POTENTIAL HUMAN HEALTH HAZARDS OF CONSUMABLE *CLARIAS GARIEPINUS* FROM TOXIC METAL POLLUTED WATER IN SOUTHWEST NIGERIA

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Abstract. The catfish *Clarias gariepinus* is one of the important sources of protein in the society. This work identifies and determines the concentration of manganese, zinc, nickel, chromium, cadmium, and lead in the flesh of catfish, in order to evaluate the health risk in its consumption by human beings. Samples were collected from eight different points, the edible parts separated and then deried. Digestion was carried out and the solutions were analyzed by atomic absorption spectroscopy in order to detect the above mentioned metals. The average daily intakes of Mn, Zn, Pb, Ni, Cr, and Cd were: 0.049, 0.035, 0.020, 0.002, 0.003, and 0.001 respectively for adults and: 0.127, 0.091, 0.053, 0.005, 0.007, and 0.003 respectively for children. Pb is one of the metals with higher rate of intake in some of the samples hence suspected to cause a higher toxicity. However, its hazard quotient (*HQ*) and health index (*HI*) are less than unity. Thus, the probability of developing cancer as a result of consuming catfish from Ogudu Creek, Lagos Southwest Nigeria, is one in ten-thousandth during a life time. Therefore, the flesh of *Clarias gariepinus* is good for human consumption.

Key words: *Clarias gariepinus*, toxic metals, health index, cancer risk, environment, pollution.

INTRODUCTION

Fishes have been and continue to be one of the reliable sources of protein in the whole world. It is often recommended to people to take fish in daily meal so that their proteins can add up to the required daily balanced diet. Catfish is one of such fishes that are readily available in the local markets and food stores all around the world. Unfortunately, nowadays the aquatic environments are polluted, thereby making fishes vulnerable to all contaminants such as heavy

Received: November 2022;
in final form January 2023.

metals. In most of the creeks, where catfish are hunted, the waters are heavily exposed to pollution [1] produced by heavy metals from varieties of natural and anthropogenic sources [6].

Heavy metals from man-made sources can easily create local conditions of elevated metal presence in aquatic systems, deteriorating the quality of water and causing damages to both flora and fauna which eventually leads to disastrous effects posing a serious threat to the health of millions of people worldwide [19].

The specific problem associated with heavy metals in the environment is their accumulation through food chain and persistence in nature [9]. Metal bio-accumulation can be defined as the process whereby an organism concentrates metals in its body from the surrounding medium or food, either by absorption or by ingestion [13]. This may occur with different patterns depending on tissue type, deposition, and excretion rates, as well as water acidification, hardness, salinity, and temperature of the ecosystem [20]. Heavy metal and metalloid contamination in water and sediment, if occurs in very high concentrations, may be a serious threat due to their toxicity, long persistence, and bio-accumulation in the food chain [15].

Generally, fishes are considered the most significant bio-monitors in aquatic environments for the estimation of metal pollution level [2], because they have many specific advantages in describing the natural characteristics of aquatic systems and in assessing changes to habitats [17]. Bio-monitoring of hazardous substances in tissues of aquatic organisms has been successfully applied during recent years for heavy metal pollution. However, fishes are found at the end of the aquatic food chain and because they accumulate metals and pass them to humans could cause chronic or acute diseases [3]. Metals with high atomic number are more toxic; if the contaminated fishes are consumed, they could aggravate the human health [28]. Some heavy metals including arsenic (As), lead (Pb), mercury (Hg), cadmium (Cd), chromium (Cr), etc. are known as potentially toxic, while others are essential metals and called trace elements such as zinc (Zn), selenium (Se), copper (Cu), etc. which are essential to maintaining the body metabolism, although they are toxic at higher concentrations. However, whatever are the categories of metals, there are specific amounts that are needed in human body but above these specified quantities they become toxic.

High concentrations of heavy metals in water are often detected in the tissue of fishes. The metals can be absorbed by fish skin through dermal contact or accumulated by the gills through breathing or ingestion [16]. The heavy metals concerned with the environmental science chiefly include Pb, Hg, Cr, Cd Zn, Cu, manganese (Mn), nickel (Ni), silver (Ag), etc. [4]. Therefore, the standard organizations and authorities have specified the critical amount of these metals that are acceptable or reasonable health-wise for daily intake. These recommended values are shown in Table 1.

Table 1

Recommended tolerable values of some heavy metals in fishes (mg/kg)

Organization	**Metals**						
	Pb	**Ni**	**Zn**	**Cr**	**Mn**	**Cd**	**References**
UNEP	0.30		5.00		0.02	0.30	[25]
IAEA-407	0.12	0.60		0.73		0.18	[27]
DIRECTIVE 2005/78/EC	0.20					0.50	[11]
FAO/WHO	0.50		5.00	0.05	5.50	0.50	[12]

Taking into account these values as references for environmental pollutions, the objectives of this work are to identify and determine the concentration in Mn, Zn, Ni, Cr, Cd, and Pb in the catfish flesh and to signal the cancer risk for the adults and children in consuming catfish (*Clarias gariepinus*) from the local fishing area, namely, Ogudu Creek, Lagos, Southwest Nigeria.

MATERIALS AND METHODS

SAMPLING LOCATION

Ogudu Creek lies on longitude 3º 24’ 09.0” E and latitude 6º 33’ 52.0” N. This creek is one of the catfish outlets, the fishing activities being very noticeable in this area. Most of the markets in this area were usually patronized by different people: retailers, fish store owners who usually sell the frozen fish, some other buy fishes to roast them dried and/or buy fresh catfish for cooking at home.

SAMPLE COLLECTION

Clarias gariepinus of about the same weight and length were collected from eight different points of Ogudu Creek, Lagos Southwest Nigeria. The average catfish length is about 25 to 38 cm, while the average weight is about 210 g to 320 g. Each of the collected samples was washed clean and sent to the laboratory for preservation.

SAMPLE PREPARATION AND CONCENTRATION MEASUREMENTS

Samples of catfish were preserved in a refrigerator after collection; afterwards the samples were carefully dissected and the fleshy parts were dried in oven for acid digestion. The dried fleshy parts were ground into fine particles. 1.0 g of the ground particles was put into 100 mL Pyrex beaker containing 10 mL of deionized water.

Finally, 7.5 mL of concentrated hydrochloric acid and 2.5 mL of concentrated nitric acid were added. The beaker was placed on a hot plate (110 °C) until its content was reduced to about 20 – 30 mL. After cooling to the temperature of the surrounding, the suspension was filtered and the filtrate was mixed with deionized water to make up a volume of 50 mL. This solution was analyzed by an atomic absorption spectrophotometer (AAS) model S4 series, Model (GBC 906) (USA) for the identification and quantification of the metals.

HEALTH RISK ASSESSMENTS

For the health risk assessment, the following parameters are considered: the daily intake (*DI*) of metals, hazard quotient (*HQ*), and the risk index (*RI*). The *DI* of any potentially toxic elements is directly related to the levels of concentrations in the daily fish consumption. In addition, the weight of the consumer has effect on the tolerance level of the contaminants. International regulators bodies prescribed the tolerance level of each of the heavy metals.

Table 2

Parameters for the health risk estimations of heavy metals

Parameters	**Units**	**Children**	**Adults**
Average body weight (*ABW)*	kg	15	65
Exposure frequency (*EF*)	Days/year	365	365
Exposure duration (*ED*)	Years	10	70
Ingestion rate (*IR*)		200	100
Average time	mg/day		
For carcinogenic effect	Days/year	365×70	365× 70
For non-carcinogenic effect	Days/year	365× *ED*	365× *ED*

DAILY INTAKE (*DI*) OF HEAVY METALS

For the estimation of the daily intake equation (1) is used.

$$DI = \frac{C \times RI}{MBW} \quad (1)$$

where *C* is the mean concentration of heavy metals in the collected samples (mg/kg wet weight), *RI* is the average rate ingestion of fish per person taken to be 0.1 kg/day for adult and 0.2 kg/day for the children (this is because nutritionist recommended more fish consumption for the children); *MBW* is the average body weight of the consumers in kg. Table 2 indicates the values of the quantities used in the computation of the health risk parameters.

HAZARD QUOTIENT (*HQ*)

Considering the metal non-carcinogenic effect, the *HQ* may be estimated as recommended by USEPA by the relationship below [23]:

$$HQ = \frac{EF \times ED \times RI \times C_f \times C}{MBW \times AT_n \times O_f D} \quad (2)$$

where *EF* is the exposure frequency (365 days/year), *ED* is the exposure duration [30 years for non-cancer risk, as used by USEPA (2011)], C_f is the conversion factor (0.208) from fresh weight (*FW*) to dry weight (*DW*) given that 79 % is the moisture content in fish, AT_n is the average exposure time (365 days/year for 30 years) characterizing no cancer risk [26]. The oral reference dose (O_fD) of the metal (that is, the estimate of the daily exposure to which the human population may be continuously exposed over a lifetime without an appreciable risk of deleterious effects). O_fD (mg kg^{-1} day^{-1}) was used for analysis according to USEPA [24].

TARGET CANCER RISK (*TCR*)

TCR has been used to indicate the carcinogenic risks. This is provided by USEPA 2011 risk-based concentration chat.

$$TCR = \frac{EF \times EDI \times RI \times C \times CSP}{ABW \times AT_c} \times 10^{-3} \quad (3)$$

where *C* is the metal concentration (μg/g), *IR* is the ingestion rate (g/day), and *CSP* is the carcinogenic potency slope for oral route (mg/kg bw/day^{-1}).

Table 3

Reference dose and cancer slope factor value for heavy metals

Elements	**Reference Dose O_fD (mg/kg bw/day)**	**Cancer slope factor (*CSP*) (mg/kg bw/day)$^{-1}$**	**References**
Zn	3×10^{-1}	–	
Mn	0.046	–	[18]
Pb	3.5×10^{-3}	8.5×10^{-3}	[24]
Ni	2×10^{-2}	17	[21]
Cd	1×10^{-3}	6.1	
Cr	3×10^{-4}	5.01×10^{-1}	USEPA IRIS 2011

The values are provided in the literatures [21]. *ATc* is the averaging time of carcinogens. Table 3 indicates the reference dose and cancer slope factor for each of the metals identified in the samples.

HEALTH RISK INDEX (*HRI*)

HRI from *THQ*s is expressed as the sum of the hazard quotients [26].

$$HRI = \sum_{n=1}^{6} THQ_{(n)} \tag{4}$$

where, *THQ* is the targeted hazard quotient and *n* is the individual metal identified in the sample. The recommended values of *HRI* for non-health issues is less than unity while greater than that may be a concern health wisely.

RESULTS AND DISCUSSIONS

Pb, Ni, Zn, Cr, Mn, and Cd were identified in the samples and the concentration levels of each of these metals were obtained and recorded in Table 4. These values were used in the evaluations of the parameters in assessing the health risk of *Clarias gariepinus* consumption.

Table 4

Mean ± SD of the heavy metal concentration per samples (mg/kg)

Samples points	**Concentrations (mg/kg)**					
	Pb	**Ni**	**Zn**	**Cr**	**Mn**	**Cd**
P1	2.99±0.03	0.52±0.24	37.73±0.07	0.07±0.81	17.15±0.90	0.07±0.06
P2	1.75±0.01	0.97±0.18	50.75±0.32	3.25±0.15	43.32±0.88	3.25±0.73
P3	35.84±0.21	0.77±0.30	39.37±0.91	3.98±0.72	91.22±0.07	0.22±0.28
P4	32.01±0.31	2.74±0.06	14.71±0.71	3.19±0.43	59.75±0.48	0.01±0.04
P5	34.87±0.50	2.61±0.41	2.79±0.87	1.77±0.52	39.11±0.32	1.06±0.11
P6	3.98±0.22	3.47±0.21	27.13±0.05	5.01±0.79	42.28±0.31	1.17±0.80
P7	1.86±0.13	1.43±0.26	19.84±0.87	0.96±0.33	26.11±0.07	0.09±0.49
P8	27.51±0.51	2.03±0.34	50.19±0.53	ND	21.17±0.64	0.93±0.17

The concentration of Pb is between 1.75 ± 0.01 and 35.84 ± 0.21 mg/kg from the sample P1 to P8. In all the samples, Ni concentration varies between 0.52 ± 0.24 mg/kg as the lowest one and 3.47 ± 0.21 mg/kg as the highest in samples P1 and P6 respectively; Zn concentrations in all samples range from 2.79 ± 0.87 mg/kg to 50.75 ± 0.32 mg/kg, sample P5 having the lowest and P2 the highest concentration; Cr concentration is in the range ND to 3.98 ± 0.72 mg/kg, but it was not detectable in sample P8. The highest Cr concentration was found in sample P3. The concentration of Mn varies between 17.15 ± 0.90 mg/kg and 91.22 ± 0.07 mg/kg for Mn and for Cd between 0.01 ± 0.04 mg/kg and 3.25 ± 0.73 mg/kg. Samples P1 and P4 have the lowest concentration in Mn and Cd, while the highest concentration of Mn is found in P3 and of Cd in P2. Estimated daily intake of the heavy metals in each sample has been computed and compared in each of the samples P1 to P8 for both the adults and the children.

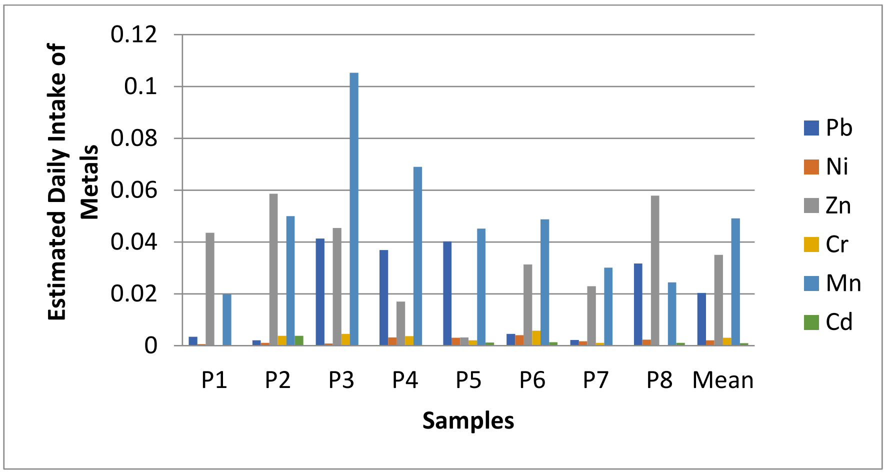


Fig. 1. Adult estimated daily intake of heavy metals.

Figure 1 shows the comparisons of the estimated daily intake of the heavy metals in adults, while Fig. 3 illustrates the estimated daily intake in children of 10 years old. In most of the samples Mn is the most prominent and Zn is very noticeable in all the samples. It is of interest that both Mn and Zn are good for human but the bio-accumulation of these metals in human body on a long term could produce negative effects. Therefore, in average, Mn, Zn, and Pb intake has the highest concentration of 0.049, 0.035, and 0.020 respectively for the adults. As for children, the average high intake of heavy metals is 0.127, 0.091, and 0.053 for Mn, Zn, and Pb, respectively as shown in Fig. 3.

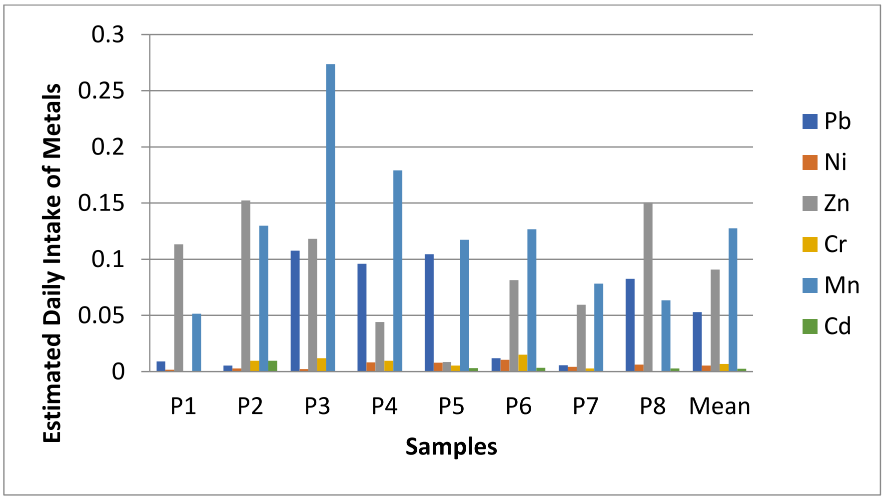
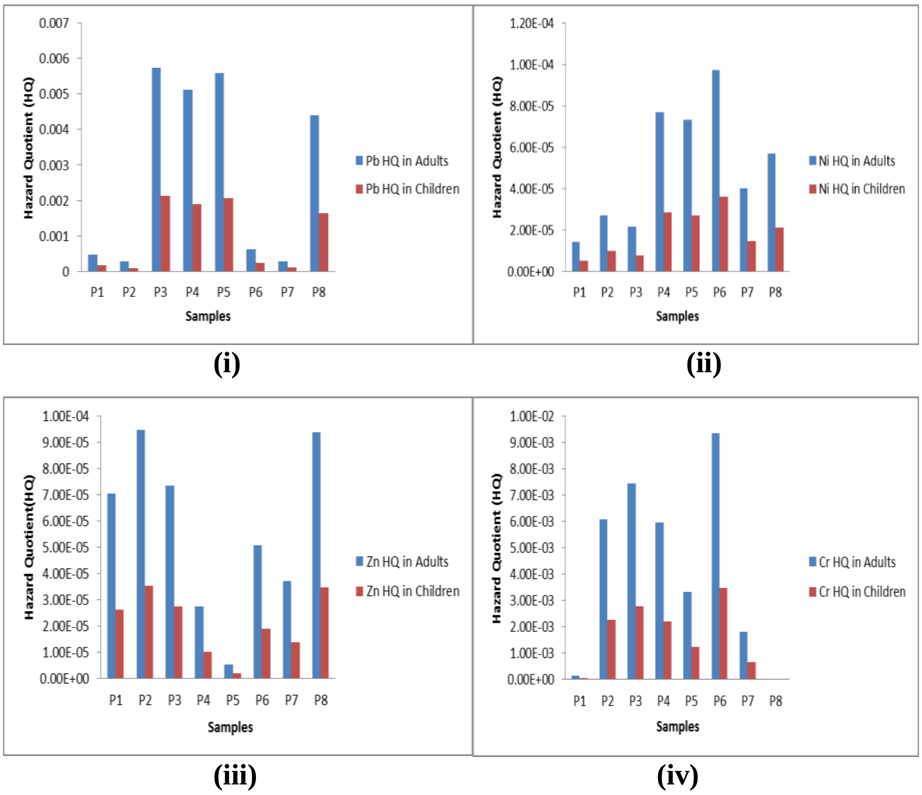
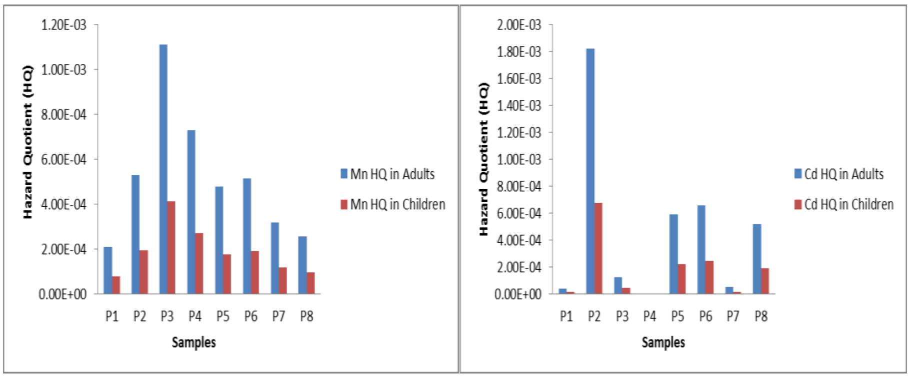


Fig. 2. Children estimated daily intakes of heavy metals.

It is of concern that Pb intake is among the metals found to be present in both the adults and children. Pb is one of the metals with a high rate of intake in some of the samples, indicating that these samples may be highly toxic as compared to the other samples contaminated with heavy metals.

In assessing the health risk in consuming *Clarias gariepinus* from Ogudu creeks, the hazard quotient *(HQ)* for each of the metal identified in each sample were computed for both adults and children in order to evaluate the potential for non-cancer health hazards from exposure to the contaminants. The *HQ* is the ratio of the potential exposure to a selected metal, relative to the level at which no adverse effects is expected from the samples. A *HQ* of < 0.2 for any given pathway is often considered acceptable [7]. Figs. 3i – 3vi show the comparison the *HQ* for both the adults and children per samples per the heavy metal. In Fig. 3i, *HQ* due to Pb has been compared for the adults and the children. The samples P3, P4, P5 and P8 have the highest *HQ* for the adults as compared to the children. In Fig. 3ii, *HQ* for Ni was compared between that of the adults and the children, resulting that *HQ* in adults is higher than that of the children. The same trend can be observed in Figs. 3iii – 3iv even though these values were lower than that in Fig. 4i. Since the *HQ* is less than 1 (Figs. 3i – 3iv) no adverse health effects are expected.





(v) (vi)

Fig. 3 (i – vi). Comparison of hazard quotient (*HQ*) of heavy metals in adults and children.

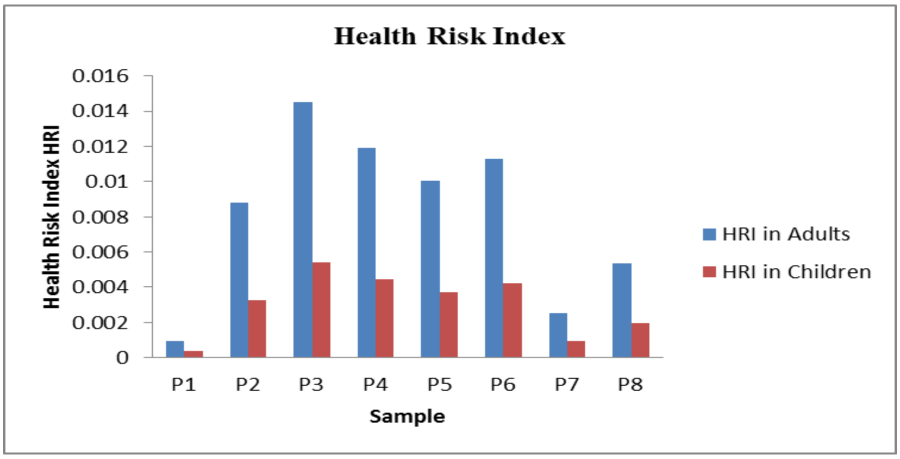


Fig. 4. Estimated health risk index (*HI*) in both adults and children.

Health risk index (*HI*) is the sum of all the *HQs* due to all the heavy metals identified from each sample. *HQ* is computed to evaluate the potential for non-cancer health hazards due to exposure to contaminants. The estimated *HI* is computed for both the adults and children from the samples and the values were compared to each other samples. Fig. 4 shows the comparisons of the *HI* in this study. For the adults, the *HI* ranges from 1.19 E–02 to 9.42 E–04. These values are far below the risk level as suggested by USEPA, WHO, and FAO. For the children, the estimated *HI* is in the range of 5.38 E–03 and 3.50 E–04 meaning that the obtained *HI* in adults is greater than that of the children. Even though, the *HI* is from both the adults and children are far less than the acceptable value for high risk. For the consumers not to be at risk, it is recommended a *HI* < 1. If *HI* >1, this indicates the risk level situations in all cases.

Some of the identified metals like Pb, Ni, Cr, and Cd etc. may be considered carcinogenic agents. Cr, if present in high concentration, in consumed fish may cause lung cancer, liver, and kidney damage, necrosis, mucosal irritation of the central nervous system followed by depression and in rare cases, death [5]**.** Cumulative high concentrations of Pb is known to severely damage the liver, kidneys, brain, nerves, and other organs provoking reproductive disorders, osteoporosis (brittle bone disease), heart disease, high blood-pressure [8].

Cd dose cumulatively may cause immediate poisoning and damage to the liver, kidneys, respiratory tract [22]. Extreme doses of Ni are reported to primarily cause contact dermatitis. Other metals cause pulmonary fibrosis, respiratory tract cancer, iatrogenic intoxication, liver damage and cardiovascular and kidney diseases [10, 14]. Therefore, there is a need to look at the targeted cancer risk (*TCR*) that may be associated with these potentially carcinogenic metals. Tables 5 and 6 show the values of the *TCR* for adults and children, respectively.

Table 5

Targeted cancer risk in adults

Samples points	**Pb**	**Ni**	**Cr**	**Cd**
P1	8.13E–08	2.83E–05	1.12E–07	1.37E–06
P2	4.76E–08	5.28E–05	5.21E–06	6.34E–05
P3	9.75E–07	4.19E–05	6.38E–06	4.29E–06
P4	8.71E–07	1.49E–04	5.11E–06	1.95E–07
P5	9.48E–07	1.42E–04	2.84E–06	2.07E–05
P6	1.08E–07	1.89E–04	8.03E–06	2.28E–05
P7	5.06E–08	7.78E–05	1.54E–06	1.76E–06
P8	7.48E–07	1.10E–04	0	1.82E–05

Table 6

Targeted cancer risk in children

Sample points	**Pb**	**Ni**	**Cr**	**Cd**
P1	3.52E–07	1.23E–04	4.86E–07	5.92E–06
P2	2.06E–07	2.29E–04	2.26E–05	2.75E–04
P3	4.22E–06	1.82E–04	2.76E–05	1.86E–05
P4	3.77E–06	6.46E–04	2.22E–05	8.46E–07
P5	4.11E–06	6.15E–04	1.23E–05	8.97E–05
P6	4.69E–07	8.18E–04	3.48E–05	9.90E–05
P7	2.19E–07	3.37E–04	6.67E–06	7.61E–06
P8	3.24E–06	4.79E–04	0	7.87E–05

The probability of developing cancer as a result of consuming catfish from this catchment area is low (1:10,000) a lifetime of the population of the adults taking catfish regularly while that of the children unlikely to occur in the same range.

Considering Tables 5 and 6, the children are at greater risk than in the adults. If we compare the adult samples and children samples one notice that the cancer risk are higher in the adults due to a long time effects of catfish consuming.

CONCLUSION

In this work samples of *Clarias gariepinus* have been collected from fish points along the Ogudu Creek in order to identify and quantitatively determine the metal concentrations: Mn, Zn, Ni, Cr, Pb, and Cd.

On the basis of the found heavy metal concentrations, the health risk index was evaluated and found to be below the unity as recommended by WHO/FAO and USEPA for risk assessment. This implies that the people consuming the fishes are not immediately at health risk.

The longtime effects of fish consumption may be a concern to the population due to the bio-accumulation of the toxic metals in catfishes. Therefore, low rate of consumption are recommend and occasional medical control of the consumers must be done. The targeted cancer risk comparison between the adults and the children shows that three out of ten thousand adults may develop cancer within a lifetime as compared to the children.

In conclusion, the probability of developing cancer by consuming catfishes is very low and the consumption of catfish flesh practically does not present a risk for people from Southwest Nigeria.

Acknowledgment. We acknowledged Miss Lawal Musilmat in assisting during the collection of the samples and Mr. Megida Sumila for helping the laboratory analysis of the samples.

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