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POTENTIAL HEALTH HAZARDS OF CONSUMING *CLARIAS GARIEPINUS* FISH CONTAMINATED WITH HEAVY METALS OF RIVER NIGER

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Abstract

Spatial and seasonal concentrations of heavy metals Zinc (Zn), Iron (Fe), Copper (Cu), and Lead (Pb) in water columns and the African Catfish *Clarias gariepinus* of River Niger at Onitsha, Nigeria were determined using Atomic Absorption Spectrophotometer (AAS). Mean concentrations of the analyzed metals were significantly higher in catfish than water columns ($P<0.05$). Bioaccumulation of heavy metals in catfish indicated that River Niger was experiencing impairment. Results also showed that mean concentrations of Zn (3.986±0.617) and Cu (0.876±0.382) in Catfish were within WHO/UNEP/FEPA permissible limits in aquatic foods but Fe (5.232±0.704) and Pb (0.228±0.266) far exceeded their limits. Since prolonged consumption of heavy metal-contaminated *Clarias gariepinus* of River Niger may pose serious human health risks, it is necessary to make a comprehensive assessment of the hazards posed by other heavy metals in many fish species found in different Nigerian water bodies.

Keywords: River Niger, heavy metals, catfish, bioaccumulation, toxicity.

1. Introduction

The section of the River Niger near its confluence with Anambra River at Onitsha in south-eastern Nigeria is economically important for trading, irrigation, fishing, transportation and recreation. Increasing human population, rapid industrialization and ever-increasing commercial activities in Onitsha Metropolis as well as the resultant continuous discharge of domestic and industrial effluents into the river are responsible for the increase in concentrations of heavy metals therein (Nsofor *et al.* 2014; Nsofor & Aguiwo 2005). Metals in the aquatic food chain eventually get into man on consumption of contaminated aquatic foods like fish. Bioaccumulation of heavy metals in fish is hazardous to both man and fish and have caused histopathological changes in vital organs and tissues of the body (Nsofor *et al.* 2014; Olojo *et al*. 2005).

Lead has been shown to cause plumbism which is characterized by weariness, nausea, abdominal pain, incoordination and convulsion. Chronic lead toxicity causes loss of appetite, kidney and liver diseases and brain damage (Fell, 1984; Gulson *et al.*, 1997). Gonzalez–Cossio *et al* (1997) reported that maternal bone lead stores are mobilized at accelerated rate during pregnancy and lactation and are associated with decrements in birth weight, growth rate and mental development in babies (Boeck, 1986). Since lead in bone persists for decades, it is possible that lead can remain a threat to foetal health many years after environmental exposure had been curtailed. Lead is extremely poisonous because it can bind in the same place as zinc and calcium ions in enzyme systems, thus producing neurotoxicity, peripheral neuropathy, hypertension and a variety of other disorders (Ferguson, 1990). Lead also inhibits the biosynthesis of haeme, the iron porphyrin component of hemoglobin resulting in anaemia. Lead is exceptionally more dangerous than other heavy metals because of its greatest production and wider use in areas where people come into contact with it, such as lead solder, painted houses, and lead additives in petrol. Absorbed copper enters the circulatory blood and is deposited in the liver and kidney where it causes Wilson's disease or hepatolenticular degeneration (Brown *et al.*, 1998). Other symptoms of copper toxicity include salivation, epigastric pain, nausea and vomiting, all of which are probably due to the irritant effect of copper on the gastrovascular mucosa. Long term exposure to high zinc intake in excess requirement results in interference with the metabolism of other trace elements. When zinc is excessively high, copper utilization is reduced. On the other hand, deficiency of zinc causes marasmic kwashiokor and hypozincaemia in children. Other symptoms include growth retardation, delay in sexual and skeletal maturation, loss of appetite and defects in the immune system (WHO, 1996).

In view of the ever-increasing importance of fish as a source of high quality animal protein in Nigeria (Nwuba & Ikpeze 2009; Nwuba *et al.* 2009) it is necessary to make a comprehensive assessment of the hazards posed by these metals through fish consumption. There is a dearth of information on bioaccumulation of heavy metals in the catfish *Clarias gariepinus* of the polluted Niger River. Hence the major aim of the study was to determine the presence of heavy metals in water columns and catfish of the section of River Niger at Onitsha. Results from this study will create public health awareness on the hazards of heavy metals toxicity and will guide in the formulation of evidence-based policy decisions for effective pollution management of the aquatic environment.

2. Materials and Methods

2.1 Sample sites and collection of sample materials

The study was carried out with surface water and the fish *Clarias gariepinus* from 3 stations of the River Niger at Onitsha (Latitude 6º 09'N and Longitude 6º 46'E), Anambra State, south-eastern Nigeria. The River flows through the industrial and commercial city of Onitsha and offers opportunity for the discharge and dumping of effluents and solid wastes from many industries and homesteads in Onitsha and environs. River Niger also serves as a sink for industrial and domestic wastes from Onitsha metropolis through surface and underground channels which discharge into the river. The timing of dry and rainy seasons at Onitsha varies from year to year. The rainy season is characterized by heavy thunderstorms between April and October while the dry season lasts from November to March. During the rains, different kinds of wastes are washed into the river, thereby polluting it the more. The collection of surface water and fish samples from the river was done over a period of twelve months that covered dry and rainy seasons of a hydrologic year. Water sampling was carried out monthly from three stations between November 2011 and October 2012, using boats equipped with outboard engines as means of transportation. On each occasion, water samples were collected from spots at each station and at 20cm below water surface in 250ml capacity plastic bottles with cork stopper. The bottles were treated with 10% nitric acid and rinsed with de-ionized water before use, to avoid metal adsorbing on the plastic bottles (Laxen and Harrison, 1981). The three sampling stations at "Upstream", "Midstream", and "Downstream" sections of the river were established at about ten kilometers apart on the stretch of the River as shown in Plate 1.

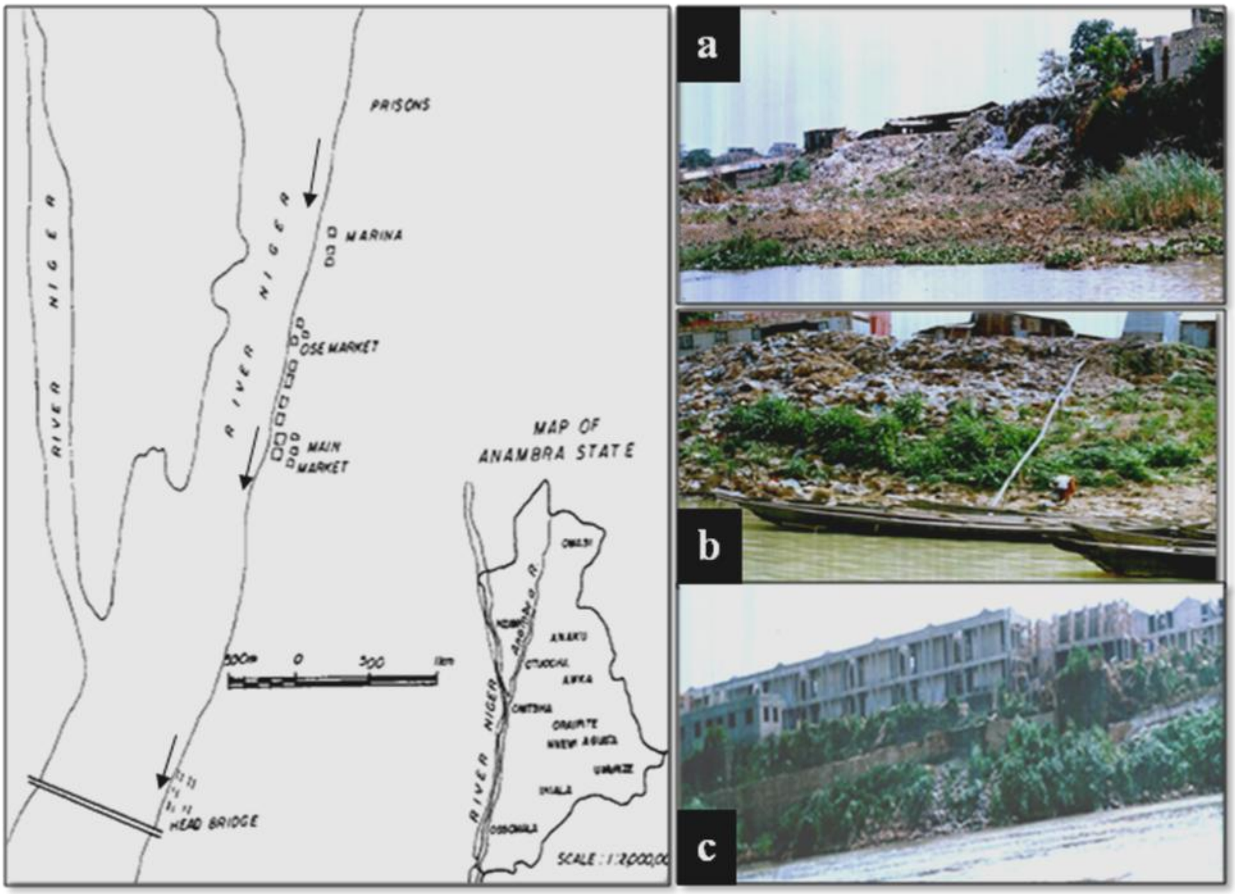

Plate 1: Section of River Niger at Onitsha, Anambra State (inset). Arrows ↓ indicate relative locations of Upstream Station I near Marina [a]; Midstream Station II near Ose-Main Market [b]; and Downstream Station III near Head Bridge [c]. The 3 stations are within source points of agricultural, industrial and municipal effluents and waste dump sites.

The samplings were carried out between 8am and 12noon, and the water samples taken to the Fishery Unit, Department of Zoology, Nnamdi Azikiwe University Awka where they were fixed with 10% nitric acid and stored in refrigerator until analysis. The live African catfish *C. gariepinus* which is much relished by the indigenous populace were procured on a monthly basis from artisanal fishermen at the fish-landing site near River Niger ethnic fish and food Ose-main Market. The fish samples were transported in ice chests to the Fishery Unit of Zoology Department, Nnamdi Azikiwe University Awka, where they were washed with clean water and the gut eviscerated to enhance drying. The fresh weights of the fishes were measured using a Mettler Top loading balance, while the total lengths were taken with a meter rule. Eighty live catfish (mean weight 192.5±7.5g; mean length 21.0±2.0cm) were procured. The fish samples were dried to a constant weight at 80ºC in Arkson scientific oven. Dried whole fish samples were ground in a porcelain mortar and homogenized to fine powder with an electric blender. Two grams of the sample was weighed into a 50ml Kjedal Flask for digestion using a*qua regia* for one hour. *Aqua regia* is a mixture of concentrated nitric acid (HNO_3) and hydrochloric acid (HCl) in the ratio of 1:3. The mixture was swirled gently and allowed to digest at 80ºC under a fume hood. Digestion continued for about fifteen minutes after disappearance of the crystals leaving a clear solution. The digester was filtered through a Whatman No. 42 filter paper into a 250ml volumetric flask, and made up to 20ml with de-ionized water. The digested sample was stored in low density polythene plastic bottles prior to analysis for heavy metals.

2.2 Preparation of standard metal solutions, instrumentation and analysis of samples for heavy metals

Water and fish samples were analyzed for Zinc (Zn), Iron (Fe), Copper (Cu), and Lead (Pb) using Atomic Absorption Spectrophotometer (AAS) Unicam 969 Model according to manufacturer's instructions. Four concentrations of each stock standard metal solution were prepared by diluting aliquots of the stock solutions to 1000ml. Each standard was aspirated into the flame of cathode ray and the absorbance recorded. A gram of zinc wire was dissolved in 10ml of HCl and diluted to 1000ml with de-ionized water. A gram of copper chloride was dissolved in 10ml of HNO_3 and diluted to 1000ml with de-ionized water. A gram of iron wire was dissolved in 50ml of HNO_3 and diluted to 1000ml with de-ionized water, and 1.83g of lead nitrate was dissolved in 100ml de-ionized water and 10ml of concentrated nitric acid (HNO_3) added. The mixture was made up to 1000ml with de-ionized water. The AAS has a hollow cathode ray discharge lamp used to produce radiation at a wavelength specific for the metal being assayed. The principle of the AAS is based on the fact that in the process of excitation and decay of atoms to ground state, energy could be absorbed or emitted. By measuring the amount of light absorbed, a quantitative determination of the concentration of analyte present in a sample can be measured. The absorption occurring is proportional to the concentration of the analyte in the sample. The calibration curve for each metal is usually obtained by plotting on a linear graph paper, the absorbance of the standard against their concentrations. The concentrations of the metal assayed are obtained from the calibration curve by interpolating the sample absorbance to the appropriate concentration (Burrell, 1975).

2.3 Statistical data analyses

Statistical analyses of data carried out included determination of means, standard deviations, and tests of significance between the stations and seasons using the multiple *t*- tests.

3.0 Results

Means of spatial and seasonal concentrations of heavy metals in analyzed water column of River Niger are shown in Table 1 while those for entire River Niger and its catfish are recorded in Table 2. Furthermore, Figure 1 revealed the differences between mean concentrations of the heavy metals in catfish and River Niger; and both values were compared with the UNEP (1996), FEPA (1991), WHO (1984) maximum permissible limits of the metals in aquatic foods.

Table 1: Means of spatial and seasonal concentrations of Zn, Fe and Cu in water columns of 3 stations of River Niger

Metal (mg/L)	Dry season (November 2011 – March 2012)			Rainy season (April – October 2012)		
	Station I	Station II	Station III	Station I	Station II	Station III
Zn	$0.278^{a} \pm 0.021$	$0.317^{b} \pm 0.019$	$0.188^{c} \pm 0.023$	$0.419^{d} \pm 0.077$	$0.411^{d} \pm 0.066$	$0.260^{a} \pm 0.042$
Fe	$2.018^{a} \pm 0.072$	$2.179^{b} \pm 0.278$	$0.055^{c} \pm 0.007$	$2.191^{b} \pm 0.190$	$2.495^{d} \pm 0.528$	$0.095^{c} \pm 0.019$
Cu	$0.006^{a} \pm 0.001$	$0.015^{b} \pm 0.004$	$0.004^{a} \pm 0.002$	$0.017^{b} \pm 0.005$	$0.145^{c} \pm 0.066$	$0.007^{a} \pm 0.003$

Values in same row with different superscripts are significantly different (P<0.05)

Table 2: Means of seasonal concentrations of Zn, Fe, Cu, & Pb in water columns and catfish of River Niger

Heavy metal (mg/L)	Dry season (Nov 2011 – March 2012)		Rainy season (April – October 2012)		Recommended maximum limits in aquatic foods		
	River Niger	Catfish	River Niger	Catfish	UNEP (1996)	FEPA (1991)	WHO (1984)
Zn	$0.261^{a} \pm 0.066$	$3.55^{b} \pm 0.432$	$0.363^{a} \pm 0.089$	$4.423^{c} \pm 0.693$	5	5-15	5
Fe	$1.417^{a} \pm 1.182$	$4.734^{b} \pm 0.221$	$1.594^{c} \pm 1.306$	$5.731^{d} \pm 1.205$	0.3	0.1-1	0.3
Cu	$0.008^{a} \pm 0.005$	$0.606^{b} \pm 0.113$	$0.056^{c} \pm 0.077$	$1.146^{d} \pm 0.343$	1	0.5-1.5	1
Pb	Not determined	$0.04^{a} \pm 0.007$	Not determined	$0.416^{b} \pm 0.472$	0.05	0.05	0.05

Values in same row with different superscripts are significantly different (P<0.05)

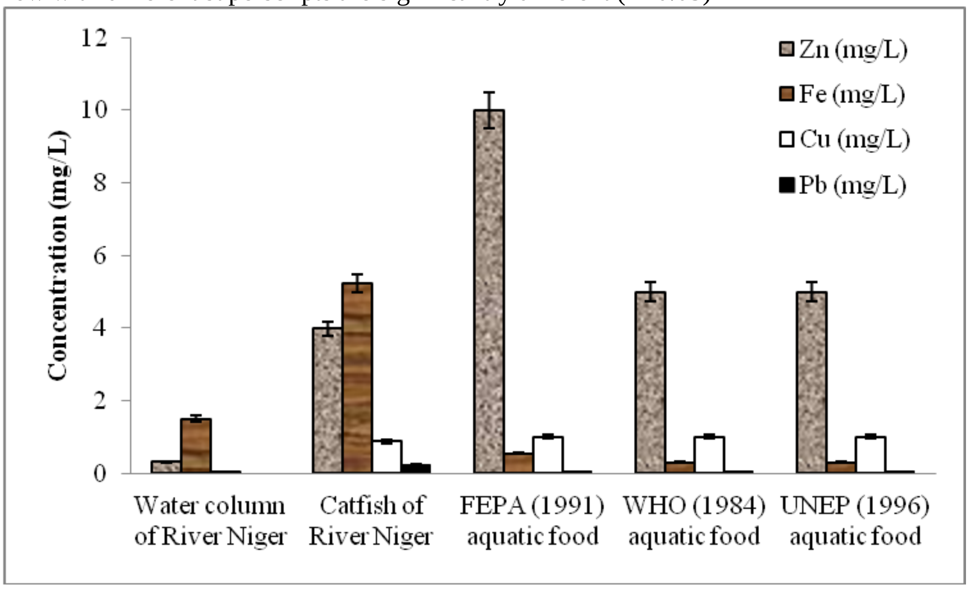

Figure 1: Concentrations of of Zn, Fe, Cu and Pb in water column and catfish of River Niger

4. Discussion

Generally, these results showed that River Niger at Onitsha was being contaminated with the studied heavy metals whose concentrations in water were lower than in the catfish; and some of them in the catfish exceeding the recommended maximum limits in aquatic foods. These findings support the fact that heavy metals are frequently present in water at rather low concentrations; and that higher metal concentrations in fish are suggestive of their ability to bioaccumulate metals above the concentrations in water. Observations from this study are in line with the findings of

Obasohan and Oronsaye (2000) who reported higher concentrations of Fe, Cu, and Zn in tissues of *Clarias gariepinus* from Ikpoba River in Benin City, Nigeria than in waters of the same river. The bioaccumulation of zinc in the studied fish was lower than international standards in aquatic foods (WHO 1984; UNEP 1996; FEPA 1991), indicating mild input of zinc into the river; zinc in the environment being toxic at even sub-lethal concentration over a long period of exposure. Zinc found in the river must have probably come from such sources as sewage, refuse dumps, effluent from paper, pulp, batteries, paint industries and discarded materials from Ose-Main Market located besides the Midstream Station of the river. It was also observed that the Midstream station accounted for more heavy metals than the up- and downstream stations; the concentrations of all analyzed metals being higher in the rainy season in both water and fish. The dumping of carcasses of old and damaged vehicles as well as solid wastes on land continuously occur indiscriminately in major towns and cities in Nigeria. A cursory survey of any waste dump site indicates the presence of metal and plastic cans of beverages, broken glasses, polythene bags and fruit juice cans. Others include pieces of metals from fabricating small scale industries, leather and rubber wears (Mayo and Mashauri, 1992). These solid wastes contain one form of heavy metal or the other and are often dumped directly into the water systems as practiced on the River Niger and its tributaries in Anambra State, Nigeria. Lack of proper waste management system has been attributed as the cause of indiscriminate dumping or burning municipal and medical wastes in open drainages in the country (Oriaku and Ikpeze, 2009). The metals from these waste dumps leach out, accumulate and contaminate water bodies, fish and other biota. The introduction of these metal pollutants above their natural load creates adverse significant impact on the biota and abiotic dynamics of water bodies (Biney *et al*., 1994). Heavy metals also constitute adverse health effects on consumers of metal- contaminated aquatic foods such as fish because metals are known to accumulate along the food chain (Reish and Oshida, 1986).

The concentrations of Fe in both River Niger and catfish species were found to be higher than international recommended maximum levels in water and aquatic foods. This indicated that the river was grossly polluted with elevated levels of Fe ions. The presence of Fe in the River could be attributed to high influx of Fe-rich effluents in the River. Iron is a major element in various minerals and rock types and reaches natural water from many sources including leaching and flaking rust from Ferro metal pipes. The elevated Fe concentrations in the River Niger area under discussion is similar to the findings of Fufeyin (1998) who reported 2-7mg/L of Fe in the water of Ikpoba River as well as Ajiwe *et al.* (1999) who reported 8.05mg/L in ground waters in Anambra State. The high Fe levels in fish species of this zone of the River are also similar to those reported by Vasquez *et al.* (1995) but contrasts with the lower concentrations recorded for *Malapterurus electricus* (2.28μg/L), S*ynodontis clarias* (11.24μg/L) and *Tilapia mariae* (11.24μg/L) from Ogba River in Benin (Wangboje and Oronsaye, 2001).

Copper is toxic to most forms of aquatic life especially fish. As little as 0.5ppm of copper in water is lethal to many algae while most fishes are affected at even lower concentrations (Jhingram, 1982). Copper is of particular interest to fish culturists because it is frequently employed as herbicide in aquatic systems (Boyd, 1979). Copper is an essential constituent of certain enzymes such as oxidase, catalase and tryrosinase which are involved in utilization of oxygen during cell respiration and energy utilization. Along with iron, copper is necessary for the synthesis of hemoglobin as well as bone formation and in the maintenance of myelin within the nervous system (Underwood, 1977). In action, copper binds with amino, carboxylate and sulphydryl groups of enzymes, thus blocking the pathway of the enzyme activity (Hutton, 1987). Well-defined homeostatic uptake and removal pathways exist for biologically essential metals. The toxic metals apparently compete with the essential metals to use the same pathways, thus disrupting the intracellular balance of the essential metal, and resulting in toxicological consequences (Shaukh *et al.,* 1995). Copper and zinc antagonize calcium accumulation by inhibiting its uptake and by enhancing its efflux. The copper concentrations observed in the River compared well with values reported for Ogba River (Obasohan & Oronsaye, 2004), Ikpoba River (Fufeyin, 1998) and Olomoro waters (Idodo-Umeh, 2002) and were below WHO Standard of 1mg/L for aquatic food. The bioaccumulation of Cu in the fish studied was within the WHO Standard of 1-3mg/L for aquatic foods. Elevated concentration of Cu in fish binds to amino and sulphydryl groups of enzymes thus blocking the pathways for enzyme activity (Hutton 1987). It also antagonizes calcium accumulation by inhibiting its uptake thereby enhancing the removal of Calcium (Okonkwo & Eboatu1998) which is indispensable in bone formation in vertebrates including fish.

Lead is a natural constituent of the air, water and biosphere and human beings ingest certain quantities in food, water and air (Benoff *et al*., 2000). Human activities and natural processes have been responsible for the presence of lead in the environment. Sources of lead in the environment come from industries dealing with production of ammunition (bullets), bathtubs, batteries, canned food, ceramics, chemical fertilizers, cosmetics, hair dyes, leaded glass, gasoline, paints, pesticides, rubber toys and tobacco smoke (Okonkwo and Eboatu, 1998, Benoff *et al;* 2003). The major use of lead in recent years has been in gasoline to increase octane rating, which is the measure of a gasoline's anti-knock characteristic. The tetraethyl lead is oxidized to lead oxide (PbO) which when removed could deposit on spark plugs and valves. Most of the lead eventually is emitted into the environment and thus ending in the atmosphere. Lead poisoning also inhibits the synthesis of haeme and thus interferes with the effective utilization of iron for growth and development in fishes (Hutton, 1987, Ademoroti, 1995). In this study, the concentrations of Pb in the catfish species was found to be higher than the international standards, indicating that the River is already experiencing some significant impairment in relation to Pb ion. The implication is that consuming catfish from the River could lead to Pb-induced health problems. Lead is a cumulative poison and a potent enzyme inhibitor, and is easily incorporated into enzyme structures. It inhibits the synthesis of haeme in organisms and thus interferes with the effective utilization of iron (Hulton 1987; Ademoroti 1995). Elevated concentrations of Pb cause cytological degenerations in fish organs as well as heart, liver and kidney dysfunction in man (Oronsaye 1997; Benoff *et al*. 2000). Lead in the River must have come chiefly from automobile exhaust pipes and lead deposits in soils which were washed into the river by runoffs during the rains. It was observed that in recent times, the number of generating plants in use within Onitsha metropolis has increased phenomenally due the epileptic supply of electricity to the Commercial City.

Many authors have reported the presence of metals in other species of fish and aquatic foods as well as adverse effects of metal toxicity in humans through consumption of fish. Chemical analysis done on the body tissues of patients who died of metal poison through eating contaminated fish in Japan revealed that 530mgPb, 3,800mgCd and 70,00mgZn were accumulated in the bones of the patients (Masazumi and Smith, 1975). In Kano, Northern Nigeria, Butt (1985), Adeniji & Mbagwu (1990) in their respective works reported high levels of Cu, Cr, Zn, Fe and Mn in fish and crops irrigated with water from Jakura and Warward Reservoirs. Consequently the Ministry of Health in Kano State prohibited the consumption of fish from the reservoirs. However due to lack of enforcement, the local fishers still exploit, process and distribute fish from contaminated reservoirs to major cities and other States in Nigeria. Ajiwe *et al* (2002) reported metal concentrations in the liver, kidney and brain of C*itharinus* species and *Notopterus afer* from the River Niger. The hepatic mercury level in *Citharinus* and *Notopterus* species ranged from 1.9 to 3.9 and 2.9 to 3.8 μg/g respectively in the two species. Tracing the source of the metal pollutants in the river and fish species to industrial effluents, the authors recommended prompt treatment of industrial effluent before being discharged into the environment. Oti (2001) also reported high levels of arsenic (0.82mg/L) and cadmium (0.7mg/L) in *Clarias gariepinus* from Aba River in Eastern Nigeria. The sources of the metals were traced to industrial and agricultural effluents from the teaming industrial concerns in the State. Medical wastes in the area were reported to be disposed off indiscriminately thereby contaminating the environment (Alexander and Ikpeze, 2009). In Mexico, Vasquez *et al* (1995) reported gross contamination by Cu (60mg/L), Cd (0.48mg/L), Fe (18.3mg/L), Pb (0.18mg/L) and Zn (115mg/L) in oysters collected from some lagoons in that country. Bozo and Horvath (1992) reported high concentrations of Pb and Cd in Hungarian waters. In their studies, Bubukutty and Chacko (1992) reported high concentrations of Cd, Zn, Pb, Mg and Cu in the soft tissues and shells of the estuarine bivalves from south West Coast of India. As a consequence of human existence on earth, enormous amounts of wastes are continually generated into the environment.

5. Conclusion

The section of River Niger flowing through Onitsha, Nigeria is experiencing impairment with heavy metals Zinc (Zn), Iron (Fe), Copper (Cu), and Lead (Pb). The African Catfish *Clarias gariepinus* of River Niger accumulate varying levels of these heavy metals in its tissues; and this knowledge serves as an early warning that prolonged consumption of heavy metal-contaminated *Clarias gariepinus* of River Niger may pose serious human health risks. It is suggested that further comprehensive assessment of the hazards posed by heavy metals in fishes and other aquatic foods be carried out in different Nigerian water bodies. Public health awareness programmes may be necessary to discourage the indiscriminate dumping of wastes in the environment, while Waste Management Agencies should be fully empowered to function more effectively.

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