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Human Health Risks Assessment of Some Heavy Metals in *Oreochromis niloticus* from a Tropical Reservoir

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Abstract

This study evaluated the human health risks of Mn, Fe, Zn, Cu, Cd, Pb, Cr, Co and Ni in *Oreochromis niloticus* inhabiting Agodi reservoir in Ibadan, Nigeria. The metals' concentrations were determined with atomic absorption spectrophotometer. Carcinogenic and non-carcinogenic risk of consumers from the intake of metals in the fish was evaluated by Health Risk Index (HRI), Health quotient (HQ) Target Hazard Quotient (THQ) and Target cancer risk (TR). The metal concentrations in the fish were below the recommended limit by Environmental Protection Agencies. HRI and HQ of each examined metal was greater than one, indicating that there was potential non-carcinogenic health risk associated with the consumption of the fish. However, the THQ and TR were less than one. This indicated that *Oreochromis niloticus* will not pose any immediate carcinogenic threat to its consumers. It is therefore recommended that only eco-friendly activities should be permitted in/around aquatic ecosystems especially Agodi reservoir in order to keep contaminants below safety limit.

Introduction

Fish is a major part of Nigerian diet and is very susceptible to environmental pollution due to the activities and processes going on in and around the aquatic area. Fish is a source of energy and protein with high biological value, and contributes to the intake of essential nutrients, such as iodine, selenium, calcium, and vitamins A and D, with well-established health benefits. It is recommended for the prevention of heart disease because it is low in total and saturated fats but provides n-3 (also called omega-3) long-chain polyunsaturated fatty acids. It is generally appreciated as one of the healthiest and cheapest source of protein because it has amino acid compositions that are higher in cysteine than most other source of protein (Orosun *et al*., 2016). Catfish and Tilapia are among the most popular fish consumed in Nigeria mainly due to their availability, taste and relatively low cost. Tilapia particularly, is the most common example of lower-fat fish that provide more of these heart-healthy nutrients (Carroll and Warwick, 2017). Hence, the need to evaluate the health risks of heavy metals in *Oreochromis niloticus*.

A general concern about the safety of foods and assessment of their risk to the general population has been on the increase in recent years (Jimoh *et al*., 2004, Dimari *et al*., 2008, Adeyeye and Ayoola 2010, Abubakar

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et al., 2014, Milam *et al*., 2012, Edward *et al*., 2013, Adesuyi *et al*., 2016; Manavia and Mazumder 2018; Akinola *et al.,* 2019 & 2020; Olawusi-Peters and Adejugbagbe, 2020). The concentrations of natural and synthetic chemical compounds in food contribute to its safety. Thus, heavy metals contamination is an important issue regarding the health of the aquatic animals which in turn affect the health of their consumers. Several studies have been done on the assessment of heavy metals on fish from different sources of water to evaluate the health risk that man and other consumers of fish may be exposed to (Adesuyi *et al*., 2016; Isibor and Imoobe, 2017; Olawusi-Peters *et al*., 2017; Olawusi-Peters *et al.,* 2019; Omobepade *et al.,* 2020; Olawusi-Peters and Adejugbagbe, 2020). According to Environmental Protection Agencies (EPAs), human health risk assessment is the estimation of the nature and probability of immediate or futuristic adverse health effects in humans exposed to chemicals in contaminated environmental media (Liu *et al.,* 2019). Risk assessment for heavy metals is estimated using parameters such as estimated daily intake (EDI), target hazard quotient (THQ), hazard index (HI) and target cancer risk (TR) introduced by United States Environmental Protection Agency (USEPA 2011; Liu *et al.,* 2019). These parameters depend not only on intake amount of contaminant but also deal with exposure frequency and duration, average body weight and oral reference dose (RfD) (Baki *et al*., 2018; Liu *et al*., 2018; Olawusi-Peters, 2021).

In Nigeria, the levels of heavy metals pollution in fish samples inhabiting some reservoirs such as Kainji Dam (Jimoh *et al*., 2004), Alau Dam (Dimari *et al*., 2008), Ikosi Dam (Adeyeye and Ayoola (2010), Kiri Dam (Milam *et al*., 2012), Ureje Dam (Edward *et al*., 2013), Awara Dam (Olawusi-Peters *et al*., 2019) have been investigated, and revealed that despite the valuable nutritional constituents of fish, their ability to bioaccumulate toxic and non-biodegradable heavy metals in their edible body parts needs adequate assessment of the concentration of heavy metals at regular intervals, so as to protect the consumers. Considering the potential toxicity, recalcitrant nature and cumulative behaviour of heavy metals as well as the frequency of fish consumption, its safety and health concerns, more research is needed to be done on all fish species consumed in Nigeria. Thus, this study monitored the concentrations of Cd, Pb, Cr, Mn, Fe, Co, Ni, Cu and Zn in *O. niloticus* inhabiting Agodi reservoir and assessed the potential human health risk (carcinogenic and non-carcinogenic) associated with its consumption.

Materials and Methods

Sample collection and preparation

A total of two hundred and sixteen (216) samples (18 samples per month) of *O. niloticus* (average weight and length of 204.65±1.28g and 15.50±0.84cm respectively) were collected from Agodi reservoir, Ibadan Oyo State, Nigeria (3º 56' 18'' E and 7º 26' 11'' N) with the help of professional local fishermen between 2015 and 2016 and were identified according to Olaosebikan and Raji (2013). The fishes were captured with cast net. They were washed with distilled water and kept in ice box and then transferred to the research laboratory of the Department of Chemistry, Bowen University Iwo, Nigeria for analyses. The fish samples were dried in a laboratory oven at 60±1°C for 5–6 hours.

Estimation of heavy metals

In the research laboratory of the Department of Chemistry, Bowen University Iwo, Nigeria; the fish samples were dissected to remove the muscles for the analysis. The muscles were oven dried at 60^{o}C for 48hours and 1g of the dried muscle tissue was digested in analytical grade HNO_3:$HClO_4$ (4:1) according to Javed *et al*. (2015) and used for the estimation of heavy metals using Atomic Absorption Spectrophotometer (Model PG990). Analytical blanks were run in the same way as the samples and concentrations were determined using standard solutions prepared in the same acid matrix. The accuracy of the applied analytical procedure was tested using the certified reference material for investigated metals. Replicate analyses of these reference materials gave good accuracy, with recovery rates for metals between 96 and 104 % for fish provided as supplementary material. Instrument calibration standards were made by diluting the standard (1000 ppm) supplied by Wako Pure Chemical Industry Ltd., Japan.

Statistical Analyses

Data obtained were subjected to descriptive statistics (to determine means and standard deviations) on the Statistical Package for Social Sciences (20.0) while the potential health risks of heavy metal consumption through *O. niloticus* were assessed based on health risk index (HRI) Health Quotient (HQ), the target hazard quotient (THQ), hazard index (HI) and target cancer risk (TR).

Health Risk Index (HRI) (which gives quantitative information on risk posed by each contaminant to the health of the fish consumers) was calculated as,

$$\boldsymbol{Health\ Risk\ Index} = \frac{Daily\ Intake\ of\ Metal\ (DIM)}{Reference\ Oral\ Dose\ (RfD)}$$

(Olawusi-Peters and Adejugbagbe, 2020)

Where,

$$\boldsymbol{DIM} = \frac{M\ \times \text{Conversion Factor} \times\ W}{Average\ body\ weight}$$

(Isibor and Imoobe, 2017)

and M is the concentration of metal in fish (mg/kg), Conversion Factor of 0.085 is to convert fresh fish weight to dry weight (Sajjad *et al*., 2009), *W* is the dry weight of the fish consumed per/day and 48g/day was estimated as the average fish consumption rate in Nigeria (Omobepade *et al.,* 2020) while the average body weight used was 60kg (Olawusi-Peters *et al*, 2019). Reference Oral Doses (RfD) was 0.040, 0.300, 0.700, 0.004, 0.001, 1.500, 0.020, 0.140 and 0.020 mg/kg/day for Cu, Zn, Fe, Pb, Cd, Cr, Co, Mn and Ni respectively (USEPA, 2011; Olawusi-Peters and Adejugbagbe, 2020).

Health quotient (which estimates the hazard heavy metal could have on humans in their later life) was determined as:

$$HQ = \frac{W \times M}{RfD \times BW}$$

(Omobepade *et al.,* 2020)

Where: *W* is the dry weight of the fish consumed per/day,
M is the concentration of heavy metal in the fish (mg/kg),

RfD is the reference oral dose,
BW is the average body weight.

Target Hazard Quotient (THQ)

THQ (which is a dimensionless quantity that defines the exposure duration and the non-carcinogenic risk within the period) was calculated as,

$$THQ = \frac{EFr \times ED \times FIR \times M}{RfD \times BW \times ATn} \times 10^{-3}$$

(Olawusi-Peters, 2021)

Where; EF is the exposure frequency (350 days/year); ED is the exposure duration (54 years, equivalent to the average life expectancy of the Nigerian population); FIR is the food ingestion rate (fish consumption values for south western adult Nigerian is 48g/person/day) (Omobepade *et al.,* 2020); M is the metal concentration in the edible parts of fish (mg/kg); RfD is the oral reference dose; BW is the average body weight and ATn is the average exposure time for non-carcinogens (19710) (USEPA 2011).

Hazard Index (HI)

The hazard index (HI) which is expressed as the sum of the target hazard quotients was calculated as,

$HI = \sum_{n-1}^{n} THQ$ (Núñez *et al*., 2018)

Where; n=number of heavy metals examined, THQ= unit THQ of *ith* heavy metal

Target Cancer Risk (TR)

Target cancer risk (TR) which indicates the carcinogenic risk (USEPA 2011) was calculated as,

$$TR = \frac{M \times FIR \times CPSo \times EF \times ED}{Bw \times ATn} \times 10^{-3}$$

Where; M, FIR, EF, ED, BW are already explained above. ATn is the averaging time for carcinogens (365 days/ year × 54 years, since in Nigeria the average life expectancy is approximately 54 years). CPSo is the carcinogenic potency slope oral (mg/kg bw-day−1). Since Mn, Fe, Co, Cu and Zn do not cause any carcinogenic effects, their CPSo have not yet been established (USEPA 2012), TR values for intake of only Ni, Pb, Cr and Cd were calculated to show the carcinogenic risk, since they were mentioned in the list of potent carcinogens (USEPA 2012). Their carcinogenic potency slope oral (CPSo) as obtained from the integrated risk information system database (USEPA, 2012) is given as 1.7, 0.009, 0.5 and 0.6 for Ni, Pb, Cr and Cd respectively. According to New York State Department of Health (NYSDOH, 2007) and Javed and Usmani (2016) the TR categories are described as, if TR $\leq 10^{-6}$ = Low; 10^{-4} to 10^{-3} = moderate; 10^{-3} to 10^{-1} = high; $\geq 10^{-1}$ = very high.

NOTE: Values below 1 for Target Hazard Quotient (THQ), Health Quotient (HQ), Health Risk Index (HRI) and Hazard Index (HI) are unlikely to result in any chronic systemic risk adverse health effects during a lifetime of exposure and would normally be considered as acceptable.

Results

The mean concentrations of metals obtained from the descriptive statistics recorded in this study were presented in Table 1 while the Daily intake of metals (DIM) was given in Table 2. HRI observed in this study (Table 3) was in the order of Co>Cd>Mn>Zn>>Fe>Cu>Pb>Ni>Cr and Mn>Co>Zn>Fe> Pb>Cu>Cd>Ni>Cr in dry and wet season respectively. HRI was higher than one (i.e. HRI>1) in all the examined heavy metals except Cr in both seasons. HQ (as presented in Table 4) was higher than one (HQ>1) in all the examined heavy metals except Cr in dry seasons. The THQ values for Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb and Zn as presented in Table 5 were 1.83×10^{-3}, 8.92×10^{-3}, 0.00×10^{-1}, 1.06×10^{-4}, 2.92×10^{-4}, 1.37×10^{-3}, 4.07×10^{-5}, 6.14×10^{-5} and 4.77×10^{-4} respectively in the dry season but were 7.67×10^{-5}, 2.05×10^{-3}, 1.11×10^{-6}, 2.62×10^{-4}, 4.70×10^{-4}, 2.62×10^{-3}, 2.45×10^{-5}, 4.18×10^{-4}, 5.28×10^{-4} and 6.44×10^{-3} respectively in the wet season. THQ was less than 1 (THQ<1) in all the examined heavy metals throughout the study with the trend of Co>Cd>Mn>Zn>Fe>Cu>Pb>Ni>Cr and Co>Mn>Zn>Fe>P b>Cu>Cd>Ni>Cr in the dry and wet season respectively

Table 1. Concentration of Metals (mg/kg) in *O. niloticus* inhabiting Agodi reservoir

Month	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn
Jan	0.00±0.00	0.00±0.00	0.00±0.00	1.36±0.45	0.00±0.00	63.33±15.42	0.00±0.00	0.00±0.00	112.19±41.12
Feb	0.00±0.00	0.00±0.00	0.00±0.00	5.19±3.93	0.00±0.00	16.00±27.71	0.00±0.00	0.00±0.00	37.85±36.50
Mar	0.23±0.40	0.00±0.00	0.00±0.00	4.22±3.20	422.50±730.49	21.83±18.13	0.00±0.00	1.79±3.10	121.89±44.54
April	0.00±0.00	0.00±0.00	0.00±0.00	3.73±0.92	602.75±0.00	43.17±8.86	3.46±3.24	0.00±0.00	61.13±2.93
May	0.47±0.48	1.30±2.25	0.64±1.11	27.42±33.94	637.00±647.23	1251.92±1100.14	0.00±0.00	13.50±21.38	382.34±124.41
June	0.00±0.00	2.06±1.10	14.58±25.26	33.93±23.40	409.17±517.91	986.50±1049.65	0.00±0.00	0.00±0.00	91.53±74.44
July	0.00±0.00	2.27±1.22	0.00±0.00	20.23±11.81	896.83±673.03	921.93±890.97	0.00±0.00	0.00±0.00	365.82±324.23
Aug	0.00±0.00	2.70±2.42	0.00±0.00	8.93±3.09	1332.33±1107.07	1003.08±756.67	3.39±5.87	1.61±0.00	446.29±398.49
Sept	0.00±0.00	0.00±0.00	0.00±0.00	3.75±5.76	35.25±39.43	41.00±26.38	1.02±1.11	0.00±0.00	114.71±178.59
Oct	0.00±0.00	0.00±0.00	0.00±0.00	2.19±0.59	0.17±0.14	78.08±65.85	0.00±0.00	0.00±0.00	309.02±37.40
Nov	0.18±0.32	14.75±25.55	0.00±0.00	3.59±3.28	0.83±1.44	124.92±22.12	1.93±3.33	0.00±0.00	100.28±128.88
Dec	11.69±20.25	0.00±0.00	0.00±0.00	8.61±7.80	0.00±0.00	46.42±36.78	0.00±0.00	0.00±0.00	235.26±23.77
Dry Season	2.38±9.05	3.49±11.37	0.00±0.00	5.54±4.78	266.63±692.31	250.75±484.94	1.06±2.93	0.32±1.25	186.38±219.21
Wet Season	0.10±0.26	0.80±1.33	2.18±9.54	13.64±18.64	429.10±532.69	477.78±762.58	0.64±1.64	2.18±8.34	206.63±183.45
WHO (2005)	0.50	2.00	0.50	3.00	30.00	0.50	5.00	2.30	67.90
FAO (2007)	0.20	2.00	0.50	3.00	30.00	0.50	-	-	-

Concentration of Metals (mg/kg) were presented as means and standard deviations

Table 2. Daily Intake of Metal (DIM) of *O. niloticus* inhabiting Agodi reservoir

Month	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn
Jan	0.00	0.00	0.00	0.09	0.00	4.31	0.00	0.00	7.63
Feb	0.00	0.00	0.00	0.35	0.00	1.09	0.00	0.00	2.57
Mar	0.02	0.00	0.00	0.29	28.73	1.48	0.00	0.12	8.29
April	0.00	0.00	0.00	0.25	40.99	2.94	0.24	0.00	4.16
May	0.03	0.09	0.04	1.86	43.32	85.13	0.00	0.92	26.00
June	0.00	0.14	0.99	2.31	27.82	67.08	0.00	0.00	6.22
July	0.00	0.15	0.00	1.38	60.98	62.69	0.00	0.00	24.88
Aug	0.00	0.18	0.00	0.61	90.60	68.21	0.23	0.11	30.35
Sept	0.00	0.00	0.00	0.26	2.40	2.79	0.07	0.00	7.80
Oct	0.00	0.00	0.00	0.15	0.01	5.31	0.00	0.00	21.01
Nov	0.01	1.00	0.00	0.24	0.06	8.49	0.13	0.00	6.82
Dec	0.80	0.00	0.00	0.59	0.00	3.16	0.00	0.00	16.00
Dry Season	0.16	0.24	0.00	0.38	18.13	17.05	0.07	0.02	12.67
Wet Season	0.01	0.05	0.15	0.93	29.18	32.49	0.04	0.15	14.05

Table 3. Health Risk Index (HRI) of *O. niloticus* inhabiting Agodi reservoir

Month	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn
Jan	0.00	0.00	0.00	2.31	0.00	30.76	0.00	0.00	25.43
Feb	0.00	0.00	0.00	8.83	0.00	7.77	0.00	0.00	8.58
Mar	15.87	0.00	0.00	7.17	41.04	10.60	0.00	30.46	27.63
April	0.00	0.00	0.00	6.35	58.55	20.97	11.76	0.00	13.86
May	31.73	294.67	0.03	46.61	61.88	608.07	0.00	229.50	86.66
June	0.00	466.56	0.66	57.69	39.75	479.16	0.00	0.00	20.75
July	0.00	513.78	0.00	34.40	87.12	447.80	0.00	0.00	82.92
Aug	0.00	612.00	0.00	15.17	129.43	487.21	11.53	27.34	101.16
Sept	0.00	0.00	0.00	6.38	3.42	19.91	3.46	0.00	26.00
Oct	0.00	0.00	0.00	3.73	0.02	37.93	0.00	0.00	70.04
Nov	12.47	3343.33	0.00	6.11	0.08	60.67	6.55	0.00	22.73
Dec	795.03	0.00	0.00	14.63	0.00	22.55	0.00	0.00	53.33
Dry Season	161.84	791.07	0.00	9.42	25.90	121.79	3.60	5.44	42.25
Wet Season	6.80	181.33	0.10	23.19	41.68	232.06	2.18	37.06	46.84

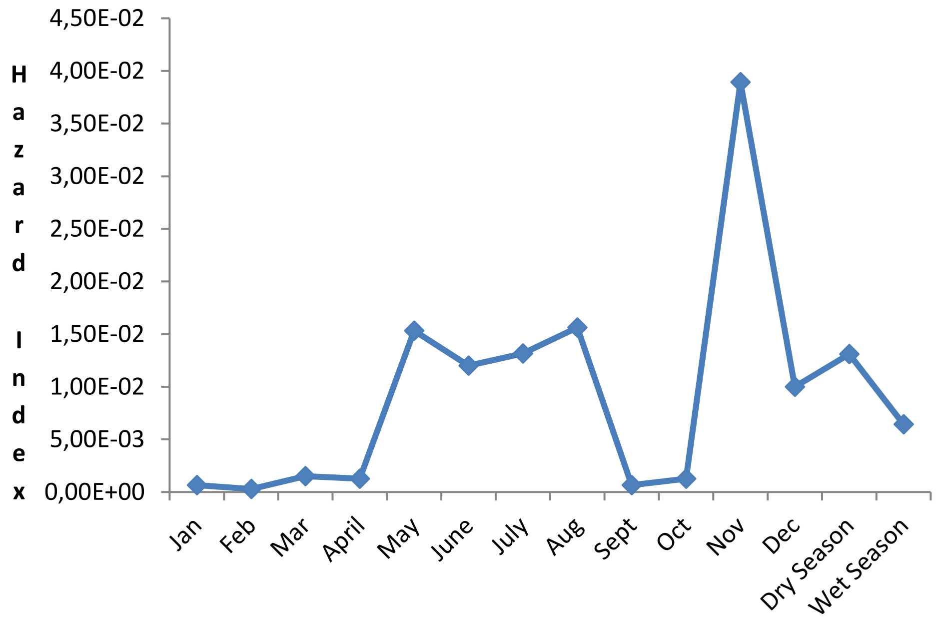

Figure 1. Hazard Index (HI) of *O. Niloticus* Inhabiting Agodi Reservoir

and would be considered as acceptable. Also, Figure 1 revealed that the HI for the dry (1.31×10^{-2}) and wet (6.44×10^{-3}) seasons were less than one (i.e. HI<1) and are unlikely to result in any chronic systemic risk adverse health effects during a lifetime of exposure.

The TR values for Ni, Cd, Cr and Pb (as presented in Table 5) were 1.38×10^{-3} (Moderate risk), 1.10×10^{-3} (Moderate risk), 0.00×10^{1} (Low/No risk) and 2.21×10^{-6} (Low risk) respectively in the dry season with corresponding values of 8.35×10^{-4} (Moderate risk), 4.60×10^{-5} (Low risk), 8.36×10^{-4} (Moderate risk) and 1.51×10^{-5} (Low risk) in the wet season. The result showed that higher TR values were recorded in the dry season for Ni and Cd while the order was reversed for Cr and Pb. Also, the trend was Ni>Cd>Pb>Cr and Cr>Ni>Cd>Pb in the dry and wet season respectively.

Discussion

Results from this study indicated that the concentrations of heavy metals were lower than the values recommended for human consumption by World Health Organisation (WHO, 2005) and Food and Agriculture Organisation (FAO, 2007). Comparatively, the concentrations recorded for all the metals were lower than the value recorded by Ramos, (2012), Rajeshkumar and Li, (2018) and Manavia and Mazumder, (2018). Although, these differences can be attributed to variations in the study area, the size, age, sex and the physiological status of the fish (Manavia and Mazumder, 2018). Other factors such as fishing seasons, microbial activity and heavy metals content in sediment, water chemistry characteristics (dissolved organic content, salinity, pH, and redox potential) assay methods should be considered.

The health risk index shows an individual's risks of heavy metal exposure based on body weight. Generally, HRI < 1 means that the exposed population is safe of metals health risk while HRI > 1 means the opposite (Orosun *et al*., 2016, Olawusi-Peters, 2021). The health risk assessment of these heavy metals revealed that all the heavy metals will pose various non-carcinogenic health risks to the consumers since the HRI values of all the metals were higher than 1. This observation is similar to the observation of Onuoha *et al.,* (2016) and Isibor and Imoobe, (2017) but is at variance with the findings of Abubakar *et al.,* (2014) and Olawusi-Peters and Adejugbagbe, (2020) who observed HRI values of less than 1 for imported frozen fish (*Trachurus Murphyi*) sold in Zaria metropolis and for *Clarias gariepinus* from Akure metropolis, in Nigeria.

Onuoha *et al.,* (2016) and Olawusi-Peters (2021) reported that even though the HQ-based assessment method does not provide a quantitative estimate for the probability of an exposed population experiencing a reverse health effect, it indeed indicates the risk level due to exposure to pollutants. The Health quotient estimated for all metals had values higher than 1. This observation is in line with the findings of Abubakar *et al.,* (2014) who observed HQ values higher than 1 for *Trachurus murphyi* sold in Zaria metropolis, Nigeria but is at variance with the findings of Olawusi-Peters and Adejugbagbe, (2020) and Omobepade *et al.,* (2020) who obtained values of less than 1 for *Clarias gariepinus* and *Nematopalaemon hastatus* from Akure metropolis and the coastal waters of Ondo State respectively. This implies that the consumers of *O. niloticus* are at risk of the heavy metals (Cd, Cr, Co, Cu, Fe, Pb, Ni, Mn, and Zn) in their later life. Li *et al.* (2014) and Omobepade *et al.,* (2020) stated that a high value of hazard quotient poses relatively high potential health risks to human beings especially for those residing in areas with serious metal pollution. Therefore, the relatively low HQ value recorded in this study means the potential risk is low. HRI and HQ implied that there was immediate and future non-carcinogenic health risk for the consumers of the fish.

THQ parameter does not estimate the risk; it only indicates a level of risk associated with exposure to pollutants; if the value of THQ < 1, it means that there are no adverse effects for the exposed population; when THQ > 1, there is a potential risk related to the metal studied in the exposed population (Al-Mahaqeri and Ahmad, 2015). THQ values of heavy metals (Cd, Cr, Co, Cu, Fe, Pb, Ni, Mn, and Zn) were below one (THQ>1) and this means that the metals would not pose any serious health hazards on the consuming population. This observation was similar to the report of Vieira *et al*. (2011) in Portugal while Falcoä *et al*. (2006) and Chahid (2016) recorded higher values for adults in Spain and Morocco respectively. Olawusi-Peters *et al.,* (2019) and Olawusi-Peters and Adejugbagbe, (2020) also reported higher THQ (Cd, Pb, and Ni) for fish species in Awara reservoir and Akure metropolis of Ondo State Nigeria respectively. Hence, the consumption of *O. niloticus* does not pose health risk concern.

THQ deal with individual heavy metal, but generally food items contain more than one heavy metal. Since HI gives the sum of the target hazard quotients (THQs) for substances that affect the same organ or target organ systems (USEPA, 2017), hazard index (HI) was therefore calculated for the nine heavy metals and revealed that the inhabitants were not exposed to health risks associated to these metals because the HI in all the metals was far less than 1. THQ and HI revealed that there was no non-carcinogenic risk for the consumption of the fish (Baki *et al*., 2018; Liu *et al*., 2018).

Like THQ the estimated lifetime cancer risk (TR) is also not a specific estimate of expected cancers. Rather, it is apparently an upper limit of the probability that the individuals may have cancer sometime in their lifetime following exposure to that toxicant (NYSDOH 2007; Javed and Usmani, 2016). According to USEPA methods, cancer risk lower than 10^{-6} is considered to be negligible,> 10^{-4} is considered unacceptable, and in the range from 10^{-4} to 10^{-6} is considered acceptable (USEPA,

Table 3. Health Quotient (HQ) of *O. niloticus* inhabiting Agodi reservoir

Month	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn
Jan	0.00	0.00	0.00	27.17	0.00	361.90	0.00	0.00	299.18
Feb	0.00	0.00	0.00	103.83	0.00	91.43	0.00	0.00	100.93
Mar	186.67	0.00	0.00	84.33	482.86	124.76	0.00	358.33	325.04
April	0.00	0.00	0.00	74.67	688.86	246.67	138.33	0.00	163.00
May	373.33	3466.67	0.34	548.33	728.00	7153.81	0.00	2700.00	1019.58
June	0.00	5488.89	7.78	678.67	467.62	5637.14	0.00	0.00	244.07
July	0.00	6044.44	0.00	404.67	1024.95	5268.19	0.00	0.00	975.51
Aug	0.00	7200.00	0.00	178.50	1522.67	5731.90	135.67	321.67	1190.11
Sept	0.00	0.00	0.00	75.00	40.29	234.29	40.67	0.00	305.89
Oct	0.00	0.00	0.00	43.83	0.19	446.19	0.00	0.00	824.04
Nov	146.67	39333.33	0.00	71.83	0.95	713.81	77.00	0.00	267.42
Dec	9353.33	0.00	0.00	172.17	0.00	265.24	0.00	0.00	627.36
Dry Season	1904.00	9306.67	0.00	110.80	304.72	1432.86	42.40	64.00	497.01
Wet Season	80.00	2133.33	1.16	272.80	490.40	2730.17	25.60	436.00	551.01

Table 4. Target Hazard Quotient (THQ) of *O. Niloticus* Inhabiting Agodi Reservoir

month	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn
Jan	0.00×10^{1}	0.00×10^{1}	0.00×10^{1}	2.61×10^{-5}	0.00×10^{1}	3.47×10^{-4}	0.00×10^{1}	0.00×10^{1}	2.87×10^{-4}
Feb	0.00×10^{1}	0.00×10^{1}	0.00×10^{1}	9.96×10^{-5}	0.00×10^{1}	8.77×10^{-5}	0.00×10^{1}	0.00×10^{1}	9.68E-05
Mar	1.79×10^{-4}	0.00×10^{1}	0.00×10^{1}	8.09×10^{-5}	4.63×10^{-4}	1.20×10^{-4}	0.00×10^{1}	3.44×10^{-4}	3.12×10^{-4}
April	0.00×10^{1}	0.00×10^{1}	0.00×10^{1}	7.16×10^{-5}	6.61×10^{-4}	2.37×10^{-4}	1.33×10^{-4}	0.00×10^{1}	1.56×10^{-4}
May	3.58×10^{-4}	3.32×10^{-3}	3.28×10^{-7}	5.26×10^{-4}	6.98×10^{-4}	6.86×10^{-3}	0.00×10^{1}	2.59×10^{-3}	9.78×10^{-4}
June	0.00×10^{1}	5.26×10^{-3}	7.46×10^{-6}	6.51×10^{-4}	4.48×10^{-4}	5.41×10^{-3}	0.00×10^{1}	0.00×10^{1}	2.34×10^{-4}
July	0.00×10^{1}	5.80×10^{-3}	0.00×10^{1}	3.88×10^{-4}	9.83×10^{-4}	5.05×10^{-3}	0.00×10^{1}	0.00×10^{1}	9.35×10^{-4}
Aug	0.00×10^{1}	6.90×10^{-3}	0.00×10^{1}	1.71×10^{-4}	1.46×10^{-3}	5.50×10^{-3}	1.30×10^{-4}	3.08×10^{-4}	1.14×10^{-3}
Sept	0.00×10^{1}	0.00×10^{1}	0.00×10^{1}	7.19×10^{-5}	3.86×10^{-5}	2.25×10^{-4}	3.90×10^{-5}	0.00×10^{1}	2.93×10^{-4}
Oct	0.00×10^{1}	0.00×10^{1}	0.00×10^{1}	4.20×10^{-5}	1.83×10^{-7}	4.28×10^{-4}	0.00×10^{1}	0.00×10^{1}	7.90×10^{-4}
Nov	1.41×10^{-4}	3.77×10^{-2}	0.00×10^{1}	6.89×10^{-5}	9.13×10^{-7}	6.84×10^{-4}	7.38×10^{-5}	0.00×10^{1}	2.56×10^{-4}
Dec	8.97×10^{-3}	0.00×10^{1}	0.00×10^{1}	1.65×10^{-4}	0.00×10^{1}	2.54×10^{-4}	0.00×10^{1}	0.00×10^{1}	6.02×10^{-4}
Dry Season	1.83×10^{-3}	8.92×10^{-3}	0.00×10^{1}	1.06×10^{-4}	2.92×10^{-4}	1.37×10^{-3}	4.07×10^{-5}	6.14×10^{-5}	4.77×10^{-4}
Wet Season	7.67×10^{-5}	2.05×10^{-3}	1.11×10^{-6}	2.62×10^{-4}	4.70×10^{-4}	2.62×10^{-3}	2.45×10^{-5}	4.18×10^{-4}	5.28×10^{-4}

2011). Thus the results of this study revealed that the carcinogenic risk for the examined metals falls within the acceptable or lower than the negligible level. This was similar to the observations of Raknuzzaman *et al*., (2016) and Liu *et al*., (2018). TR indicated that there was no carcinogenic risk associated with the consumption of the fish. However, if anthropogenic interference on the ecosystem is not controlled/monitored, there is high tendency that the risk will increase with time. Thus, activities that may increase the tendencies of contaminants in the study area should be regulated so as not to increase the concentrations of heavy metals viz. a viz. the health risks.

Conclusion

This study provided information on heavy metals concentration in *O. niloticus* and its associated health risk for existing and prospective consumers in and around Agodi reservoir in Oyo State, Nigeria. All the metals detected were below the values recommended by FAO and WHO. HRI quantifies risks posed by each metal on the health of the fish consumers, hence the values higher than the threshold (1) indicated that there may be overall non-carcinogenic health risks due to consumption of the fish. This is buttressed by the result of HQ which estimates the effects of heavy metals on humans in their later life. However, THQ which defines the hazard in relation to exposure duration shows that the fish currently have no negative effect on the consumers since THQ for each metal was less than 1. Also, HI which expresses the effects of all examined minerals on the consumers revealed that there is currently no health issue caused by the consumption of the fish. Also, TR suggested that the exposure doses of most elements for human consumption were safe for carcinogenic risk. Therefore, the entire human population who consumes *O. niloticus* from Agodi reservoir can continually depend on its supply. However, if all other routes of entry of heavy metal are considered the potential health risks for consumers might be increased. It is therefore, recommended that considerable attention should be given to the potential health risk of heavy metals via other exposure pathways such as other dietary sources (grains, livestock, vegetables/fruits, and water), inhalation, and skin exposure, since fish only accounted for a part of the human diet. Summarily, fishes dwelling in contaminated waters should be consumed with caution lest it may cause carcinogenic and non-carcinogenic risks to the exposed population.

Author Contribution

Ajibare A.O.: Conceptualization, Formal Analysis, Methodology, Visualization and Writing -original draft, Review and editing; Ogungbile P.O.: Conceptualization, Project Administration, Resources, Investigation, Methodology, Visualization and Writing -original draft; Ayeku P.O.: Conceptualization, Data Curation, Formal Analysis, Methodology, Writing -review and editing; and Akande J.A.: Supervision, Writing - review and editing.

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