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Monitoring of metals in *Tilapia nilotica* tissues, bottom sediments and water from Nworie River and Oguta Lake in Imo State, Nigeria

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Tilapia (*Tilapia nilotica*), bottom sediments and water were collected from Nworie River and Oguta Lake. The muscle, liver and gills of the fish as well as the bottom sediments and water were analysed for Al, Cr, Cd, Pb, As, Zn, Mn, Co, Se, Cu, Ni and Fe using atomic absorption spectrophotometer to highlight the importance of tissue selection in monitoring research, contamination studies and human health risk assessment. Higher concentrations of metals were found in the gills and muscle tissues than in liver, except for Fe and Ni in the liver of *T. nilotica* from Nworie River and Fe in the liver of *T. nilotica* from Oguta Lake. Fe was the highest accumulating metal in the gills of fish samples collected from the two study areas, while Mn was the lowest. All metals were found to be below the international permissible limits. In water samples and bottom sediments, none of the metals exceeded the legal limits for the protection of the aquatic biota. The estimated daily intake (EDI) was below the reference dose (RfD) established by the US-EPA and the hazard quotient values indicated that there was no carcinogenic risk to humans.

Key words: Bottom sediment, water, metals, *Tilapia nilotica*, River Nworie, Oguta Lake.

INTRODUCTION

Aquatic environment, especially fresh water environment, has been of significant importance to the human race. Hence, its contamination has become a worldwide problem in recent times. Water quality refers to the chemical, biological and physical characteristics of water (Diersing, 2009). It is a measure of the condition of water relative to the requirement of one or more biotic species and/or to any human need or purpose (Johnson et al., 1997).

Environmental pollution is a worldwide problem and heavy metals belong to the most important pollutants. Metals tend to accumulate in water and move up the food chain. Heavy metals are commonly found in natural waters and some are essential to living organisms, yet they may become highly toxic when present in high concentrations. Aquatic animals (including fish) bioaccumulate trace metals in considerable amounts and fish have been recognized as good accumulators of organic

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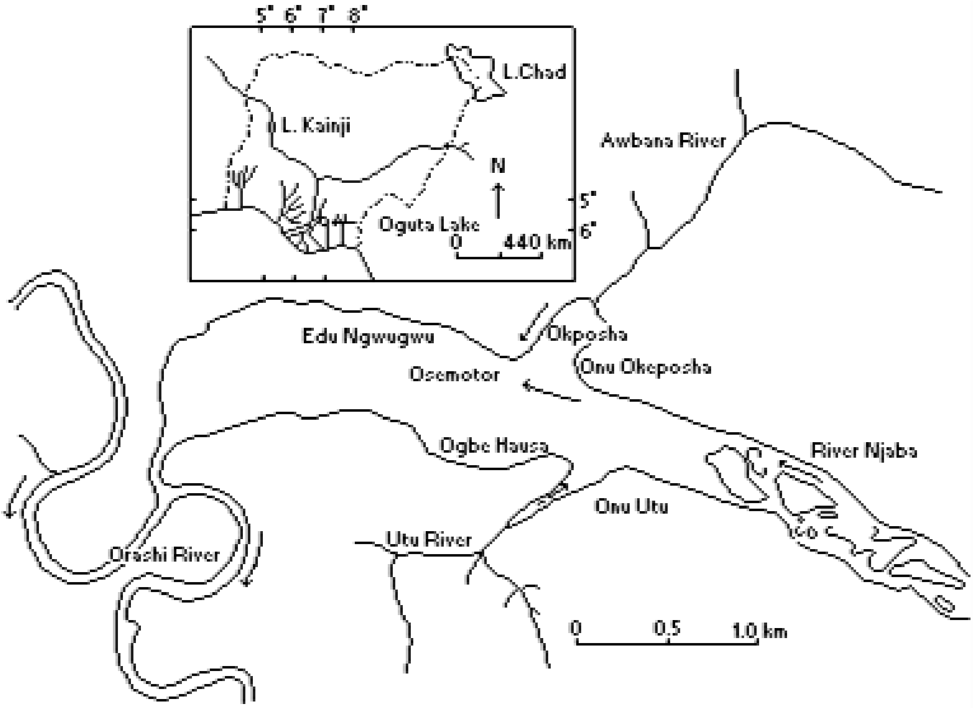

Figure 1. Map of Oguta Lake.

and inorganic pollutants (King and Jonathan, 2003)

Water pollution has become a global problem. Water is essential to all living organisms and in all aspects of human life. Unfortunately, the availability and quality of water have been impacted upon by both natural and anthropogenic sources, leading to poor water quality and productivity of aquatic ecosystems (FAO, 1992). Most heavy metals have no beneficial functions in the human body and can be highly toxic. They enter the body through ingestion, inhalation and skin and accumulate in body tissues faster than the body's detoxification pathways can dispose of them (Ekpo et al., 2008).

Diffusion, facilitated transport or absorption in gills and surface membranes are the mechanism of uptake from water (Oguzie, 1996). The concentration of heavy metals in fish depends on the rate of uptake of food through the gut and the rate of excretion (Bull et al., 1981). Sediments can be sensitive indicators when monitoring contaminants in aquatic environments and are polluted with various kinds of hazardous and toxic substances, including heavy metals. These accumulate in sediments through several pathways, including disposal of liquid effluents, terrestrial run-off and leachate carrying chemicals originating from numerous urban, industrial and agricultural activities, as well as atmospheric deposition (Cohen, 2003).

Fish are notorious for their ability to bioconcentrate heavy metals in their muscles and since they play an important role in human nutrition, they need to be carefully screened to ensure that high levels of toxic trace metals are not being transferred to man through fish consumption (Adeniyi and Yusuf, 2003).

Imo State is one of the 36 states of Nigeria and one of the five states that make up the South East geo-political zone of Nigeria. Owerri is the capital and the largest city in Imo state. Imo state lies within latitudes 4°45'N and 7°15'N and longitudes 6°50'E and 7°25'E. It occupies the area between the lower part of River Niger and the upper and middle of Imo River from which it derives its name (Okoro et al., 2014).

Oguta Lake is the largest natural lake in Imo State and is supposed to have originated from a natural depression. This region is located within the equatorial rainforest belt. Most of the rainforest has been replaced by oil palm plantations especially around the Lake. The lake has a high diversity of phytoplankton which falls in 107 genera (Okoro et al., 2014). Its coordinates are 5°42'24 "N and 6°47'33 "E. It is of enormous importance to the local population (the people of Oguta, Orsu, Obodo, Nkwesi and Awomama) as a source of water, fish, tourism, transport and also as an outlet for sewage (Okoro et al., 2014). The primary inflows are Utu, Awbana and Njaba Rivers and its maximum depth is 8 m (Okoro et al., 2014) with Nigeria as the only basin country (Figure 1).

Nworie River is a tributary of the Otammiri River which is one of the main Rivers in Imo State. Nworie River is about 9.2 km in length. Its coordinates are 5°30'N and 7°00'E (Figure 2). The Nworie River is subject to intense

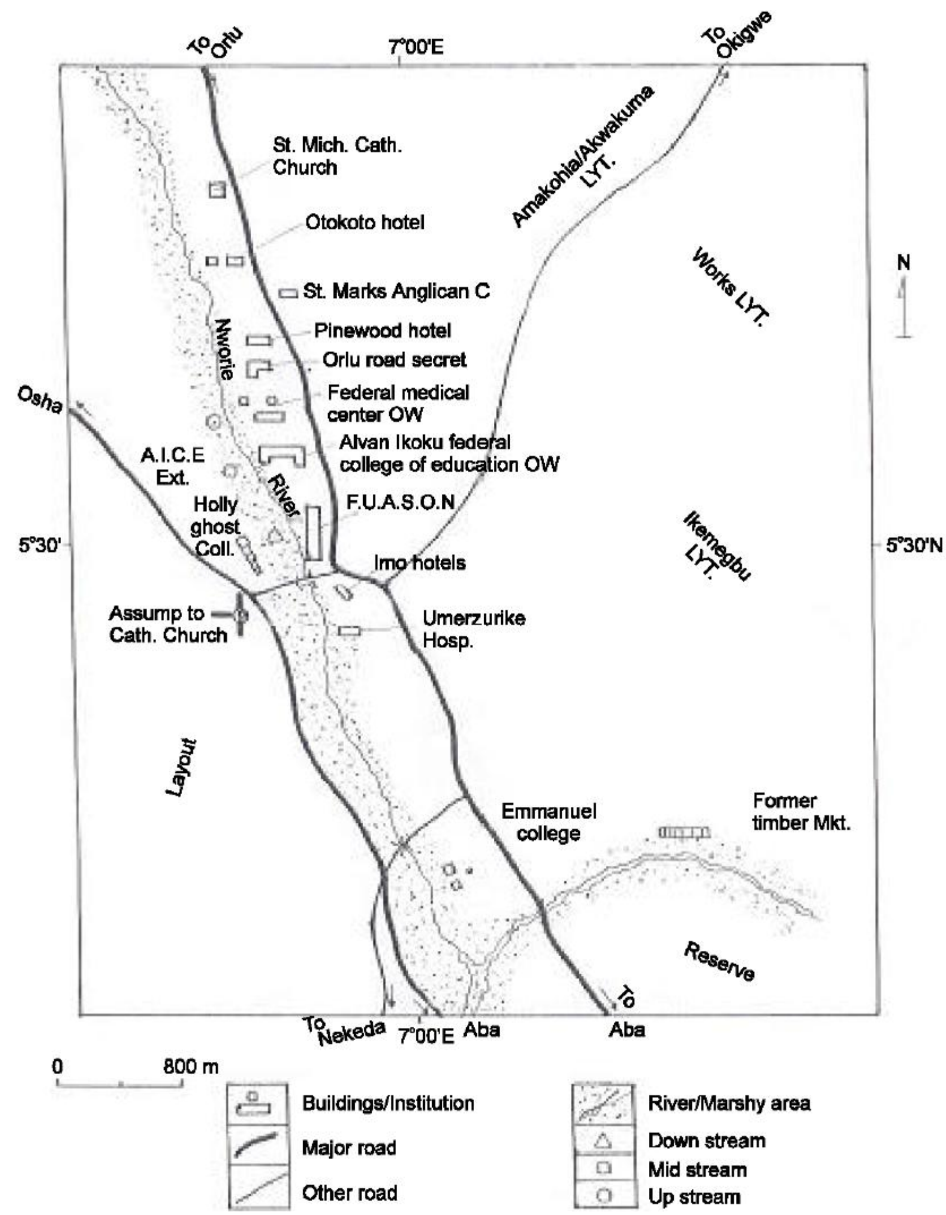

Figure 2. Map of Nworie River.

human and industrial activities and is used as a source of drinking water by the poor, when the public water system fails. The Nworie River is polluted by organic wastes, but in the year 2008, above acceptable levels of chemical pollution was reported (Okorie and Acholonu, 2008).

This study is geared towards determining the distribution of some heavy (Cr, Cd, Pb, As, Zn, Co, Se, Cu, Ni and Fe) and trace (Al, Mn) metals in fish tissues, water and bottom sediments of Nworie River and Oguta Lake in Imo State, Nigeria with the view of establishing baseline data on the current pollution status of the River. The results obtained from this study would also provide information on background levels of metals in the water, sediments and fish tissues of the two waterbodies contributing to the effective monitoring of both environmental quality and health of the organisms inhabiting the water bodies.

METHODOLOGY

Sample collection and preparation

120 g of two matured fish samples were bought from fishermen at the bank of Nworie River and Oguta Lake. The fish samples were

Table 1. The metal concentration in Nworie River and Oguta Lake in comparison with water quality guideline (mg/L).

Guideline	Al	Cd	Cr	Mn	Ni	Pb	Fe	Zn	References
SON	0.200	0.003	0.050	0.200	0.020	0.010	0.300	3.000	SON, 2007
WPCL	-	0.003	0.020	-	0.020	0.010	0.450	4.250	WPCL, 2004
CIW	-	0.010	0.100	-	0.200	5.000	-	-	ANONYMOUS, 1997
WHO	0.200	0.010	0.050	0.500	0.020	0.050	0.300	3.000	WHO, 2003
EPA	-	0.010	0.050	0.020	-	0.050	0.500	5.000	EPA, 2002
EC	-	5.000	50.00	0.050	20.00	10.00	-	-	EC, 1998
Study area	Al	Cd	Cr	Mn	Ni	Pb	Fe	Zn	
Nworie River	0.133	<0.001	0.319	<0.001	<0.001	<0.001	0.413	0.001	THIS STUDY
Oguta Lake	0.100	<0.001	0.327	<0.001	<0.001	<0.001	0.083	0.002	THIS STUDY

SON- Standard Organisation of Nigeria, EPA- Environmental Protection Agency (US), WPCL- Water Pollution Control Legislation, EC- European Commission, CIW- Canadian Index of Wellbeing, WHO- World Health Organisation.

separately placed in iceboxes. They were deep frozen at about −20°C and stored until analysis. The two different fish samples from the Nworie River and Oguta Lake were dissected with stainless steel knife. The tissues (muscle, liver and gill) were then collected and washed with distilled water and cut into small pieces (2 - 3 cm).The tissues were oven dried at 65°C over night and allowed to cool at room temperature. Bottom sediment samples were obtained from the same point where water samples were collected. At each point, the sediment sample was taken superficially by using pre cleaned 100 ml, wide mouthed, disposable plastic containers and packed separately in pre cleaned polyethylene bags. They were brought to the laboratory, dried in oven for 3 h at 105°C to constant weight and then ground into fine powder using pestle and mortar.

The dried samples were ground using a glass mortar. After all samples were passed through a nylon sieve (0.5 mm), they were stored in airtight plastic vials inside desiccators. Digestion of the samples was carried out based on the method described by Rahman et al. (2012) with slight modifications and using $HClO_4$: HNO_3 acids of 1:3 proportions. The samples were mineralised at 200°C for sixty minutes.

Water samples of one litre in volume were collected from each study area and were adjusted to pH 2 with 2 ml HNO_3. Before collection, the sample bottles were cleaned by washing them with detergent, soaked in 50% HCl for 2 h, washed with water and then rinsed with distilled water. The sample bottles were kept in 1% nitric acid before their use.

Analytical methods

After acid digestion, metal concentrations were determined using atomic absorption spectrophotometer (Shimadzu AA6650F) according to APHA 3111 method (APHA, 1998). Results of tissue analysis were calculated in dry weight basis. All laboratory plastic and glass ware were cleaned by soaking overnight in a 10% nitric acid solution and then rinsed with deionised water.

Transfer factor (TF)

The transfer factors in fish tissues, aquatic ecosystem, which include water and sediments, were calculated according to (2001) as follows.

$$\text{TF} = \frac{Metal\ \ Concentration\ \ \ in\ Sediment\ /Water}{Metal\ \ Concntration\ \ \ in\ Tissue}$$

Risk assessment

The risk for human health as a result of eating tilapia was evaluated by calculating estimated daily intake (EDI) using the following equation (Onsaint et al., 2010):

$$\text{EDI} = \frac{\text{Cfish} \times \text{Dfish}}{\text{BW}}$$

Where C_{fish} = average trace element concentration in fish muscle (µg/g dry weight), D_{fish} = the global average daily fish consumption (g/day) which is only 6.5 g/person for Nigerians (Williams and Unyimadu, 2013), and BW = average body weight (kg). US-EPA risk analysis, considering an adult average body weight of 70 kg (US-EPA, 2000). The Hazard quotient (HQ) was calculated by dividing the estimated daily intake (EDI) by the established RfD to assess the health risk from fish consumption. There would be no obvious risk if the HQ were less than 1 (Onsaint et al., 2010).

Statistical analysis

The results are presented as mean of triplicate determination.

RESULTS

Table 1 shows the metals constituent of Nworie River and Oguta Lake and reference fresh water values. Metal concentration in Nworie River decreased in the sequence Fe>Cr>Al>Zn, whereas the metals concentration in Oguta Lake decreased in the sequence Cr>Al>Fe>Zn.

Table 2 shows the total extractable metals from Nworie River sediments, Oguta Lake sediments and other sediment quality guidelines. The metal concentrations in sediments samples from Nworie River decreased in the sequence Fe>Cr>Cu>Zn, whereas metal concentration in sediment samples from Oguta Lake decreased in the

Table 2. The metal concentration in Nworie River and Oguta Lake sediment in comparison with sediment quality guidelines (mg/kg dry weight).

Guideline	Cd	Cr	Mn	Ni	Pb	Cu	As	Zn	Fe	References
LEL	0.60	-	0.60	16.00	31.00	2.00	-	26.00	10.30	NOAA, 2009
TEL	0.99	8.00	0.99	22.70	35.00	2.32	8.20	43.40	10.28	NOAA, 2009
PEC	4.90	370.00	4.90	48.60	128.00	3.02	70.00	111.00	20.03	NOAA, 2009
SEC	10.00	-	10.0	75.00	250.00	2.02	-	110.00	35.30	NOAA, 2009
Locality	Cd	Cr	Mn	Ni	Pb	Cu	As	Zn	Fe	
Nworie River	<0.001	0.327	<0.001	<0.001	<0.001	0.090	<0.002	0.001	0.413	This study
Oguta Lake	<0.001	0.319	<0.001	<0.001	<0.001	0.076	<0.002	0.002	0.083	This study

LEL, Lowest element level; TEL, threshold element level; PEC, probable effect concentration; SEC, severe effect level.

Table 3. Mean concentration (mg/kg dry weight) of metals in different tissues of fish from Oguta Lake and Nworie River.

Metal	Tilapia (Oguta Lake)			Tilapia (Nworie River)		
	Muscle	Gill	Liver	Muscle	Gill	Liver
Al	6.670	10.000	3.330	6.670	10.000	3.330
Cr	3.820	3.610	1.410	5.820	0.361	0.361
Mn	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Fe	<0.001	9.910	11.600	19.000	16.500	26.400
Co	2.290	2.030	1.520	1.780	2.030	1.520
Ni	0.342	4.430	<0.001	1.090	0.684	3.410
Pb	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Zn	4.010	4.580	1.640	5.890	5.970	4.660
As	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Se	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Cd	<0.001	<0.001	<0.001	<0.001	0.075	0.150
Cu	0.998	0.800	2.000	1.200	0.998	1.200

sequence Cr>Fe>Cu>Zn.

Table 3 shows the metal concentration in fish tissues from Nworie River and Oguta Lake samples. The results obtained showed that the metal concentrations in Oguta Lake fish tissues decreased in the sequence Al>Zn>Cr>Co>Cu>Ni> for fish muscle, Al>Fe>Zn>Ni>Cr>Co>Cu for fish Gill and Fe>Al>Cu>Zn>Co>Cr for fish liver. Metal concentrations in Nworie River fish tissues decreased in the sequence Fe>Al>Zn>Cr>Co>Cr for fish muscle, Fe>Al>Zn>Co>Cu>Ni>Cr>Cd for fish Gill and Fe>Zn>Ni>Al>Co>Cu>Cr>Cd for fish liver.

The transfer factor of heavy metals and trace metals from water sediments and fish tissues from Nworie River and Oguta Lake are presented in Tables 4 and 5. The results showed that transfer factor of sediment were greater than those of water for both Oguta Lake and Nworie River. All transfer factors for Nworie River were less than 1, so there is no concern for potential health effect (Huang et al., 2008). On the other hand, transfer factor from sediment was above 1 for Al, Fe (except in muscle) Zn (in liver) and cadmium (in liver). The profile of transfer factor from sediment to fish liver in the case of Tilapia from Nworie River was in the order of Al>Cr>Co>Cu>Fe>Ni. Aluminium was the greatest metal accumulated by Tilapia from sediment, while accumulation of Nickel was the lowest.

In Tilapia from Oguta Lake, the highest values of transfer factor from sediment to fish liver was in the order Al>Cd>Fe>Zn>Ni>Cu>Cr. Nickel accumulated more from sediment to fish muscles followed by aluminium. Nickel was the highest accumulating metal in fish tissues with transfer factor of 4. Since the concentration of Mn, Pb, Se, Cd, As were below the detection limit in both Oguta Lake and Nworie River in the fish tissues, water and sediments, the transfer factor for these metals were not calculated.

The global average quantity of fish consumed per

Table 4. Transfer factors (Tf) of metals in different tissues of tilapia fish from Oguta Lake.

Parameter	Al	Cr	Mn	Fe	Co	Ni	Pb	Zn	As	Se	Cd	Cu
Water/Muscles	0.02	0.84	NC	0.00	0.11	NC	NC	0.00	NC	NC	NC	0.08
Sediment/Muscles	1.50	0.10	NC	0.70	0.66	4.00	NC	0.47	NC	NC	NC	0.80
Water/Gills	0.01	0.09	NC	0.01	0.13	NC	NC	0.00	NC	NC	NC	0.10
Sediment/Gills	1.00	0.11	NC	1.76	0.75	0.31	NC	0.41	NC	NC	NC	1.00
Water/Liver	0.03	0.23	NC	0.01	0.17	NC	NC	0.00	NC	NC	NC	0.17
Sediment/Liver	3.00	0.27	NC	1.50	1.00	NC	NC	1.15	NC	NC	2.07	0.40

NC, Not calculated.

Table 5. Transfer factor (Tf) of metals in different tissues of tilapia from Nworie River.

Parameter	Al	Cr	Mn	Fe	Co	Ni	Pb	Zn	As	Se	Cd	Cu
Water/muscles	0.02	0.06	NC	0.02	0.13	NC	NC	0.00	NC	NC	NC	0.08
Sediment/muscles	1.00	0.06	NC	0.78	0.71	1.56	NC	0.13	NC	NC	NC	0.67
Water/gills	0.01	0.91	NC	0.03	0.11	NC	NC	0.00	NC	NC	NC	0.09
Sediment/gills	0.67	0.94	NC	0.90	0.63	2.50	NC	0.12	NC	NC	NC	0.80
Water/liver	0.04	0.91	NC	0.02	0.15	NC	NC	0.00	NC	NC	NC	0.08
Sediment/liver	2.00	0.95	NC	0.54	0.84	0.50	NC	0.16	NC	NC	NC	0.84

NC, Not calculated.

person (assuming a 70 kg person) per day is 6.5 g/person for Nigerians (Williams and Unyimadu, 2013). Multiplying this value with the average concentration of each metal (Al, Cr, Mn, Fe, Co, Ni, Pb, Zn, As, Se, Cd and Cu) in the analysed fish samples, the average daily intake (consumption) of metal from fish can be estimated. The estimated daily intake of Al, Cr, Fe, Co, Ni, Zn and Cu in fish from Oguta Lake and Nworie River ranged from 0.03 - 2.30 and 0.10 - 1.76, respectively (Table 6). The estimated daily intake of metals through fish consumption can be ordered as following Fe>Al>Zn>Cr>Co>Cu>Ni for Oguta Lake and Fe>Al>Cr>Zn>Co>Cu>Ni for Nworie River. The results showed that the EDI of metals from Nworie river and Oguta Lake were all lower than the reference dose (RfD) value for all metals studied and the values of hazard quotient were lower than 0.01, except for Cr, Co and Ni (Table 6).

DISCUSSION

Metals are very important in environmental research owing to their impact on human health. Indeed, many common heavy metals (Al, Cr, Mn, Fe, Co, Ni, Pb, Zn, As, Se Cd and Cu) are known to form materials that are potentially toxic to the environment (Turkmen and Ciminli, 2007; Chi et al., 2007; Fallah et al., 2011) and the anthropic effect of heavy metals such as Se on fish and other aquatic life are less studied (Guerin et al., 2011). The higher elemental concentration in bottom sediments of Nworie River and Oguta Lake was in agreement with the concept that bottom sediments contains higher concentration of metals than that of overlying water (Depinto and Martin, 1980). The metals concentrations in the sediment showed that the concentrations did not exceed the probable effect concentrations.

The Al, Cd, Cr, Mn, Ni, Pb, Fe and Zn in the water from Nworie River and Oguta Lake were compared with National and International Standards. The result obtained showed that the metals concentration from Nworie River and Oguta Lake did not exceed the WHO (2003), Environmental Protection Agency (EPA), Water Pollution Control Legislation (WPCL 2004), Anonymous, Criterion for Irrigation Water (CIW) and SON (Standards Organisation of Nigeria 2007) guidelines (Table 1).

In the present study, the values of the metals were within range in the muscle, liver and gills of the fish analysed from the two sample sites. However, the results reported in the literature are wide and depend on many external variables, which make it difficult for comparisons. Nevertheless, the distribution patterns of different elements in the tissues analysed in this study are comparable. Most of the elements were found to be preferentially accumulated in gills. The high metal concentrations in the gills could be due to the formation

Table 6. The dietary intakes of metals through fish consumption from Oguta Lake and Nworie River.

Metal	Concentration in muscle of *Tilapia*		Permissible limit (mg/kg dry weight) in fish tissue	EDI (µg/kg b.w/day)		RfD µg/kg b.w/day USEPA, 2005	Hazard quotient (EDI/RfD)	
	Oguta Lake	Nworie River		Tilapia (Oguta Lake)	Tilapia (Nworie River)		Tilapia muscle (Oguta Lake)	Tilapia muscle (Nworie River)
Al	6.670	6.670	-	0.62	0.62	-	-	-
Cr	3.820	5.820	1 (FAO,1983)	0.35	0.54	3	0.11	0.18
Mn	<0.001	<0.001	0.5 – 1.2 (WHO, 1982)	NC	NC	140	NC	NC
Fe	24.800	19.000	1 – 4.5 (WHO, 1982)	2.30	1.76	700	<0.01	<0.01
Co	2.290	1.780	0.01 (USFDA, 1993)	0.21	0.17	20	0.01`	0.01
Ni	0.342	1.090	10 (FAO, 1983)	0.03	0.10	1.5	0.02	0.06
Pb	<0.001	<0.001	0.5 (FAO, 1983)	NC	NC	0.05	NC	NC
Zn	4.010	5.890	50 (FAO, 1983)	0.37	0.55	300	<0.01	<0.01
As	<0.002	<0.002	0.27 (USFDA, 1983)	NC	NC	0.3	NC	NC
Se	<0.002	<0.002	0.01 (USFDA, 1993)	NC	NC	5	NC	NC
Cd	<0.001	<0.001	0.5 (FAO, 1983)	NC	NC	1	NC	NC
Cu	0.998	1.200	30 (FAO, 1983)	0.09	0.11	40	<0.01	<0.01

NC, Not calculated.

of complex ions with the mucus, which virtually cannot be completely removed from the gill Lamellae before preparation for the analysis (Khali and Faragallah, 2008). Furthermore, the absorption of metals into the gills surface as the first target for pollutants in water could also have a significant influence on the total levels in the gills. The gills are metabolically active parts that can accumulate higher levels of heavy metals, as reported in various fish species such as *Cyprinus carpio* and *Tinca tinca* from Lake Beysehir, Turkey (Khali and Faragallah, 2008) as well as *Oreochromis mossambicus* and *Cyprinus gariepinus* from Olifant River, South Africa (Marzouk, 1994). Deb and Fukushima (1999) confirmed that metals may be in high concentrations in the gill, lungs and digestive gland of fishes because of their relatively high potential for metal accumulation.

Dural et al. (2007) and Ploetz et al. (2007) reported that the highest levels of Cd, Pb, Cu and Fe were found in the gills of fish species such as *Sparus aurata, Dicentrarchus Labrax, Mugil cephalus* and *Scomberomorus cavalla*. Yilmaz et al. (2007) reported highest levels of Cd, Co and Cu accumulation in gills of *Leuciscus cephalus* and *Lepomis gibbosus*, while the metal accumulations were at lower levels in fish muscle. Similarly, high rates of accumulation of heavy metals in the gills tissue have been reported by other researchers (Celechovska et al., 2007; Alhas et al., 2009). The concentration of metals accumulated in the gill tissue of fish is a fairly good indicator of the concentrations of metals in the water where the fish live (Heath, 1987). High levels of metal accumulation in the gills of fish from Nworie River and Oguta Lake examined can be considered to be representative of the high levels of metal concentrations in the water. Gills are in constant contact with water and are exposed to metal contamination.

Furthermore, in the present study, high levels of Al, Fe and Cu were particularly found in the liver of fish from both Nworie River and Oguta Lake, when compared with those in other tissues. This may be due to detoxification pathways accumulating toxic elements in the liver (Ekeanyanwu et al., 2011). In the present study, muscles contained the least concentrations of metals in fish from Nworie River and Oguta Lake. The results obtained in this study are quite consistent with those reported in literature (Khalil and Faragallah, 2008; Fidan et al., 2008; Eneji et al., 2011; Can et al., 2012; Subotic et al., 2013). According to Allen-Gill and Martynov (1995), the reason for low levels of heavy metals could be the low levels of binding protein in muscles.

The presence of metals in high levels in fish environment does not indicate a direct toxic risk to fish, if there is no significant accumulation of metals by fishes (Kamaruzzaman et al., 2010). In this present study, transfer factors of 12 metals for sediment and water in Tilapia from Nworie River and Oguta Lake (Tables 4 and 5) were computed. The results indicated that transfer factors from water (for both Nworie River and Oguta Lake) were all below 1.00, which means that no bioaccumulation of any metal occurred from water so there is no concern for potential health effect (Huang et al., 2008). On the other hand, all transfer factors from sediment were higher than 1.00 which means that Tilapia accumulated metals from sediments from the two sample areas. This observation was not in agreement with some previous studies where it was reported that fish accumulated metals from water (Rasheed, 2001).

Recently, the consumption of fresh water fishes has become popular among Imo State people and the intake of trace elements through fresh water fish consumption is of great concern. To evaluate the health risk to Imo State people through consumption of fresh water fishes, the daily intake of metals was estimated on the basis of the concentration (wet weight basis) of metals in the muscle of fish and daily consumption. The rates of fresh water fish consumption were 6.5 g/person for Nigerians (Williams and Unyimadu, 2013). In the present study, all the estimated daily intakes of Al, Cr, Mn, Fe, Co, Ni, Pb, Zn, As, Se, Cd and Cu were below the guideline values. Thus, the presence of these elements in the muscle of fresh water fish may not cause any serious health risk to Imo State Residents. Nevertheless, the liver and gills are occasionally consumed by humans and recycled by fishermen to feed the fish (Onsaint et al., 2010). Few studies have been conducted on the exposure of trace elements through fish consumption in Nigeria and the data obtained in the present study could be valuable and may provide useful information for assessing the potential health risks for Imo State people consuming fresh water fishes. Since there are no guideline values or provisional limits for metal intake (g/day/body weight), the results obtained in this study could be used to derive such guideline values. However, this needs to be further examined in future studies.

Conclusion

Although, the levels of metals were found to be within permissible limits, bioaccumulation and magnification is capable of leading to toxic level of these metals in fish even when the exposure is low. There is need for constant monitoring of the metal concentrations in Nworie River and Oguta Lake since the rivers serve as source of drinking water, irrigation and fish for local inhabitants in the study areas.

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Conflict of interest

The authors declare that there is no conflict of interest.

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