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Assessment of Heavy Metal Concentrations in Water and Body Parts of Four Commercial Fish Species in River Okpokwu, Benue State, Nigeria.

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Abstract: *The study investigated the concentrations of heavy metals in water and selected fish species of River Okpokwu. Chromium (Cr) and Lead (Pb) were all below instrument detection limit in water and fish samples across the three stations in the two season while, (0.03±0.01 and 0.02±0.00) in dry and rainy season respectively with a mean value of 0.01±0.00 in both seasons. Iron (Fe) was highest at station A (3.95±0.03 and 0.37±0.02) but lowest at station B (0.81±0.01 and 0.25±0.01) for dry and rainy season respectively. Cd was beyond detection limit for all samples and in all body part except in the liver of C. gariepinus and was higher (0.06±0.09) in dry season. Copper (Cu) was below instrument detection limit for water at stations A and B in both seasons but was detected at station C and was higher in the muscle (1.92±0.14, 2.18±0.04, 2.01±0.03 and 1.71±0.04), gill (2.03±0.24, 2.83±2.10, 2.03±0.06 and 2.89±0.01) and liver (2.05±0.20, 2.94±0.01, 2.06±0.04 and 2.94±0.11) for C. gariepinus , O. niloticus , P. annectens and T. zili respectively in dry than in rainy season while Fe was observed to be lower in the muscle (27.33±2.44, 49.90±0.90, 40.98±0.07 and 44.96±0.91), gill (40.44±3.85, 51.51±0.14, 42.62±0.24 and 46.52±0.13) and liver (47.60±0.48, 52.24±0.12, 47.75±0.14 and 50.58±0.11) in the rainy season than in dry season for C. gariepinus, O. niloticus, P. annectens and T. zili respectively. Mn was higher in the muscle (1.61±0.08, 6.02±0.03, 1.66±0.00 and 5.61±0.03) gill (1.68±0.78, 6.06±0.15, 1.69±0.03 and 5.96±0.15) and liver (1.72±0.08, 6.12±0.03, 1.71±0.03 and 6.04±0.02) in the dry season than in the rainy season for C. gariepinus, O. niloticus, P. annectens and T. zili respectively. In conclusion, heavy metal concentrations in water and fish of River Okpokwu were affected by seasons, as the dry season concentrations were significantly higher than the rainy season concentrations. Also, heavy metals distribution in the river (water and fish), follow the same pattern, indicating a close correlation between the levels in water and in fish. The fact that both dry and rainy season mean levels of Cd, Cu, Fe and Mn were below WHO (1985) and FEPA (2003) recommended levels in food, suggested that the fishes of River Okpokwu is fit for human consumption. Recommendation was made based on the findings.*

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I. Introduction

Fish play an important role in the development of a nation. Apart from being a cheap source of highly nutritive protein, it also contains other essential nutrients required by the body (Sikoki and Otobotekere, 1999). Water is a vital resource for fish. It is the medium in which fish live. The growth of any fish is directly related to the water quality, the feeding and the genetic potential of fish (Ajana et al., 2006).

Nigeria is naturally endowed with large bodies of natural water (both fresh and marine) in the flood plains, rivers, lakes and lagoons. Therefore, the role of aquaculture and fish farming is worth considering along other uses of water, such as irrigation, domestic, and industrial power generation and others.

Heavy metal pollution in rivers gives threat to public water supplies and also to consumers of fisheries sources (Terra et al., 2008). Occurrence of heavy metals in aquatic environment is of major ecological and public health concern because of their toxicity at cert\in concentration, translocation through food chain, non-biodegradability, which is responsible for their accumulation in the biosphere, threat to human and environment (Eneji et al., 2012). Ahmad et al. (2004) found level of heavy metal in sediments of Kelantan river such as Pb, Zn, Cu and Cd. Mazlin et al. (2009) found that Oreochromis spp have greater capacity for heavy metal bioaccumulation of Pb and Cd. Eneji et al (2012) in their study, reported that River Benue is only moderately contaminated with Cd, Cu, Zn, Mn, Pb, Cr and Fe.

The objective of this study therefore is to determine concentrations of heavy metals in water and selected fish species of River Okpokwu with a view to providing information on the degree of contaminant of the river and the body part of the fish and plan management strategies accordingly.

II. Material and Methods

Description of Study Area

River Okpokwu transverses Ogbadibo, Okpokwu, Ado Local Government Areas of Benue State to Cross River State. There is a coal deposit in Owukpa, Ogbadibo Local Government Area which is upstream of River Okpokwu in Igumale, Ado Local Government Area of Benue where the sampling sites are located. The river is used for irrigation, recreation, sewage disposal, fishing etc.

The study area is the only portion of the river where there are true riparian communities, with settlements on both banks of the river. The area is located between latitude 6^{o} 48' 0" N and longitude 7^{o} 58' 0" E. It contains mineral and natural resources in commercial quantities such as limestone, kaolin, petroleum and coal. The river covers about 76.76km. The climate is characterized by two distinct seasons, the dry season (November – April) and Wet season (May – October).

The three sampling stations (figure 1) were located at Igumale (Station A, known as Madam Ori side, Station B, known as Ogbe side and station C known as Igede side), all in Ado Local Government Area of Benue State. These stations were selected considering the riparian nature and activities of the settlements.

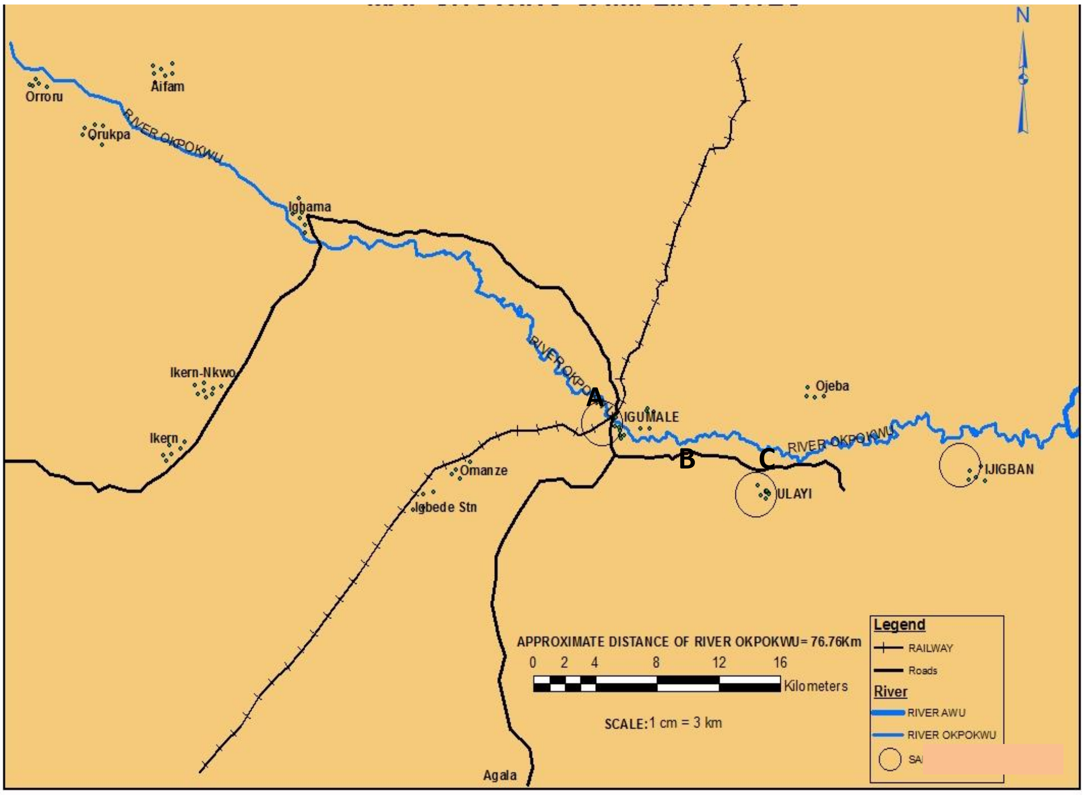

Figure 1: Map of River Okpokwu showing the sampling sites

Source: Benue State Ministry of Land and Survey (2016).

Collection of Fish Samples

The fish specimens used for the study were obtained from fishermen operating along River Okpokwu from May, 2015 to April, 2017. The fish species were randomly sampled in the mornings between 07.00hr – 10.00hr after landing of catches. These were examined and identified in their fresh state using identification key by Olasebikan and Raji (1998, 2004), Idodo (2003) and Paugy et al., (2004). Length and weight measurements of fish species were taken by means of measuring board and top loading Weighing balance. Both total length and standard length were determined.

Heavy Metal Analysis

In each sampling station, water samples were collected at a depth of about 20 cm below water surface in 250 ml capacity plastic bottles. The bottles were pre-treated by soaking in 10% nitric acid for 24 hours after

which they were rinsed with distilled water before being used for sample collection (Laxen and Harrison, 1981). Water samples were filtered through 0.45 μm membrane filters to remove suspensions and digested according to the standard method of APHA, (1995). In order to reduce absorption of metals onto the walls of the sampling bottles, the water samples were acidified immediately after collection. 5 ml nitric acid was added to 100 ml of water sample and then the samples were placed in pre-cleaned polythene bottle and sealed until analysis. Water samples were mixed vigorously before aspiration into the flames of an Atomic Absorption Spectrophotometer (Alpha-4 cathodeon) for metal determination. The sample was then left to cool, filtered through 0.45 μm membrane filters, and then diluted to 100 ml with distilled deionized water. Values were expressed in mg/L.
To prepare fish samples for analysis, the standard AOAC Official Method 937.07 (AOAC, 2000) was followed. Larger fishes were eviscerated, and the needed organs such as muscle, liver and gill removed and oven dry at 100^{o}C. Dried fish samples were homogenized in a blender and one gram of homogenate was digested by microwave digestion system. Approximately 20 g of each fish samples were introduced in seperate acid cleaned jars and digested with hot concentrated nitric acid. All organic materials in each sample were completely digested. The digests were allowed to cool, filtered through a 0.45 μm Millipore membrane filter, transferred to 50 ml volumetric flasks and made up to mark with 1% nitric acid and diluted with distilled water to 25 ml. The digestion of each sample was made in triplicate and three blanks were also performed in order to check the purity of reagents and any possible contamination. The digests were kept in plastic bottles and all determinations were made using Atomic Absorption Spectrophotometer (AAS). The specific cathode lamps were selected accordingly, since each has its characteristic wavelength. The instrument was calibrated with standard known concentration and the values were recorded. Absorbance is directly proportional to the concentration of the metal ion present in the sample and it was recorded through the instrument.

Statistical Analysis

All data were analyzed using analysis of variance (ANOVA). The effect of significance in ANOVA was tested using Fisher protected LSD to distinguish difference between means.

III. Results

Results of the mean heavy metals in the water from the three sampling stations during the dry and rainy season are presented in Table 2. Cadmium (Cd), Manganese (Mn), Chromium (Cr) and Lead (Pb) were all below instrument detection limit in water samples across the three stations in the two season while Copper (Cu) was below instrument detection limit at stations A and B in both seasons but was detected at station C, (0.03±0.01 and 0.02±0.00) in dry and rainy season respectively with a mean value of 0.01±0.00 in both seasons. Iron (Fe) was highest at station A (3.95±0.03 and 0.37±0.02) but lowest at station B (0.81±0.01 and 0.25±0.01) for dry and rainy season respectively.

Table 2: Mean Heavy Metals Concentration in Water at the Three Stations in Dry and Rainy Seasons

Element	Station	Season/ Mean		P Value
		Dry	Rainy	
Cd	A	BDL	BDL	
	B	BDL	BDL	
	C	BDL	BDL	
	Mean	BDL	BDL	
Cu	A	BDL	BDL	
	B	BDL	BDL	
	C	0.03±0.01	0.02±0.00	0.00
	Mean	0.01±0.00	0.01±0.00	0.04
Fe	A	0.39±0.03	0.37±0.02	0.00
	B	0.29±0.01	0.25±0.01	0.00
	C	0.35±0.00	0.31±0.00	0.00
	Mean	0.12±0.21	0.27±0.22	0.62
Mn	A	BDL	BDL	
	B	BDL	BDL	
	C	BDL	BDL	
	Mean	BDL	BDL	
Cr	A	BDL	BDL	
	B	BDL	BDL	
	C	BDL	BDL	
	Mean	BDL	BDL	
Pb	A	BDL	BDL	
	B	BDL	BDL	
	C	BDL	BDL	
	Mean	BDL	BDL	

BDL – Below Detection Limit

Results of mean heavy metals in the muscle, gill and liver of the selected fish species in dry and rainy seasons are presented in Table 3. Cd was beyond detection limit for all species and in all body part except in the liver of C. gariepinus and was higher (0.06±0.09) in dry season. Cr and Pb were below instrument detection limit in all body parts for all fish species. Cu was higher in the muscle (1.92±0.14, 2.18±0.04, 2.01±0.03 and 1.71±0.04), gill (2.03±0.24, 2.83±2.10, 2.03±0.06 and 2.89±0.01) and liver (2.05±0.20, 2.94±0.01, 2.06±0.04 and 2.94±0.11) for C. gariepinus , O. niloticus , P. annectens and T. zili respectively in dry than in rainy season while Fe was observed to be lower in the muscle (27.33±2.44, 49.90±0.90, 40.98±0.07 and 44.96±0.91), gill (40.44±3.85, 51.51±0.14, 42.62±0.24 and 46.52±0.13) and liver (47.60±0.48, 52.24±0.12, 47.75±0.14 and 50.58±0.11) in the rainy season than in dry season for C. gariepinus, O. niloticus, P. annectens and T. zili respectively. Mn was higher in the muscle (1.61±0.08, 6.02±0.03, 1.66±0.00 and 5.61±0.03) gill (1.68±0.78, 6.06±0.15, 1.69±0.03 and 5.96±0.15) and liver (1.72±0.08, 6.12±0.03, 1.71±0.03 and 6.04±0.02) in the dry season than in the rainy season for C. gariepinus, O. niloticus, P. annectens and T. zili respectively.

Table 3: Mean Heavy Metals (mg/L) in Body Parts of Selected Fish Species in Dry and Rainy Seasons

Fish Parts	Element	Fish Species	Season		P Value
			Dry	Rainy	
Muscle	Cd	C. gariepinus	BDL	BDL	
		O. niloticus	BDL	BDL	
		P. annectens	BDL	BDL	
		T. zili	BDL	BDL	
	Cu	C. gariepinus	1.92±0.14	1.59±0.12	0.07
		O. niloticus	2.18±0.04	2.15±0.04	0.01
		P. annectens	2.01±0.03	1.99±0.04	0.00
		T. zili	1.71±0.04	1.57±0.04	0.02
	Fe	C. gariepinus	28.32±2.42	27.33±2.44	0.77
		O. niloticus	50.41±0.99	49.90±0.90	0.26
		P. annectens	43.42±0.04	40.98±0.07	0.00
		T. zili	46.44±0.99	44.96±0.91	0.27
	Mn	C. gariepinus	1.61±0.08	1.47±0.05	0.08
		O. niloticus	6.02±0.03	6.00±0.04	0.00
		P. annectens	1.66±0.00	1.64±0.00	0.00
		T. zili	5.61±0.03	5.29±0.04	0.00
	Cr	C. gariepinus	BDL	BDL	
		O. niloticus	BDL	BDL	
		P. annectens	BDL	BDL	
		T. zili	BDL	BDL	
	Pb	C. gariepinus	BDL	BDL	
		O. niloticus	BDL	BDL	
		P. annectens	BDL	BDL	
		T. zili	BDL	BDL	
Gill	Cd	C. gariepinus	BDL	BDL	
		O. niloticus	BDL	BDL	
		P. annectens	BDL	BDL	
		T. zili	BDL	BDL	
	Cu	C. gariepinus	2.03±0.24	2.01±0.24	0.41
		O. niloticus	2.83±2.10	2.78±0.01	0.91
		P. annectens	2.03±0.06	2.01±0.05	0.00
		T. zili	2.89±0.01	2.84±0.01	0.00
	Fe	C. gariepinus	43.88±4.23	40.44±3.85	0.55
		O. niloticus	52.29±0.16	51.51±0.14	0.00
		P. annectens	44.78±0.31	42.62±0.24	0.00
		T. zili	47.25±0.17	46.52±0.13	0.00
	Mn	C. gariepinus	1.68±0.78	1.62±0.74	0.81
		O. niloticus	6.06±0.15	6.04±0.14	0.38
		P. annectens	1.69±0.03	1.66±0.02	0.00
		T. zili	5.96±0.15	5.88±0.14	0.40
	Cr	C. gariepinus	BDL	BDL	
		O. niloticus	BDL	BDL	
		P. annectens	BDL	BDL	
		T. zili	BDL	BDL	
	Pb	C. gariepinus	BDL	BDL	
		O. niloticus	BDL	BDL	
		P. annectens	BDL	BDL	
		T. zili	BDL	BDL	
Liver	Cd	C. gariepinus	0.06±0.09	0.04±0.08	0.18
		O. niloticus	BDL	BDL	
		P. annectens	BDL	BDL	
		T. zili	BDL	BDL	
	Cu	C. gariepinus	2.05±0.20	2.03±0.18	0.12
		O. niloticus	2.94±0.01	2.89±0.02	0.00
		P. annectens	2.06±0.04	2.04±0.05	0.00

	T. zili	2.94±0.11	2.92±0.01	0.01
Fe	C. gariepinus	47.60±0.48	46.46±0.51	0.01
	O. niloticus	52.24±0.12	51.51±0.10	0.00
	P. annectens	47.75±0.14	46.88±0.25	0.00
	T. zili	52.13±0.11	50.58±0.11	0.00
Mn	C. gariepinus	1.72±0.08	1.70±0.10	0.00
	O. niloticus	6.12±0.03	6.09±0.02	0.00
	P. annectens	1.71±0.03	1.70±0.01	0.00
	T. zili	6.04±0.02	6.01±0.03	0.00
Cr	C. gariepinus	BDL	BDL	
	O. niloticus	BDL	BDL	
	P. annectens	BDL	BDL	
	T. zili	BDL	BDL	
Pb	C. gariepinus	BDL	BDL	
	O. niloticus	BDL	BDL	
	P. annectens	BDL	BDL	
	T. zili	BDL	BDL	

BDL – Below Detection Limit

IV. Discussion

Heavy metals are harmful to aquatic organisms and human health at certain levels of exposure because they are non-degradable (Singh et al., 2011). Active metabolite body parts such as liver, gill and kidney concentrate more on an amount of heavy metal than other parts like muscle (Dural et al., 2007). Fish are often seen on top of the aquatic food chain and may accumulate large amount of heavy metals from its environment (Mansour and Sidky, 2002). In addition, fishes are one of the indicative aspects in freshwater ambience, for the evaluation of heavy metals pollution and health risk potential of human consumption (Papaqiannnis et al., 2004). Oreochromis niloticus as commercially important fish species (Christopher et al., 2009) can survive at adverse environmental conditions because their resistance to disease is strong, their respiratory demand are slight so that they can tolerate low oxygen, high ammonia levels and wide range of salinity (Zhou et al., 1998). Tilapia fish have a greater capacity for metal bioaccumulation than tiger prawn (Mokhtar et al., 2009). Heavy metals are accumulated through different organs of the fish body parts (Rao and Padmaja, 2000). Most studies have been concerted only on the accumulation of heavy metals in the edible part (muscle), in view of the fact it is the main fish part that is consumed by human beings (Keskin et al., 2007). Muscle is not always a good indicator of the entire body fish contaminations and therefore, it is vital to analyze other body parts as well, such as the gills and liver (Has-Schon et al., 2006). Due to existence of metal-binding proteins in some tissues, for example metallothioneins in the liver can accumulate significantly higher metal concentration than the muscles (Ploetz et al., 2007; Uysal et al., 2008a). The liver is the site of metal metabolism (Usero et al., 2003). Whereas, the concentration of metals in gills represents the concentration of metals in water (Uysal et al., 2008b). In the present study, heavy metal concentrations were highest in the liver than in both the gill and muscle. This is in agreement with the findings of Ploetz et al., (2007), Uysal et al., (2008a) and Usero et al., (2003).

The mean concentration of Iron (Fe) obtained in this present study was 0.002mg/L which is lower than the WHO recommended permissible limit (0.1mg/L) for drinking water; and below literature values of 0.408, 0.80, 1.90 and 3.80 mg/L for River Niger, Warri River, Ogunpa River Ibadan and Rimi River Kaduna, respectively (Oboh and Edema 2007). The obvious sources of Fe in rivers may be natural contamination from weathering processes of soil, leachates from waste dumps and municipal drain waters, flowing into the river. Fe is important for transporting oxygen around the body. Fe deficiency remains the top most cause of anemia, as confirmed by the analysis of a large number of reports on the burden of disease in 187 countries between 1990 and 2010 (Kassebaum et al., 2014). Fe concentration in this study is higher compared to that reported by Mogobe et al., (2015) in Chanoga, Okavango Delta in Botswana. The differences could be due to differences in environmental conditions between Nigeria and Botswana. Dry season mean values of iron were significantly higher than the rainy season values in fish body parts but lower in dry season than in rainy season in the water body. The great difference between values of Fe in fish body parts and water may be attributed to bioaccumulation of the element over time. It could also be attributed to adsorption to sediment particles as a result of the reduced water volume usually associated with increased evaporation rate in the dry season which increases the concentration of iron in the water. This can affect the environment as well as the health of the inhabitants near the river who depend on the water as their source of drinking and fishing activities.

The generally low concentration of Fe in the river implies it does not have the potential to disrupt aquatic life and cannot cause adverse effects on aquatic organisms and human health in the locality. The Fe values in both seasons in water fell below WHO and FEPA maximum tolerable level of 50 mgL^{-1} but slightly higher in the body parts of Oreochromis niloticus and in the liver of Tilapia zilli. This agrees with the concept that concentrations of heavy metals in fish tissues are always higher than that of water (Maxwell et al., 2013). The mean values of Fe concentration in water columns of all the sampling stations of River Okpokwu were below the World Health Organization (2004) limits for drinking water, Fe = 3.0 mg/L and 2.0 mg L^{-1} (WHO, 2008). Iron concentration in fish body parts was below WHO and FEPA tolerable levels in the present study.

From the study, it has been observed that lead (Pb) was below instrument detection limit. Lead is a well known toxicant that has several deleterious effects on human health even at low concentrations. The metal can accumulate in increasing concentration in the body of an organism. Pb permissible level by WHO and Federal Ministry of Environment of Nigeria is 0.01mg/L. The Below instrument Detection Limit (BDL) for Pb obtained in this study for both water and fish body parts could be due to less discharge of solid waste such as Pb batteries, PVC plastics, paints alloys, shots of ammunition and fireworks. This is in agreement with the report of Galadima et al., (2012) on River Niger.

High lead levels could be due to anthropogenic emissions from the combustion of leaded gasoline (tailpipe emissions) by the numerous number of engine boat loitering in inland waters. The major heavy metal cases in Nigeria were believed to be associated with lead poisoning. Galadima et al., (2012) reported that Zamfara lead poisoning is the worst and most recent heavy metals incidence in the Nigerian records that claimed the lives of over 500 children within seven months in 2010.

Manganese (Mn), even though an essential nutrient element for plants and animals, water containing more than 1 mg/L manganese may impart objectionable staining properties on clothes during laundry operations. The mean concentration of Mn in this study is below instrument detection limit for water in the water body but visible in the body parts of the fish samples. All the Mn values obtained in this study were below the values reported by Eneji et al., 2012 and Eneji et al., 2011 both on River Benue.

Copper (Cu) though an essential element that promotes the activity of certain enzyme systems in the human body, particularly in the synthesis of catecholamine, has an emetic action and is also toxic to man and animals when ingested in large amounts (Pearson 1976). Cu occurs in water in different forms, a typical form being Copper humic acid complex (Cabaniss and Shuman 1987). The mean concentration of Cu in River Okpokwu (0.01g/L) is lower compared to WHO maximum acceptable concentration (2.0 mg/L) in drinking water, meaning that River Okpokwu is fit for human consumption. All the cu concentrations in fish body parts were below the FAO (1983) maximum acceptable concentration of 30 mg/kg. Municipal effluents and leachates from solid waste dumps could be contributive factors to the Cu levels in rivers (Eneji et al., 2012).

Chromium (Cr) an essential for sugar metabolism in plants and animals is involved in the role the insulin plays in the transport of glucose in the cells for glycolysis which is the first step in adenosine triphosphate production. Sugar metabolism may be disrupted when the daily dose is too low. The source of Cr in rivers could be surface run offs and leachates associated with municipal solid waste dumps, fireworks and discharges from small scale local tanneries. The mean concentration of chromium in this study is below instrument detection limit. This is in agreement with the findings of Eneji et al., (2012) on river Niger, Ogunpa River Ibadan and Rimi River Kaduna. The maximum permissible limit of Cr for drinking water by WHO (2004) is 0.05mg/L.

Cadmium (Cd) enters into aquatic ecosystems from the wastewaters of electroplating, chemical industries, hazardous wastes, fireworks and poorly managed (highly mixed) municipal solid waste around the water body (Sha'Ato et al., 2007). In the fish, Cd is absorbed both from the surrounding water by the gills and from the food by digestion and then transported through the blood, mainly to the liver and kidneys (Van Den Broek et al., 2002). Cd mean concentration in this study is below instrument detection limit in water and in all the body parts of the four selected fish species except for liver of Clarias gariepinus which accounted (0.06±0.09 and 0.04±0.08mg/kg in dry and rainy seasons. This report is in agreement with reports of Voight (2003), and Cucuk and Engun (2005) who reported that cadmium mainly accumulates in the liver than in the muscle tissues. The mean Cd concentration in the liver of C. gariepinus is below the maximum permissible limit by MFA (1 mg/kg), FAO (0.5 mg/kg) and USFDA (0.01-0.21 mg/kg).

V. Conclusion

Heavy metal concentrations in water and fish of River Okpokwu were affected by seasons, as the dry season concentrations were significantly higher than the rainy season concentrations. Also, heavy metals distribution in the river (water and fish), follow the same pattern, indicating a close correlation between the levels in water and in fish. The fact that both dry and rainy season mean levels of Cd, Cu, Fe and Mn were below WHO (1985) and FEPA (2003) recommended levels in food, suggested that the fishes of River Okpokwu is fit for human consumption.

VI. Recommendation

If proper measures are taken for the treatment of sewage before discharge and restrictions are enforced on various anthropogenic activities, the health of the river can be maintained.

It is therefore recommended that relevant organizations/stakeholders should encourage continual research on the general metal composition and physico-chemical parameters of inland water.

References

[1]. Ahmad, A. K., Mushrifah, I. and Othman, M. S. (2009). Water Quality and Heavy Metal Concentrations in Sediment of Sungai Kelantal, Kelantal Malaysia: A base Line Study.Sains Malaysiana, 38 (4): 435 – 442.

[2]. Ajana, A. M; Adekoya, B.B; Olunuya O. A. and Ayankanuwo J.O. (2006). Practical fish farm Alliance Community Information Nigeria. Pp 88.

[3]. AOAC, (2000). Official Methods of Analysis. Association Of Official Analytical Chemists, Washington, DC.

[4]. APHA (1995). Standard Methods for the examination of Water and Wastewater. Sixteenth Edition, pp 423-17

[5]. Cabaniss, S.E. Shuman, M.S. (1987). Copper binding by dissolved organic matter: II. Variation in type and source of organic matter. Geochemical et Cosmochimica Acta. 52, 195-200.

[6]. Christopher, A.E., Vincent, O., Grace, I., Redecca, E. and Joseph, E. (2009). Distribution of heavy metals in bones, gills, livers and muscles of (Tilapia) Oreochromis niloticus from Henshaw Town Beach market in Calabar Nigeria. Pak. J. Nutr., 8: 1209-1211.

[7]. Cucuk, B. and Enugun, K. (2005). The effects of cadmium on levels of glucose in serum and glycogen reserves in the liver and muscle tissues of Cyprinus carpio (L. 1758). Turk. J. Vet. Anim. Sci., 29: 113-117.

[8]. Dural, M., Goksu M. Z. L. and Ozak, A. A. (2007). Investigation of heavy metal levels in economically important fish species captured from the Tuzla Lagoon. Food Chem., 102: 415-421.

[9]. Eneji, I. S., Sha'Ato R. and Annune, P. A. (2012). An Assessment of Heavy Metal Loading in River Benue in the Makurdi Metropolitan Area in Central Nigeria. Environmental Monitoring Assessment, 184: 201 – 207.

[10]. FAO, (1983). Compilation of legal limits for hazardous substances in fish and fishery products. Food and Agriculture Organization, FAO Fish Circ., 464:5-100.

[11]. Galadima, A and Garba, Z.N. (2012). Heavy metals pollution in Nigeria: causes and consequences. Elixir Pollution 45: 7917-7922

[12]. Han-Schon, E., Bogut, I. and Strelec, I. (2006). Heavy metal profile in five fish species included in human diet, domiciled in the end flow of river Neretva (Croatia). Arch. Environ. Contam. Toxicol., 50: 545-551.

[13]. Idodo, U.G. (2003). Freshwater fishes of Nigeria (Taxonomy, ecological Rates, diets and utilization). Umeh Publishers Limited, Benin City, Nigeria. 232pp.

[14]. Eneji, I. S., Sha'Ato, R. and Annune, P. A. (2011). Bioaccumulation of Heavy Metals in Fish (Tilapia zilli and Clarias gariepinus) Organs From River Benue, North-Central Nigeria. Park. J. Anal. Environ. Vol. 12: 1&2

[15]. Kassebaum, N. J., Jasrasaria, R., Naghavi, M., Wulf, S. K., Johns, N., Lozano, R., Regan, M., Weatherall, D., Chou, D. P., Eisele, T. P., Flaxman, S. R., Pullan, R. L., Brooker, S. J., Murray CJ. (2014). A systematic analysis of global anemia burden from 1990 to 2010. Blood, 123(5):615-24.

[16]. Keskin, Y., R. Baskaya, O. Ozyaral, T. Yurdun, N. Luleci and O. Hayran, (2007). Cadmium, lead, mercury and copper in fish from the Marmara Sea, Turkey. Bull. Environ. Contam. Toxicol., 78: 258-261.

[17]. Laxen, D. P. H. and Harrison, R. M. (1981). A Scheme for Physiological specification of trace Metals in fish samples. Sci. Tot. Environ. 19: 59 – 82.

[18]. Maxwell, A., Michael, K. and Musah, S. Z. (2013). Heavy Metals Concentrations in some selected Fish Species in Tono Irrigation Reservoir in Navrongo, Ghana. Journal of Environment and Earth Science, 3 (1):109-119

[19]. Mazlin, B. M., Ahmad, Z. A. Vicneswaram, M. and Sarva, M. P. (2009). Assessment Level of Heavy Metals in Penacus Monodo and Oreochromis spp. In Selected Aquaculture Ponds of High Densities of Development Area. European Journals of Scientific Research 30(3): 348 – 360.

[20]. Mansour, S.A. and Sidky, M.M. (2002). Ecotoxicological studies. 3. Heavy metals contaminating water and fish from Fayoum Governorate, Egypt. Food Chem., 78: 15-22.

[21]. Mogobe, O., Mosepele, K. and Masamba W. R. L. (2015). Essential mineral content of common fish species in Chanoga, Okavango Delta, Botswana. African Journal of Food Science. 9(9): 480-486

[22]. Mokhtar, M.B., Aris, A.Z., Munusamy, V. and Praveena, S.M. (2009). Assessment level of heavy metals in Penaeus monodon and Oreochromis spp in selected aquaculture ponds of high densities development area. Eur. J. Sci. res., 30: 348-360.

[23]. Oboh, I.P. and Edema, C.U. (2007). Levels of heavy metals in water and fishes from River Niger. Journal of Chemical Society of Nigeria, 32(2). 29-34

[24]. Olasebikan, B.D. and Raji, A. (1998) and (2004). Field guide to Nigerian

[25]. Papagiannis, I., Kagalo, I., Leonardos, J., Petridis, D. and Kalfakaou,V. (2004). Copper and zinc in four freshwater fish species from Lake Pamvotis (Greece). Environ. Intl., 30: 357-362.

[26]. Paugy, D; Leveques, C. and Tengels, G.G. (2004). The Fresh and Brackish Water Fisheries of West Africa. Vol. 2 Melanie stiassny, Guy G. Tengels and Carl D. Hopkins (Eds). IRD 815Pp.

[27]. Pearson,D. (1976). The chemical analysis of foods. 7th edn. London: Churchill Livingstone.

[28]. Ploetz, D.M., Fitts, B.E. and Rice,T.M. (2007). Differential accumulation of heavy metals in muscle and liver of a marine fish, (king Mackerel, Scomberomorus cavalla Cuvier) from the Northern Gulf of Mexico, USA. Bull. Environ. Contamination Toxicol., 78: 134-137.

[29]. Rao, L.M. and Padmaja, G. (2000). Bioaccumulation of heavy metals in M. cyprinoids from the harbor waters of Visakhapatnam. Bull. Pure Applied Sci., 19: 77-85.

[30]. Sha'Ato, R., Aboho, S.Y., Oketunnde, F.O., Eneji, I.S., Unazi, G. and Agwa S. (2007). Survey of solid waste generation and composition in a rapidly growing urban area Central. Waste Management, 27, 352-358.

[31]. Sikoki, F. D. and A. J. T. Otobotekere, (1999). Fisheries In: The Land and People of Bayelsa State Central Niger Delta. E.C. Alagoa, (Ed). Port Harcourt, pp 301-319.

[32]. Singh, J., Upadhyay, S. K., Pathak, R. K. and Gupta, V. (2011). Accumulation of Heavy Metals in Soil and Paddy Crop (Oryza sativa), Irrigated with Water of Ramgarh Lake, Gorakhpur, up, India. Toxicological and Environmental Chemistry, 93, 462-473.

[33]. Terra, B.F, Araujo, F.G, Calza, C.F, Lopes, R.T, and Teixeira, T.P (2008). Heavy metals in tissues of three fish species from different trophic levels in a tropical Brazilian river. Water Air Soil Pollut. 287: 275-284.

[34]. Usero, J., Izquierdo, C., Morillo, J. and Gracia, I. (2003). Heavy metals in fish (Solea vulgaris, Anguilla anguilla and Liza aurata) from salt marshes on the Southern Atlantic coast of Spain. Environ. Intl., 29: 949-956.

[35]. Uysal, K., Kose, E., Bulbul, M., Donmez, M. and Erdogan, Y. (2008a). The comparison of heavy metal accumulation ratios of some fish species in Enne Dame Lake (Kutahya/Turkey). Environ. Monit. Assess., 157: 355- 362.

[36]. Uysal, K., Emre, Y. and Kose, E. (2008b). The determination of heavy metal accumulation ratios in muscle, skin, and gills of some migratory fish species by Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES) in Beymelek Lagoon (Antalya/Turkey). Microchem. J., 90: 67-70.

[37]. Van den Broek, J. L., Gledhill K. S., and Morgan, D. G. (2002). Heavy Metal Concentrations in the Mosquito Fish, Gambusia holbrooki, in the Manly Lagoon Catchment. In: UTS Freshwater Ecology Report 2002, Dept. Environ. Sci. Univ. Technol., Sydney.

[38]. Voight, H.R. (2003). Concentration of mercury and cadmium in some coastal fishes from the Finnish and Estonian parts of the Gulf of Finland. Proc. Estonian Acad. Sci. Biol. Ecol., 52: 305-318.
[39]. WHO (2004). Guidelines for drinking water quality. vol. 1, 6^{th} Edition. Geneva: World Health Organization. pp80-83.
[40]. WHO, (2008). Guidelines for Drinking Water Quality. 3rd Edn., Health Criteria and Supporting Information, WHO, Geneva, pp 668.
[41]. Zhou, H.Y., Cheung, R.Y.H., Chan, K.M. and Wong, M.H. (1998). Metal concentrations in sediments and Tilapia collected from Inland waters of Hong Kong. Water Res., 32: 3331-3340.

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