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Spatial and Temporal Variations of Some Heavy Metals in Water, Sediment and *Chrysichthys nigrodigitatus* (Lacepède, 1803) from Ologe Lagoon, Lagos, Nigeria

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ABSTRACT

Heavy metals remain pollutants of great concern to ecologists because of its persistent nature in the environment and its adverse effects on aquatic biota and man. The levels of four heavy metals (Cu, Fe, Zn and Pb) were investigated between January, 2010 and December, 2010 in three sampling stations (Agbara, Imude and Obele) of Ologe Lagoon. The metal contents were measured in water column, sediment and *Chrysichthys nigrodigitatus*. The highest concentration (972.99±60.93 μg L^{-1}) of Zn in water was recorded in Obele while the lowest value (581.14±42.36 μg L^{-1}) occurred in Imude. The concentrations of the heavy metals in sediments of all the sampling stations was significant ($p<0.05$). The highest concentrations of Cu (1.25±0.09 μg g^{-1}) and Pb (4.11±0.29 μg g^{-1}) in sediment were recorded in Obele while their lowest values (Cu, 0.55±0.05 μg g^{-1}; Pb, 0.13±0.02 μg g^{-1}) occurred in Imude. The values of the heavy metals in *C. nigrodigitatus* from Agbara was significantly ($p<0.05$) higher than the values recorded in the other sampling stations. The highest concentrations of Fe (44.30±1.76 μg g^{-1}), Zn (26.43±1.37 μg g^{-1}) and Pb (0.17±0.04 μg g^{-1}) in *C. nigrodigitatus* were reported in Agbara while their lowest values (Fe, 24.41±1.01 μg g^{-1}; Zn, 14.82±0.98 μg g^{-1}; Pb, 0.02±0.01 μg g^{-1}) occurred in Obele. Seasonal dynamics had effect on metal content of water and sediment but its effect was not significant ($p>0.05$) in *C. nigrodigitatus* except for Cu. This study has shown that Ologe Lagoon contains heavy metals. However, these heavy metals are still within the limits considered safe for human consumption.

Key words: Catfish, seasonal variation, physico-chemical parameters, Lagos Lagoon complex, sediment

INTRODUCTION

The world has been experiencing increased industrialization over the past decades and Nigeria is not an exception. The rate of industrialization in Nigeria increased considerably especially after the discovery of oil in 1958 in Oloibiri which is in present day Bayelsa state, South-south, Nigeria (Ndimele, 2008). Industries increased in good numbers and it was a good development at that time because there were jobs for the ever increasing population. However, it soon dawn on the government and people of Nigeria that they did not prepare adequately to handle the level of industrialization they had anticipated.

These industries produced wastes but there were no proper waste disposal mechanisms. So, the natural water bodies became dump sites for various pollutants including heavy metals. Heavy metal are pollutants of great ecological concern because once they enter biological systems, they can not be eliminated by simple biological processes (Iwegbue *et al*., 2008; Kamaruzzaman *et al*., 2011). They bioaccumulate until their threshold level is reached after which they inflict all sorts of injury on the animal or man involved. The effects could range from teratogenicity especially mercury poisoning to low intelligent quotient in children caused by Pb poisoning (Azmat and Talat, 2006; Etesin and Benson, 2007; Ndimele *et al*., 2009).

Chrysichthys nigrodigitatus is a member of the catfish family consumed by many people especially in sub-saharan Africa. The heavy metal level of *Chrysichthys nigrodigitatus* have been studied previously by Adeosun *et al*. (2010) but few previous studies of heavy metals in this fish species and other fishes in Ologe Lagoon have been carried out. Ndimele *et al*. (2009) studied the lead (Pb) content of *Chrysichthys nigrodigitatus* from Ologe Lagoon while Kumolu-Johnson *et al*. (2010) evaluated the heavy metal level of *Cynothrissa mento* from the same lagoon.

The aim of this study is to evaluate the heavy metal content of water, sediment and *Chrysichthys nigrodigitatus* from Ologe Lagoon. This will assist the government in formulating the right policies, if it is not in existence yet, that will control the discharge of industrial effluents and save our natural ecosystems from extinction.

MATERIALS AND METHODS

This study is a continuation of an earlier study in which the lead (Pb) content of *Chrysichthys nigrodigitatus* from Ologe Lagoon was investigated (Ndimele *et al*., 2009). This study was conducted between January, 2010 and December, 2010 and monthly samples of water, sediment and biota (*Chrysichthys nigrodigitatus*) were collected from each sampling station.

Sampling sites: Lagos is one of the 36 states in Nigeria and it is surrounded by water. There are four major lagoons in Lagos State that form the Lagos Lagoon complex. These are Lagos Lagoon, Epe Lagoon, Lekki Lagoon and Ologe Lagoon. However, these are not the only inland water bodies in Lagos. Others are Badagry Creek, Kuramo and several others that have either not been studied at all or have not been studied adequately. Ologe Lagoon (Fig. 1) is a fresh water lagoon system that lies between latitudes 6°27'N and 6°30'N and longitudes 3°02'E and 3°07'E (Anetekhai *et al*., 2007). Odewunmi (1995) reported that the three most important sources of water into Ologe Lagoon are Rivers Owo, Ore and Opomu in Ogun State, Nigeria. Three sampling sites were selected based on their nearness to point of discharge of effluent from Agbara Industrial Estate {Agbara (P_1)}. The second sites {Imude (P_2)} was chosen because of the intensity of fishing activities in that area and the third site {Obele (P_3)} was chosen to evaluate the spread or distribution of heavy metals in the lagoon.

Physico-chemical analysis: Nine Physico-chemical parameters were analysed monthly. Water samples were collected from each sampling sit in 1-Litre plastic containers. Before the plastic containers were used for sampling, they were washed with tap water and later rinsed with 10% nitric acid to remove pollutants or contaminants which may interfere with the values of the water quality parameters to be measured. Temperature and pH were determined *in situ* by using a mercury-in-glass thermometer and pH meter (Extec 407227), respectively. Conductivity, salinity and Total dissolved solids were evaluated by the use of a combined conductivity-TDS-salinity meter

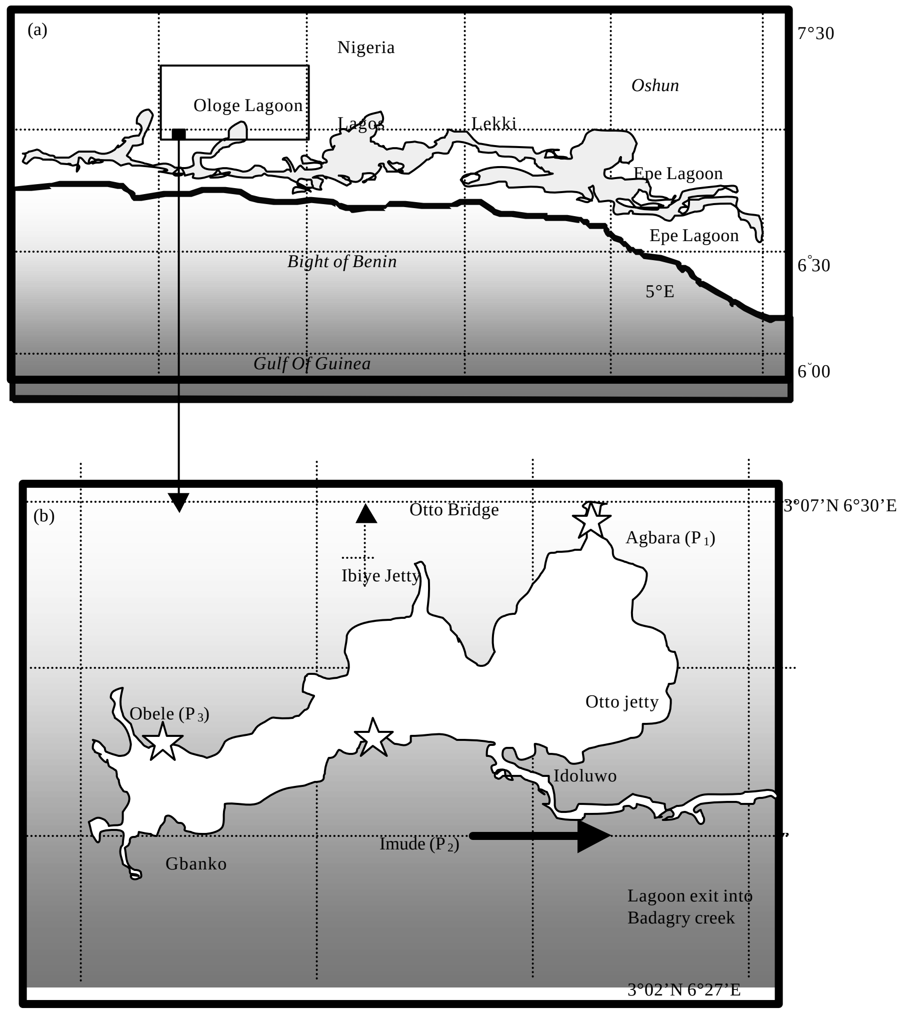

Fig. 1 (a-b): Location of study site (a) Map of lagos lagoon complex-inset: Ologe lagoon and (b) Map of Ologe lagoon. Sampling stations are marked with stars (Scale: 1: 150,000)

(Hanna portable EC/TDS/Salinity meter Model HI 9835, Hanna Instruments Inc., USA). Total alkalinity and total hardness were measured using the methods described by American Public Health Association (APHA, 1998). Dissolved oxygen was measured by titration using the method described by Boyd (1981) while turbidity was measured using nephelometer (Analite portable nephelometer Model 156, Mcvan Instrument, Mulgrave).

Metal analyses: Water, sediment and fish (*C. nigrodigitatus*) samples were collected from the three sampling sites {Agbara (P_1), Imude (P_2) and Obele (P_3)} of Ologe Lagoon between January, 2010 and December, 2010.

Sample collection, storage and preservation: Water samples were collected at each sampling station at a depth of about 20 cm below water surface in 250 mL plastic bottles with secured covers/screw caps. The sample bottles were soaked in 10% nitric acid for 24 h and rinsed with distilled water prior to being used (Laxen and Harrison, 1981). The water samples were acidified immediately after collection by adding 5 mL nitric acid (Analar grade) to minimise adsorption of metals onto the walls of the bottles (APHA, 1985; Ademoroti, 1996).

Polythene bags were used to collected sediment samples. These polythene bags were treated with 10% nitric acid before use. Grab samples of sediment were collected into these polythene bags with the help of steel pipe (2 inch diameter) pressed with pressure through the water column to obtain a sediment layer of about one foot (Ali and Fishar, 2005). All samples were stored in a deep freezer at-10°C (Ademoroti, 1996). *C. nigrodigitatus* were caught using different fishing gears such as gill nets, baited hooks and traps set overnight prior to collection. The fish samples were washed in water to remove dirt and later stored in deep freezer (-10°C). 5-7 samples of *C. nigrodigitatus* were collected from each of the sampling sites in every sampling day.

Triplicate samples of water, sediment and *C. nigrodigitatus* were collected at each sampling site in every sampling day.

Sample treatment: Water samples were not subjected to any other treatment, but were mixed thoroughly before aspiration into the flames of an Atomic Absorption Spectrophotometer (Alpha-4 cathodeon) for metal determination. Values are expressed in μg L^{-1}.

The sediment and fish samples were allowed to thaw at room temperature (i.e., ~28°C). The sediment samples were dried in an oven to constant weight at a temperature of about 106±23°C. They were then ground to powder and sieved through 2 mm mesh screen to remove coarse materials. The fish samples (208 in all) were oven-dried at a temperature of about 105°C and then homogenised. Digestion of all sediment and fish samples was done in accordance with the methods described by American Public Health Association (APHA, 1985) and Food and Agricultural Organization/Swedish International Development Cooperation Agency (FAO/SIDA, 1986). After digestion, the sediment and fish sample was analyzed for metal concentration using an Alpha-4 cathodeon Atomic Absorption Spectrophotometer (APHA, 1985) and the analytical procedure was checked using reference material (DORM 1, Institute of Environmental Chemistry, NRC Canada). Concentrations of heavy metals were expressed in μg g^{-1} dry weight.

Statistical analysis: Variations among sampling stations and between seasons (dry and wet) were tested by Analysis of Variance (ANOVA) and t-test, respectively using computer Statistical Package for Social Sciences (SPSS) for windows (v. 17.0). Where differences exist, they were partitioned by Fisher's Least Significant Difference (LSD) at $p = 0.05$.

RESULTS AND DISCUSSION

The physico-chemical parameters did not vary significantly ($p>0.05$) among the sampling stations. Temperature, pH, conductivity, total dissolved solids, dissolved oxygen and salinity range between 25.87±1.97-26.52±1.44°C, 7.41±0.14-7.81±0.18, 198±79-289±64 μs cm^{-1}, 101±26-151±30, 3.84±0.51-4.51±0.79 mg L^{-1} and 0.17±0.03-0.20±0.04 ppt, respectively (Table 1). The values of the water quality parameters are within the range reported in previous studies in Ologe Lagoon except total alkalinity and total hardness which have increased considerably. Kumolu-Johnson *et al.* (2010) reported temperature (30.50±0.22-31.00±0.37°C), pH (6.27±0.18±6.63±0.39), dissolved oxygen (3.03±0.51-4.97±0.65 mg L^{-1}), total alkalinity (3.05±0.22-5.33±1.86 mg L^{-1}) and total harness (43±14-48±16 mg L^{-1}) in Ologe Lagoon. The values of the physico-chemical parameters observed in this study are within the range reported by

Table 1: Physico-chemical parameters of the sampling stations

Parameter	Agbara (P_1)	Imude (P_2)	Obele (P_3)
Temperature (°C)	26.52±1.44[a]	26.25±1.37[a]	25.87±1.97[a]
pH	7.41±0.14[a]	7.81±0.18[a]	7.79±0.16[a]
EC (μs cm^{-1})	289±64[a]	198±79[a]	276±67[a]
TDS (mg L^{-1})	151±30[a]	101±26[a]	141±45[a]
Salinity (ppt)	0.18±0.05[a]	0.17±0.03[a]	0.20±0.04[a]
Turbidity (NTU)	72.20±12.26[a]	76.67±22.42[a]	74.22±18.33[a]
DO (mg L^{-1})	3.84±0.51[a]	4.16.±0.54[a]	4.51±0.79[a]
Alkalinity (mg L^{-1})	119±26[a]	126±28[a]	130±34[a]
Hardness (mg L^{-1})	108±35[a]	101±29[a]	112±39[a]

Values in the same row and with the same superscript letters are not significantly (p>0.05) different All values are expressed as Mean±SE

Table 2: Mean annual heavy metal (Cu, Fe, Zn and Pb) concentrations in water (μg/l), sediment (μg g^{-1} dry weight) and *Chrysichthys nigrodigitatus* (μg g^{-1} dry weight) from Ologe Lagoon

Sampling station	Cu	Fe	Zn	Pb
Water				
Agbara (P_1)	4.08±0.23[a]	51.99±6.01[a]	797.63±26.30[a]	5.06±0.12[a]
Imude (P_2)	3.83±0.21[a]	61.41±5.06[a]	581.14±42.36$_b$	4.54±0.05[a]
Obele (P_3)	4.25±0.12[a]	50.42±6.35[a]	972.99±60.93[c]	4.53±0.04[a]
Sediment				
Agbara (P_1)	0.78±0.08[a]	313.74±35.79[a]	40.84±5.31[a]	0.38±0.05[a]
Imude (P_2)	0.55±0.05[a]	100.58±12.69[b]	98.67±12.45[b]	0.13±0.02[a]
Obele (P_3)	1.25±0.09[b]	244.26±19.99[c]	63.61±13.72[c]	4.11±0.29[b]
Chrysichthys nigrodigitatus				
Agbara (P_1)	2.74±0.17[a]	44.30±1.76[a]	26.43±1.37[a]	0.17±0.04[a]
Imude (P_2)	1.85±0.09[b]	33.50±1.16[b]	18.53±0.90[b]	0.05±0.01[b]
Obele (P_3)	1.74±0.10[b]	24.41±1.01[c]	14.82±0.98[c]	0.02±0.01[b]

Values in the same column and with the same superscript letters are not significantly (p>0.05) different. All values are expressed as Mean±SE

previous study on tropical water bodies (Agboola *et al.*, 2008). They also fall within the range recommended by Federal Environmental Protection Agency (FEPA, 2003) for rearing of freshwater fish species. However, total alkalinity (119±26-130±34 mg L^{-1}) and total hardness (108±35-112±39 mg L^{-1}) values were higher than FEPA standards. This result have further confirm earlier studies by Kumolu-Johnson *et al.* (2010) and Ndimele *et al.* (2009) that the water of Ologe Lagoon possesses the right qualities required for fish survival.

The mean annual concentrations of the investigated heavy metals in water, sediment and *C. nigrodigitatus* are shown in Table 2. The concentrations of the heavy metals in the water column amongst the sampling stations was not significant (p>0.05) except Zn. The highest mean annual concentrations of Cu (4.25±0.12 μg L^{-1}) and Zn (972.99±60.93 μg L^{-1}) in water occurred in Obele while their lowest values (Cu, 3.83±0.21 μg L^{-1}; Zn 581.14±42.36 μg L^{-1}) were recorded in Imude. The concentrations of Fe range from 50.42±6.35-61.41±5.06 μg L^{-1} while Pb varied between 4.53±0.04 μg L^{-1} in Obele to 5.06±0.12 μg L^{-1} in Agbara. Figure 2 shows the monthly variations of the heavy metals in water column of Ologe Lagoon.

The seasonal variations of the metals in water are shown in Table 3. The dry season values of all the heavy metals were significantly (p<0.05) higher than the rainy season values except Pb. The

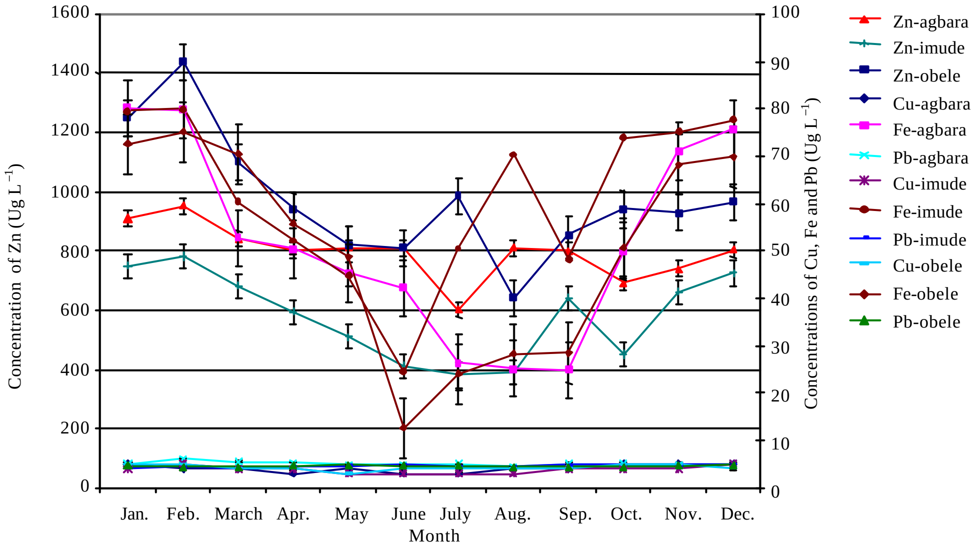

Fig. 2: Mean monthly concentrations of Cu, Fe, Zn and Pb (µg L^{-1}) in Water column of Ologe Lagoon

Table 3: Seasonal variation of metals (Cu, Fe, Zn and Pb) in water (µg L^{-1}), sediment (µg g^{-1} dry weight) and *Chrysichthys nigrodigitatus* (µg g^{-1} dry weight) from Ologe Lagoon

Season	Cu	Fe	Zn	Pb
Water				
Dry	4.53±0.13^{a}	72.58±2.00^{a}	901.95±56.69^{a}	4.75±0.14^{a}
Rainy	3.71±0.14^{b}	41.77±3.51^{b}	699.62±41.16^{b}	4.68±0.06^{a}
Sediment				
Dry	1.08±0.10^{a}	264.80±28.22^{a}	62.94±8.46^{a}	1.77±0.57^{a}
Rainy	0.70±0.07^{b}	175.75±25.88^{b}	71.10±5.14^{a}	1.35±0.38^{a}
Chrysichthys nigrodigitatus				
Dry	2.41±0.16^{a}	36.97±2.40^{a}	20.97±1.49^{a}	0.08±0.02^{a}
Rainy	1.89±0.12^{b}	32.00±2.00^{a}	19.18±1.41^{a}	0.08±0.03^{a}

Values in the same column and with the same superscript letters are not significantly ($p>0.05$) different. All values are expressed as Mean±SE

mean annual concentrations of the heavy metals in this study are below the World Health Organization standards for drinking water (WHO, 2008). WHO recommended 2.0, 2.0, 3.0 and 0.01 mg L^{-1} as limits for Cu, Fe, Zn and Pb, respectively. In addition, the values are lower than the United States Environmental Protection Agency (USEPA, 1996) limits for the protection of aquatic ecosystems except Zn. USEPA recommended 4.70 µg L^{-1} for a 4 day average of 45 mg L^{-1} hardness for Cu, 1000 µg L^{-1} for Fe and 6 µg L^{-1} for Zn. The results of the investigated metals in water column of Ologe Lagoon have shown that the concentrations of these metals are still within the tolerable limits that may not do any harm to the biota in the lagoon. However, it is important to monitor the metal level in this water body regularly in order to detect sudden upsurge in metal content. This is vital because Agbara Industrial Estate continues to empty its effluent into Ologe Lagoon.

The concentrations of the heavy metals in sediments of all the sampling stations was significant ($p<0.05$) (Table 2). The highest concentrations of Cu (1.25±0.09 µg g^{-1}) and Pb (4.11±0.29 µg g^{-1})

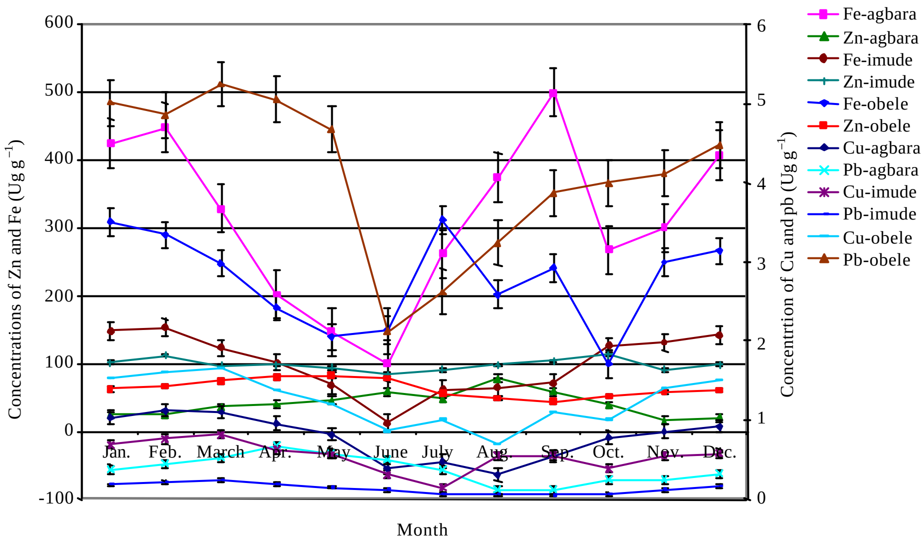

Fig. 3: Mean monthly concentrations of Cu, Fe, Zn and Pb (μg g^{-1}) in sediment of Ologe Lagoon

in sediment were recorded in Obele while their lowest values (Cu, 0.55±0.05 μg g^{-1}; Pb, 0.13±0.02 μg g^{-1}) occurred in Imude. The concentrations of Fe and Zn range between 100.58±12.69-313.74±35.29 μg g^{-1} and 40.84±5.31-98.67±12.45 μg g^{-1}, respectively. The monthly variation of the heavy metals in sediment of Ologe Lagoon is shown in Fig. 3. Table 3 shows that there was significant difference ($p<0.05$) between the dry and rainy season values of the heavy metals in sediments of Ologe Lagoon. The high concentration of Fe reported in this study is in agreement with the study by Kakulu and Osibanjo (1988) and Kumolu-Johnson *et al.* (2010). Asaolu and Olaofe (2005) opined that high Fe concentration is expected because Fe occurs in naturally high concentrations in Nigerian soils. The concentrations of heavy metal recorded by Kumolu-Johnson *et al.* (2010) who carried out their study between April, 2007 and March, 2008 are higher than the values in the present study. Kumolu-Johnson *et al.* (2010) reported 81.6±11.7-335±35 μg g^{-1} and 47.6±5.3-98.5±10.1 μg g^{-1} for Fe and Zn, respectively. The slight decrease in metal content in sediment in Ologe Lagoon recorded over a 2 year period might be due to passive phytoremediation by the invasive aquatic macrophyte, water hyacinth (*Eichhornia crassipes*) present in Ologe Lagoon (Ndimele, 2010; Ndimele and Jimoh, 2011; Ndimele *et al.*, 2011).

The highest concentrations of Fe (44.30±1.76 μg g^{-1}), Zn (26.43±1.37 μg g^{-1}) and Pb (0.17±0.04 μg g^{-1}) (Table 2) in *C. nigrodigitatus* were recorded in Agbara which is the sampling station that is nearest to effluent discharge point from Agbara Industrial Estate. The lowest values (Fe, 24.41±1.01 μg g^{-1}; Zn, 14.82±0.98 μg g^{-1}; Pb, 0.02±0.01 μg g^{-1}) for these three metals occurred in Obele. The values of the heavy metals in *C. nigrodigitatus* from Agbara was significantly ($p<0.05$) higher than the values recorded in the other sampling stations. This might be due to the nearness of Agbara to effluent discharge point from Agbara Industrial Estate.

Seasonal dynamics had no significant ($p>0.05$) effect on the metal load of *C. nigrodigitatus* except Cu (Table 3). Figure 4 shows the monthly variation of heavy metal in *C. nigrodigitatus* from Ologe Lagoon. The values of the metals in *C. nigrodigitatus* recorded in this study is below the standards (Cu = 3.0 μg g^{-1}, Fe = 100 μg g^{-1}, Zn = 10-75 μg g^{-1}) set by WHO (2008). The

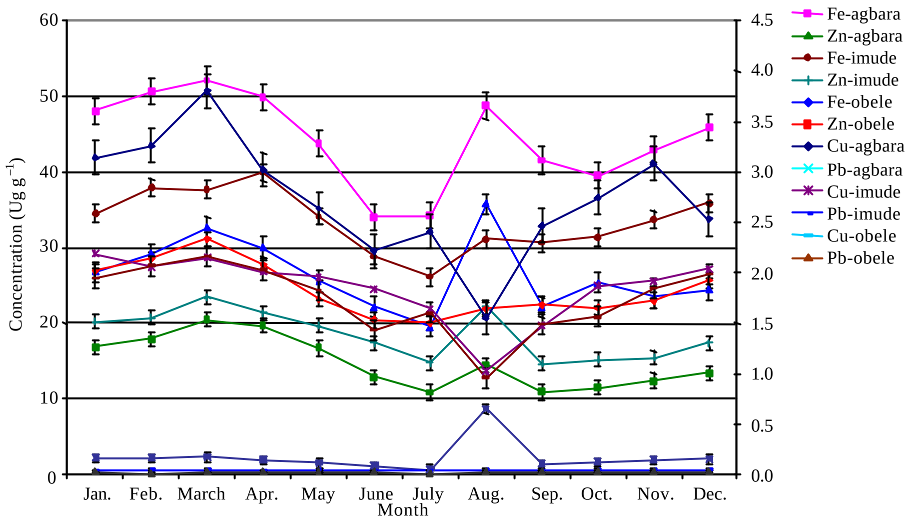

Fig. 4: Mean monthly concentrations of Cu, Fe, Zn and Pb (μg g^{-1}) in *Chrysichthys nigrodigitatus* from Ologe Lagoon

implication of this is that *C. nigrodigitatus* from Ologe Lagoon can still be consumed but care must be taken. This is because heavy metals can bioaccumulate in living systems till it reaches the threshold level when it becomes harmful (Ghosh *et al*., 2006; Kamaruzzaman *et al*., 2010).

CONCLUSION

This study has shown that some heavy metals are present in measurable quantities in Ologe Lagoon but their concentrations in water, sediment and *Chrysichthys nigrodigitatus* is still safe for human consumption. However, regular monitoring exercise should be conducted in this lagoon and the other ones that form part of the Lagos Lagoon complex in order to promptly detect sudden increases that may be harmful to aquatic biota and man.

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REFERENCES

APHA, 1985. Standard Methods for the Examination of Water and Wastewater. 17th Edn., American Public Health Association, Washington, DC., Pages: 1268.

APHA, 1998. Standards Methods for the Analysis of Water Wastewater. 20th Edn., American Public Health Association, Washington, DC. USA., Pages: 1270.

Ademoroti, C.M.A., 1996. Standard Methods for Water and Effluents Analysis. Foluder Press Ltd., Ibadan, Nigeria, pp: 182.

Adeosun, F.I., I.T. Omoniyi, Y. Akegbejo-Samsons and O.O. Olujimi, 2010. Heavy metals contamination of *Chrysichthys nigrodigitatus* and *Lates niloticus* in Ikere Gorge, Oyo state, Nigeria. Afr. J. Biotechnol., 9: 6578-6581.

Agboola, J.I., M.A. Anetekhai and A.A.B. Denloye, 2008. Aspects of the ecology and fishes of Badagry creek (Nigeria). J. Fish. Aquat. Sci., 3: 184-194.

Ali, M.H.H. and M.R. Fishar, 2005. Accumulation of trace metals in some benthic invertebrate and fish species relevant to their concentration in water and sediment of Lake Qarun, Egypt. Egypt J. Aquat. Res., 31: 289-301.

Anetekhai, M.A., G.A. Akin-Oriola, O.J. Aderinola and S.L. Akintola, 2007. Trace metal concentration in *Macrobrachium vollenhovenii* from Ologe Lagoon, Lagos, Nigeria. J. Afrotropical Zool., 3: 25-29.

Asaolu, S.S. and O. Olaofe, 2005. Biomagnifications of some heavy and essential metals in sediments, fish and cray from Ondo State Coastal Region. Pak. J. Sci. Ind. Res., 48: 96-102.

Azmat, R. and R. Talat, 2006. Metals contamination in edible carnivorous fishes of arabian sea. J. Applied Sci., 6: 1974-1977.

Boyd, C.E., 1981. Water Quality in Warm Water Fish Ponds. Agricultural Experimental Station, Auburn University, Alabama, AL., USA., Pages: 359.

Etesin, U.M. and U.N. Benson, 2007. Cadmium, copper, lead and zinc tissue levels in Bonga Shad (*Ethmalosa fimbriata*) and Tilapia (*Tilapia guineensis*) Caught from Imo River, Nigeria. Am. J. Food Technol., 2: 48-54.

FAO/SIDA, 1986. Manual of methods in aquatic environmental research part 9. Analysis of Metals and Organochlorines in Fish. FAO Fisheries Technical Paper No. 212. Food and Agricultural Organization/Swedish International Development Cooperation Agency, pp: 21-33.

FEPA, 2003. Guidelines and standards for environmental pollution control in Nigeria. Federal Environmental Protection Agency, pp: 238.

Ghosh, L., S. Adhikari and S. Ayyappan, 2006. Distribution of lead, cadmium and chromium in sediment and their availability to various organs of a freshwater teleost, *Labeo rohita* (Hamilton). J. Fish. Aquatic Sci., 1: 200-208.

Iwegbue, C.M.A., S.O. Nwozo, E.K. Ossai and G.E. Nwajei, 2008. Heavy metal composition of some imported canned fruit drinks in Nigeria. Am. J. Food Technol., 3: 220-223.

Kakulu, S.E. and O. Osibanjo, 1988. Trace heavy metal pollution status in sediments of Niger Delta area. J. Chem. Soc. Nigeria, 13: 9-11.

Kamaruzzaman, B.Y., B. Akbar, K.C.A. Jalal and S. Shahbudin, 2010. Accumulation of metals in the gills of Tilapia fingerlings (*Oreochromis niloticus*) from *in vitro* toxicity study. J. Fish. Aquat. Sci., 5: 503-509.

Kamaruzzaman, B.Y, Z. Rina, B. Akbar John and K.C.A Jalal, 2011. Heavy metals accumulation in commercially important fishes of South West of Malaysian coast. Res. J. Environ. Sci., 5: 595-602.

Kumolu-Johnson, C.A., P.E. Ndimele, S.L. Akintola and C.C. Jibuike, 2010. Copper, zinc and iron concentrations in water, sediment and *Cynothrissa mento* (Regan 1917) from Ologe Lagoon, Lagos, Nigeria: A preliminary survey. Afr. J. Aquat. Sci., 35: 87-94.

Laxen, D.P.H. and R.M. Harrison, 1981. A scheme for the physiological specification of trace metals in fish samples. Sci. Total Environ., 19: 59-82.

Ndimele, P.E., 2008. Evaluation of phyto-remediative properties of water hyacinth (*Eichhornia crassipes* [Mart.] Solms) and biostimulants in restoration of oil-polluted wetland in the Niger Delta. Ph.D. Thesis, University of Ibadan, Nigeria, pp: 237.

Ndimele, P.E., A. Jenyo-Oni and C.C. Jibuike, 2009. The levels of lead (Pb) in water, sediment and a commercially important fish species (*Chrysichthys nigrodigitatus*) (Lacepede, 1803) from Ologe Lagoon, Lagos, Nigeria. J. Environ. Extension, 8: 70-75.

Ndimele, P.E., 2010. A review on the phytoremediation of petroleum hydrocarbon. Pak. J. Biol. Sci., 13: 715-722.

Ndimele, P.E. and A.A. Jimoh, 2011. Water hyacinth (*Eichhornia crassipes* (Mart.) Solms.) in phytoremediation of heavy metal polluted water of Ologe Lagoon, Lagos, Nigeria. Res. J. Environ. Sci., 5: 424-433.

Ndimele, P.E., C.A. Kumolu-Johnson and M.A. Anetekhai, 2011. The invasive aquatic macrophyte, water hyacinth {*Eichhornia crassipes* (Mart.) solm-Laubach: Pontedericeae}: Problems and prospects. Res. J. Environ. Sci., 5: 509-520.

Odewunmi, S.G., 1995. Lagos State: Location, Extent and Constituency. In: Fundamental of General Studies, Noah, A.O.K. (Ed.). Rex Charles Publication, Ibadan, Nigeria, pp: 114-131.

USEPA, 1996. Water quality criteria documents for the protection of aquatic life in ambient water: 1995 Updates. United States Environmental Protection Agency, EPA 820-B-96-001, United States Environmental Protection Agency, September 1996, Office of Water Regulations and Standards. Washington DC.

WHO, 2008. Guidelines for Drinking Water Quality. 3rd Edn., Health Criteria and Supporting Information, WHO, Geneva, Pages: 668.