

Transfer Factor and Bioaccumulation of Heavy metals in Fishes from Rivers Owan and Evbiobe, Edo State, Nigeria

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Research

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ABSTRACT

The Transfer factors and bioaccumulation of heavy metals in three fish species (*Clarias gariepinus*, *Murmyrus rume* and *Tilapia zilli*) were assessed in Rivers Owan and Evbiobe. The availability of Cu, Cr, Pb, Fe, Mn, Cd and Zn in water, sediment, fish and plants samples from the rivers was detected using Atomic absorption spectrophotometer. The result revealed that all the investigated fish species bio-concentrated the trace metals from the rivers water more than the sediment while there was no notable transfer of pollutants from the examined plants to the fish species. The transfer factor of the metals in fishes from water increased in order of Cr > Zn Cu > Pb > Mn > Fe > Cd for *Clarias gariepinus* and *Tilapia zilli* with a slight swap between Pb and Mn in *Mormyrus rume*, all from Owan river. *Clarias gariepinus* and *Tilapia zilli* in Evbiobe river had TF values in order of Cr > Pb > Fe > Cd > Zn > Mn > Cu and Cr > Zn > Fe > Pb > Cd > Cu > Mn respectively.

Keywords: Transfer factor, bioaccumulation, fish, Owan and Evbiobe rivers

1. INTRODUCTION

The aquatic environment makes up a major part of the environment and resources of the interested area. Therefore, its safety is directly related to human health (Ebong *et al.*, 2014). Pollution, loss of biodiversity, and habitat destruction are probably the main environmental threats for aquatic ecosystems. Moreover, the excessive contamination of aquatic ecosystems has evoked major environmental and health concerns worldwide (Abdel Bark, 2011). Pollutants can induce various biological responses in fish, affecting the organisms from the biochemical to the population-community levels (Adefemi, *et al.*, 2004; Bashir *et al.*, 2013), and cause various harmful effects on wildlife (Bashir *et al.*, 2013). Among the various toxic pollutants, trace metals represent a harmful group of elements due to their strong impact on stability of aquatic ecosystems, toxicity persistence, and accumulation tendency (Ekeanyanwu and Etienajirhevwe, 2012). Among trace metals, some are potentially toxic (Cd, Cr, Pb, and Hg), and many are essential (Cu, Zn, Fe, and Mn) (Eno and Etuk, 2015). Even essential metals can produce toxic effects when the metal intake is excessively elevated (Bashir *et al.*, 2013).

Fish are widely used in quality assessment of aquatic environment and as bio indicators of environmental pollution (Biswas *et al.*, 2012). So, field studies on early adverse effects of contaminants, measured directly in organisms in their natural environment, represent one of the main target areas in environmental bio-monitoring programs.

Fishes that are of interest to this study are *Clarias gariepinus*, *Mormyrus rume*, and *Tilapia spp.* *Clarias gariepinus*, also known as African sharptooth catfish is a species of catfish of the family Clariidae. They are found throughout Africa and the Middle East, and live in freshwater lakes, rivers, and swamps, as well as human-made habitats, such as oxidation ponds or even urban sewage systems. The African sharptooth catfish is a large, eel-like fish, usually of dark gray or black colouration on the back, fading to a white belly, with an average adult length of 1–1.5 m (3 ft 3 in–4 ft 11 in). In Africa, this catfish has been reported as being second in size only to the vundu of the Zambesian

waters, although FishBase suggests that African sharptooth catfish surpasses that species in both maximum length and weight (Froese *et al.*, 2014).

These fish have slender bodies, flat bony heads and broad, terminal mouths with four pairs of barbels. They also have large accessory breathing organs composed of modified gill arches. Also, only the pectoral fins have spines (Anoopet *et al.*, 2009). It is a nocturnal fish, which feeds on living, as well as dead, animal matter. Because of its wide mouth, it is able to swallow relatively large prey whole. It has been known to take large water-birds such as the common moorhen. *Clarias gariepinus* is also able to crawl on dry ground to escape drying pool, to survive in shallow mud for long periods of time during the rainy season. Spawning mostly takes place at night in the shallow, inundated areas of the rivers, lakes and streams. Courtship is preceded by highly aggressive encounters between males. Courtship and mating take place in shallow waters between isolated pairs of males and females. The male lies in a U-shape curved around the head of the female, held for several seconds. A batch of eggs is released followed by a vigorous swish of the female's tail to distribute the eggs over a wide area. The pair usually rests after mating (from seconds up to several minutes) and then resume mating (Jansen-van-Rensburget *et al.*, 2013).

Parental care for ensuring the survival of the catfish offspring is absent except by the careful choice of a suitable site. Development of eggs and larvae is rapid, and the larvae are capable of swimming within 48–72 hours after fertilization (Anoopet *et al.*, 2009). The flesh is tasty and usually consumed as a special delicacy in Africa.

1.1. *Mormyrus rume*

This species belong to the genus *Mormyrus*, of the family *Mormyridae*. The *Mormyridae* is well represented in the local waters with twenty-six different species belonging to six genera. The Mormyrids have the anal fin less than half of the length of the dorsal fin. They have a trunk-like snout and a small mouth. They grow to about a meter in length, usually have a uniform greyish yellow colour on the back and sides

and it's fairly common. Large specimens are capable of giving noticeable electric charges sometimes at the rate of 150-200 pulses per minute (Amoo *et al.*, 2006). They are typical bottom dwellers found in deep, rocky pools in surface water, where the current is not swift. Due to absence of spines and the slender bodies, it is most difficult to catch using any kind of fishing gear in the areas inhabited by *Mormyrus rume*. The flesh is tasty but contains excess fat hence; preservation by freezing for a long time is difficult. They are therefore generally sold fresh (Froese *et al.*, 2014).

1.2. *Tilapia spp*

Tilapia spp belong to a large family of *Cichlidae*. *Cichlidae* include several hundred species of rather generalized freshwater percloid fishes. They are a conspicuous element in the freshwater fauna of Africa and tropical countries. They have a deep laterally compressed body, a double lateral line and their dorsal fins are divided into spines and rays with spot at the base. They have a terminal mouth and truncated or round in shape tail. The habit of *Tilapia* in guarding their young has given them considerable advantage in the colonization of their chosen habitat (Froese *et al.*, 2014). The three important species that are popular in Nigeria and many other tropical regions include *Oreochromis niloticus*, *Sarotherodon galilaeus* and *Tilapia zilli* (Jansen-van-Rensburg *et al.*, 2013). *Tilapia zilli* was used for this study. *Tilapia* features importantly in many fisheries, and because of their great adaptability, high fecundity and rapid growth rate, they are used extensively for fish culture (Adefemi *et al.*, 2004). Most *Tilapia* species occur in schools or at least in loose congregation. Such schools may be migratory, but often show a strong tendency to remain within a particular area (Jansen-van-Rensburg *et al.*, 2013).

Transfer Factor (TF) is the ratio of trace metal in the concentrating matrix to the concentration in the ambient matrix under equilibrium conditions. Sediment to fish transfer factor and water to fish transfer factor was computed using the equation given by Muzyed (2011).

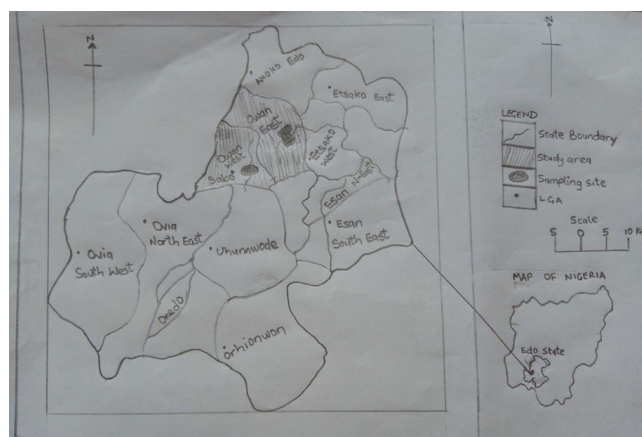
$$\text{Transfer Factor (TF)} = \frac{\text{Concentration of metals in fish muscle}}{\text{Concentration of metals in abiotic media}}$$

where the abiotic media represent water, sediment and food samples. If the transfer factor is greater than 1.0, then bioaccumulation for metals occur in fish or plant species.

2. MATERIALS AND METHODS

2.1. The Study Area

The areas of study are Rivers Owan and Evbiobe, which transverse through Owan East and Owan West Local Government Areas of Edo State, Nigeria. It lies within the equatorial climatic region, between longitude 05° 40" to 06° 45" and latitude 05°44" to 07° 34". These rivers serve as drinking water source for most residents in the area, even though Owan river is a washing zone for automobiles of all sorts on daily basis while a major market site is located behind Evbiobe river; thus exposing the rivers to some levels of pollution. Also, fishing activities are practiced in this area as a source of income and livelihood while the major occupation of the people is farming with the use of fertilizer; a practice that could lead to "Eutrophication" (excessive growth of aquatic weed) if the farm land is eroded into the rivers by storm water during the raining season.



Plot 1: Map of Study area, showing the sampling locat

Live samples of three species of fish, *Clarias gariepinus* (Catfish), *Mormyrus rume* and *Tilapia zilli* were obtained along the sampling route of the rivers with the assistance of local fishermen. The samples were transported live to the laboratory. In the laboratory,

the fishes were killed by asphyxiation, weighed and scales removed from *Tilapia zilli* and then washed with distilled water. Their intestines were later removed, and each fish separated into two parts, the head and the trunk and these were further washed with distilled water and the water allowed drying between two pieces of filter paper (Amoo *et al.*, 2006; Bashir *et al.*, 2013). The samples were kept in the freezer prior analysis.

Each of the powdered samples was further oven-dried at 105°C to a constant weight. Each sample (2.0g) was weighed into a 200ml Kjeldahl digestion flask; 10ml of concentrated HNO₃ were added followed by 2ml each of 62% HClO₄ and H₂SO₄. The flask was heated on an electric heating mantle to al-

most dryness after the evolution of white dense fumes (Salami and Non, 2002; Bashir *et al.*, 2013). The flask was set aside to cool after which the content was diluted with some quantities of distilled water and then filtered into a 50ml volumetric flask and the solution was made to mark with distilled water. A blank sample was also prepared. All solutions were analyzed for heavy metals using Atomic Absorption Spectrophotometer.

RESULTS AND DISCUSSION

The transfer factors (TF) for all the metals examined in this study for fish/water, fish/sediment, fish/*I.aquatica* and fish/*S.molesta* are presented in Tables 1, 2, 3 and 4 respectively.

Table 1: Trace metals' transfer factor for fish/water in the rivers

Samples	Cu	Cr	Pb	Mn	Fe	Cd	Zn
Cg OR-1	33.39	241.00	22.27	16.60	16.64	14.00	179.00
Mr OR-2	25.67	174.00	12.05	16.00	11.13	5.00	132.22
Tz OR-3	35.50	221.00	1.81	5.31	9.69	5.00	220.00
Cg ER-4	4.90	99.00	82.00	9.42	17.90	12.00	10.36
Tz ER-5	4.88	51.81	12.00	3.21	12.74	5.00	15.96

Where Cg = Clariasgariepinus, Mr = Mormyrusrume, Tz = Tilapia zilli, OR = Owan river ER = Evbiobe river

Table 2: Trace metals' transfer factor for fish/sediment in the rivers

Samples	Cu	Cr	Pb	Mn	Fe	Cd	Zn
Cg OR-1	1.21	3.54	5.76	0.19	0.52	1.16	1.00
Mr OR-2	0.96	2.56	3.12	0.18	0.34	0.41	0.74
Tz OR-3	1.31	3.25	0.47	0.06	0.30	0.41	1.23
Cg ER-4	0.54	2.48	8.20	0.36	0.73	2.40	1.35
Tz ER-5	0.53	1.30	1.20	0.12	0.52	1.00	2.08

Where Cg = Clariasgariepinus, Mr = Mormyrusrume, Tz = Tilapia zilli, OR = Owan river ER = Evbiobe river

Table 3: Trace metals' transfer factor for fish/plant (*Ia*) in rivers

Samples	Cu	Cr	Pb	Mn	Fe	Cd	Zn
Cg OR-1	0.32	1.31	0.27	0.15	0.55	0.41	7.45
Mr OR-2	0.25	0.95	0.15	0.15	0.36	0.15	5.49
Tz OR-3	0.34	1.20	0.02	0.05	0.32	0.15	9.17
Cg ER-4	0.27	0.90	0.66	0.21	0.56	0.30	7.82
Tz ER-5	0.27	0.47	0.10	0.07	0.40	0.10	12.05

Where Cg = Clariasgariepinus, Mr = Mormyrusrume, Tz = Tilapia zilli, OR = Owan river ER = Evbiobe river

Table 4: Trace metals' transfer factor for fish/plant (Sm) in the rivers

Samples	Cu	Cr	Pb	Mn	Fe	Cd	Zn
Cg OR-1	0.22	0.86	0.17	0.12	0.44	0.26	13.11
Mr OR-2	0.18	0.62	0.09	0.11	0.29	0.09	9.65
Tz OR-3	0.24	0.79	0.01	0.04	0.25	0.09	16.11
Cg ER-4	0.15	0.98	0.39	0.15	0.42	0.27	13.23
Tz ER-5	0.15	0.51	0.06	0.05	0.30	0.11	20.38

Where Cg = *Clarias gariepinus*, Mr = *Mormyrus rume*, Tz = *Tilapia zilli*, OR = Owan river ER = Evbiobe river

The result revealed that all the investigated fish species bio-concentrated the trace metals from the rivers water more than the sediment while there was no notable transfer of pollutants from the examined plants to the fish species (Table 1). This observation might be associated with the feeding habits of the fish species rather than their dwelling zones, even though the dwelling zones also contributed as these fish species might not be feeding on the examined plants as food. This deduction is further strengthened by the report of Amoo *et al.* (2006) and Ahmed *et al.* (2017), who stated that some fish species like *Tilapia zilli* are filter feeders sipping food particles from the water than the sediment. Although *Clarias gariepinus* and *Mormyrus rume* are bottom sediment dwellers, their feeding pattern might have more influence in metal transfer (Amoo *et al.* 2006; Bashir *et al.* 2013; Ahmed *et al.* 2017). Hence, the reason for the higher values of the transfer factor recorded in the water than that of sediment (Tables 2 and 3). This confirmed the earlier assertion that fish bio-accumulates trace metals from water than from sediments and was linked with the feeding behavior of the examined fish (Abdel-Bark *et al.*, 2011). The transfer factors in the different fish species also showed that *Clarias gariepinus*, followed by *Mormyrus rume* recorded the highest concentration when compared with *Tilapia zilli* in both Owan and Evbiobe rivers. This connoted the contributions of dwelling area of each fish species in the aquatic habitats as *Tilapia zilli* resides mostly on the water shores while *Clarias gariepinus* and *Mormyrus rume* that feed on particles from both the water and bottom sediments are more susceptible to accumulate more pollutants from the water bodies as typical bottom sediment dwellers (Adefemi *et al.*, 2004; Ali *et al.*, 2011; Eno and Etuk, 2015).

The transfer factor of the metals to fish from water increased in order of Cr > Zn > Cu > Pb > Mn > Fe > Cd for *Clarias gariepinus* and *Tilapia zilli* with a slight swap between Pb and Mn in *Mormyrus rume*, all from Owan river. *Clarias gariepinus* and *Tilapia zilli* in Evbiobe river had TF values in order of Cr > Pb > Fe > Cd > Zn > Mn > Cu and Cr > Zn > Fe > Pb > Cd > Cu > Mn respectively. It was generally noted that Cd had the least TF values in all the fish samples while Cu and Mn recorded the least values in *Clarias gariepinus* and *Tilapia zilli* respectively from Evbiobe river and Cr was the highest concentrated in all the examined fishes from Owan and Evbiobe rivers. However, the transfer factor in water was much greater in magnitude than their corresponding sediment samples.

The ability of fish to accumulate trace metals depends on its ecological needs, exposure duration, the feeding behavior, its metabolism, and degree of pollution in sediment, water, food as well as salinity and temperature of the water (Bashir *et al.* 2013; Eno and Etuk, 2015). In addition, Tane and Eshalomi-M (2015) attributed the accumulation of a particular metal to the presence of the metal in the water column, the physiological role of each element and the preference of an element to bind to or replace some element in its tissue. The transfer factor (TF) of the elements in sediment was least concentrated in Mn for all the fish samples from Owan and Evbiobe rivers and Pb had the highest values in *Clarias gariepinus* and *Mormyrus rume* from both rivers (Table 2). The Table revealed that there was no bioaccumulation of some elements while other elements were bioaccumulated by the fish species. The TF values are in the order of Pb > Cr > Cu > Cd > Zn > Fe > Mn, Pb > Cr > Cu > Zn > Cd > Fe > Mn and Cr > Cu > Zn > Pb > Cd

> Fe > Mn in *Clarias gariepinus*, *Mormyrus rume* and *Tilapia zilli* respectively from Owan river while *Clarias gariepinus* and *Tilapia zilli* from Evbioebe river recorded values in order of Pb > Cr > Cd > Zn > Fe > Cu > Mn and Zn > Cr > Pb > Cd > Cu > Fe > Mn respectively.

Tables 3 and 4 depict the transfer factor of examined plants (*Ipomoea aquatica* and *Salvinia molesta*) to the different fish species. The study showed that there was no appreciable transfer of metals from plants to fish as all the TF values, except Zn were well below one, for all the plant samples. The result for transfer factor in this research is consistent with the findings of many authors (Rasheed, 2001; Abdel-Bark et al., 2011; Eno and Etuk, 2015). Rasheed (2001) computed the transfer factor for some metals from water, sediment, plants and *Tilapia nilotica* in Nasser Lake and his results indicated that only transfer factors from water for all metals were greater than one. According to Abdel-Bark et al. (2011), if there is no significant accumulation by fish tissues, the presence of the metals in high levels in fish environment may not indicate a toxic risk to fish and man the ultimate consumer of fish. In contrast, bioaccumulation and biomagnification of trace metals via food chain and assimilation by humans might pose a health risk.

Figures 1, 2, 3 and 4 present the bioaccumulation (logarithm of the ratio) of investigated metal levels in fish/water, fish/sediment, fish/*Ipomoea aquatica* and fish/*Salvinia molesta* respectively.

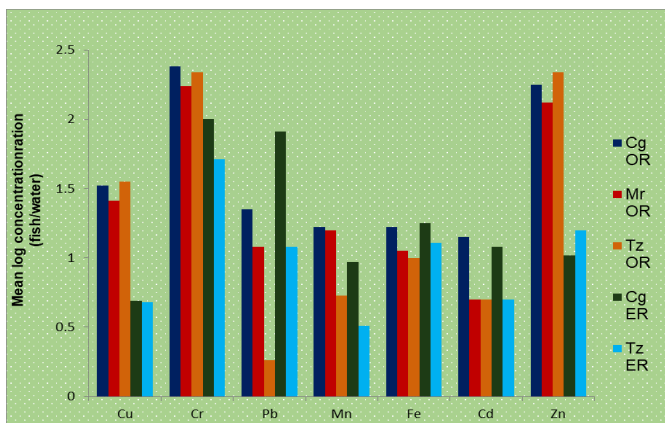


Figure 1: Comparison of mean concentrations of

metals in fish and water column

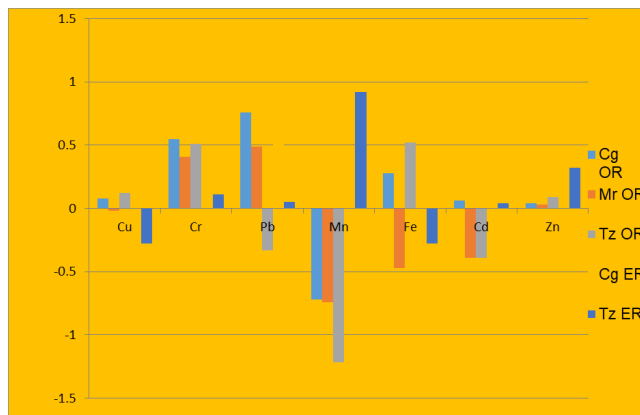


Figure 2: Comparison of mean concentrations of metals in fish and sediment

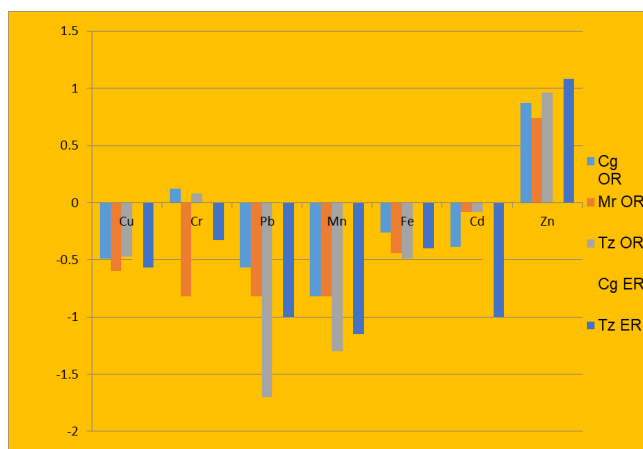


Figure 3: Comparison of mean concentrations of metals in fish and aquatic plant (*I. aquatica*)

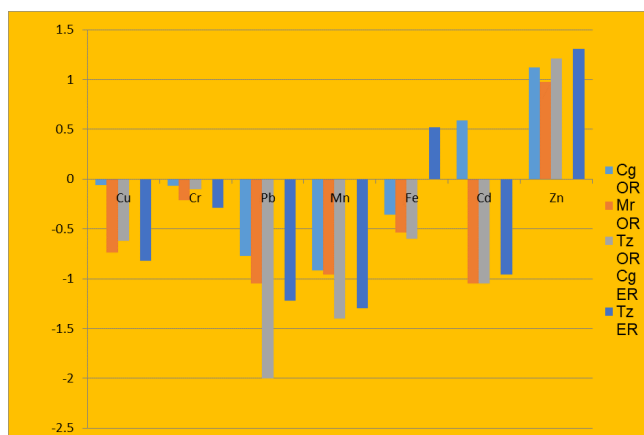


Figure 4: Comparison of mean concentrations of metals in fish and aquatic plant (*S. molesta*)

It was observed that higher concentrations of the metals in the fish samples than in the water were recorded thus, suggesting bioaccumulation of these metals in the fish body. Similar observations have been reported by many workers in Nigeria (Okoye, 1991; Asaolu, 2003; Obodo, 2004; Adefemi *et al.*, 2004; Amoo *et al.*, 2006; Olaniran *et al.*, 2013) and all over the world (e.g Chale, 2002; Karadede *et al.*, 2004; Al-Weher, 2008; Indrajith *et al.*, 2008; Saha and Hossan, 2011; Dhanakumar *et al.*, 2015).

Cr and Zn had the highest bioaccumulation in the fish samples from Owan river and Pb in *Tilapia zilli* from Owan river was least bio-accumulated while *Clarias gariepinus* from Evbiobe river bio-concentrated Pb than other elements. This observation strongly upholds the report of Rasheed (2001) that high concentrations of trace metal in water might not represent the metals' bioavailability unless it has been proved by that the organism in question has the tendency to bioaccumulate the metals investigated. This was noticed in the higher Pb levels in Fish samples from Owan river than those from Evbiobe river (Tables 3 and 4.) whereas reverse trend of higher bioaccumulations of Pb in *Clarias gariepinus* from Evbiobe river was observed while the three fish species from Owan river had lower Pb bioaccumulations as recorded in Fig1. Aiyesanmi (2008), attributed such trend to the ability or tendency of each organism to bio concentrate metals and the extent at which an organism can eliminate these metals from its body or level of the excretory mechanism in the organism.

On the other hand, concentrations of Cr and Zn in the sediment were higher than the values of other metals obtained in all the fish samples from both rivers, while Cu and Fe in fish samples from Evbiobe river and Pb and Cd from Owan river did not bioaccumulate in the fish. Others recorded greater concentration in fish than in sediment, possibly due to low deposition of these metals on sediment; or they are more in their exchangeable or labile form in the sediment matrix, thus having low resident time in the sediment; or they are more bio-accumulated in the fish (Aiyesanmi, 2008). However, higher concentrations of some heavy metals in the sediment compared

to fish have been reported by Okoye (1991) and Asaolu *et al.*, (1997) for Lagos lagoon and Ondo State coastal waters respectively. Similarly, Mohammed *et al.* (1982) in their study of heavy metal concentration in fish and sediment samples from AD-Danna sewage outfall area in Saudi Arabia and Boran and Altinok (2010) in their study of heavy metals in water, sediment and living organisms in the Black Sea also recorded higher concentration of metals. Trace metals are naturally present in all bed sediment samples, but they do not accumulate at the same rate in different fish species and other aquatic fauna (Al-Weher, 2008). Several factors have been proposed to be responsible for the differences in bioaccumulation of metals by fish species and same species in different water bodies. These include speciation, organic matter content, redox state of metals, exposure at the sediment/ water interface, species differences in prey selection, and uptake and elimination kinetics for fish and prey (Saha and Hossan, 2011; Dhanakumar *et al.*, 2015). For example, trace metals are ingested with particulate matter (streambed sediment or suspended sediment in the water column) by benthic organism and can then accumulate and move through the food chain (Adefemi *et al.*, 2004).

The bioaccumulation of these metals in the fish tissues might be beneficial if the metals were essential, but could be harmful in case of highly toxic metals (Aiyesanmi *et al.*, 2010). For example, Fe, Zn, Mn and Cr are essential micronutrient for growth, but their excessive concentration with others such as Cd, Pb and Cu without any significant biological function can be toxic to aquatic organisms. However, the levels of most metals in the fishes of this research are well below the maximum permissible limit (MPL) for fish muscle set by the Us Food and Drug Administration (WHO, 2011). For instance, the highest concentrations recorded for Zn, Cu and Cd in the fishes from this study are 8.40mg/kg, 2.38mg/kg and 0.22mg/kg as against their MPL values of 40.0mg/kg, 30.0mg/kg and 2.0mg/kg respectively. Hence the levels of these trace elements in the fishes may not constitute any health risk, but care should be taken considering the fact that most humans around riverine

areas regularly consume large quantity of fish. Consumption of large quantities of fishes that are slightly polluted might result to bioaccumulation and biomagnification of these pollutants in humans exposed to them for a long period of time.

The ratio of fish to aquatic plant (*Ipomoea aquatica* and *Salvinia molesta*) in Fig.3 and Fig. 4 respectively showed that there was no significant bioaccumulation by all the examined fish species from the metals except Zn in the plant samples. This might suggest that the fish species do not depend on the examined aquatic plants as food. This further strengthened the fact that the extent of accumulation of metals in a fish is a reflection of the concentration of such metals in the environment as well as the fishes' interaction (either through feeding, inhalation or dermal contact) with that species of plant in use (Adefemi, 2004; Ali *et al.*, 2011; Eno and Etuk, 2015).

CONCLUSION

It was generally noted that Cd had the least TF values in all the fish samples from River Owan while Cu and Mn recorded the least values in *Clarias gariepinus* and *Tilapia zilli* respectively from Evbiobe river and Cr was the highest concentrated in all the examined fishes from both rivers. However, the transfer factor in water was much greater in magnitude than their corresponding sediment samples as all the fish species bio-accumulated the examined metals from the rivers water.

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