthys nigrodigitatus*, *Tilapia zillii* and *Macrobrachium macrobrachion* caught in Badagry creek, Lagos, Nigeria. Transnational Journal of Science and Technology. 2012;2(7):34-47.

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/20885