International Academic Journal of Advanced Educational Research
ISSN: 5280-5299 | Volume 9, Issue 9 | October, 2023 | pages 43 – 53
DOI: 245-142-523-71-996
Double Blind Peer Reviewed International Research Journal
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Uptake of Lead, Zinc and Chromium in Selected Fish Species from Komadugu River in Gashua, Yobe State Nigeria

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Abstract: *The nutritional value of fish may be affected by the environment in which it exists. The threat of toxic and trace metals in the environment is more serious than those of other pollutants due to their non-biodegradable nature. This is coupled with their bio-accumulative and biomagnification potentials. Within the aquatic habitat, fish cannot escape from the detrimental effects of these pollutants. In this study, uptake of lead (Pb), zinc (Zn) and chromium (Cr) in African characid (Clarias gariepinus) and African arowana (Heterotis niloticus) were investigated. Concentrations of the heavy metals were determined by Atomic Absorption Spectrophotometry after microwave digestion of samples of the fish species. The mean concentrations of Pb in African characid (Clarias gariepinus) and African Arowana (Heterotis niloticus) in this study were 1.0525±0.46 and 0.860 ± 0.22 mg/kg respectively. The permissible limits for Pb in fish set by the World Health Organization (WHO) and Food and Agricultural Organization (FAO) is 1mg/kg. The National Agency for Food, Drug Administration and Control (NAFDAC), Nigeria and European Union values are 2.0 and 0.3mg/kg respectively. The mean values of Zn in this study for African characid (Clarias gariepinus) and African arowana (Heterotis niloticus) are1.155±0.04 mg/kg and 2.365 ± 0.23 mg/kg respectively. These values are below the permissible limits of 50 and 100 set by NAFDAC, Nigeria and WHO.The mean value of Cr for African characid (Clarias gariepinus), 1.31±0.41 is greater than the recommended value of 0.05 –0.15mg/kg set by WHO and FAO, but less than 12 – 13mg/kg set by Food and Drug Agency (FDA).*

Keywords: *Aquatic habitat; Pollutants; Uptake; Permissible limit; Digestion*

1. Introduction

Although fish is a major source of protein (Rasheed, 2001), it is also a major source of heavy metals in food (Siverperumal *et al.,* 2007). Furthermore, fish species are used as bio-indicators of heavy metals (Svobodova *et al.,* 2004) because heavy metal concentration depicts both the present and the past pollution load of an environment (Ravera*et al.,*2003). Therefore, the safety of fish species for human consumption needs to be constantly studied especially, in areas already known to be polluted.. As a result, fishes are considered as a better specimen for investigation of pollutant loads than water sample because of the significant level of metal they bioaccumulate (Atuma and Egborge, 1986). It is significantly important to determine and monitor heavy metal level in foodstuffs, particularly sea and freshwater food. Heavy metal ion can easily accumulate in such food compared to other foodstuffs that can course harmful effect on human health (Allen-Gill and Marynor, 1995). Discharge of industrial water or wastewater without a pretreatment into the lake, rivers, stream, and sea, primarily causes an increase in the heavy metals in those water bodies. Moreover, such water is speedily polluted by chemical substances, paint, pesticides, petroleum products, and industrial, domestic and modern agriculture waste (FEPA, 1991).

In trace amounts many elements are useful to the human body but in large amounts, they cannot be excreted and thus, bio-accumulate in the body interfering with enzyme activities thus, hindering many body functions (Ongwuegbu and Ijioma, 2003). On the other hand, no amount of some particular element is considered safe. It is importance to constantly study the amount of elements in fishes found in various water bodies to check if they conform to tolerable limits established by regulatory agencies including the World Health Organization (WHO), Food and Agricultural Organization (FAO), National Agency for Food, Drug Administration and Control (NAFDAC), Nigeria and European Union values, Food and Drug Agency (FDA especially, in polluted areas. This is very important if one notes that people depend on fish as a major source of protein but unfortunately, fishes accumulate some dangerous elements from the surrounding water to an amount hundreds or even thousands of times higher than the surrounding water (Osman *et al.,* 2007).

2. Materials and Methods

2.1 The Study Area

The Yobe River, also known as the Komadugu Yobe River is a river in West Africa that flows into Lake Chad through Nigeria and Niger. In Yobe State, it is located on longitud12º52´N and latitude 10º58´E in Gashua, Bade Local Government Area. Its tributaries include River Hadejia , River Jama'are , and the Komadugu Gana River. The river forms a small part of the international border between Niger and Nigeria with 150 km and flows a total of 320 km (KYBP, 2006). There are concerns about changes in the river flow, economy and ecology due to upstream dams, the largest at present being the Tiga Dam in Kano State, with plans for the Kafin Zaki dam in Bauchi State (NPC, (2006). The River Yobe provides a means of subsistence for hundreds of thousands of people who work in a variety of commercial and agricultural endeavours along its almost 200 km length in the state's northern region, which spans seven local government areas (LGAs) from Nguru to Yunusari. Notable towns near the river include Gashua, Geidam and Damasak in Nigeria, and Diffa in Niger (Wakawa *et al*, 2017).

Figure 1: Catchment Area of the Komadugu River

2.2 Instruments, Apparatus and Reagents
All equipment and instruments used in this research were calibrated before conducting the experiments. All glassware used were thoroughly washed with detergents and tap water and then rinsed with deionized water. Suspected contaminants wares were cleaned with 10% concentrated Nitric acid (HNO_3) and metal surfaces rinsed with deionized water. The digestion tubes were soaked with 1% (w/v) potassium dichromate in 98% (v/v) H_2SO_4.
In preparation of reagents, chemicals of analytical grade purity and distilled water were used. All glassware and plastic containers were washed with detergents.
2.3 Digestion of the Fish Samples
The fish samples were weighed, decapitated, cut into smaller pieces using knife and then dried in an oven for 48hours at 120^0C. The dried samples were ground and milled with a mortar and pestle into fine powder. A microwave digester (Master 40 serial No: 40G106M) was used in digesting the fish samples in a digestion tube to which 0.1g of sample was added at a time, followed by 6mL of 65% HNO_3 and 2mL of 30% H_2O_2 and allowed to stand for a while. The digestion was carried out at 180°C, 1800W in a time of 30mins.The digestion was followed by cooling at room temperature in the microwave and the sample was diluted with de-ionized water. Potential presences of selected heavy metals in chemicals used in digestion were determined. Blanks were used simultaneously in each batch of the analysis to authenticate the analytical quality (SINEO, 2013).

2.4 Atomic Absorption Spectrometric Analysis

The fish extracts were analyzed for lead (283.5nm), zinc (213.9nm) and chromium (3579nm) using flame atomic absorption spectrophotometry. Blank determinations were made prior to sample analysis. Heavy metal concentrations in fish extracts were obtained in triplicates from calibration curves and expressed as mg/kg. Metals in chemicals used in digestion were determined. Blanks were used simultaneously in each batch of the analysis to authenticate the analytical quality (SINEO, 2013).

2.5 Statistical Analysis
The data were analyzed in triplets and expressed as mean and standard deviation. The mean of all treatments was subjected to a One-way analysis of variance (ANOVA) using IBM SPSS Statistics 23 software and mean differences were performed using the Tukey test. All graphs were plotted using Microsoft Excel 2013.

3. Results and Discussion

Fish is a basic and important food for human nutrition, providing protein, and healthy fatty acid with low cholesterol level that is healthy for consumption and capable of reducing the risk of heart diseases and stroke as well as essential minerals and vitamins (Agbugui *et al.,* 2011). The role of Fisheries in the ecosystem serving as food along the food chain, hence their presence and importance cannot be overlooked as the heavy metal accrued in fish results to an impact in human health (Azaman *et al.*, 2015; Agbugui *et al.,* 2019).

Heavy metals differ widely in their chemical properties and are used extensively in electronics, Machines and the artefacts of everyday life as well as in high-tech applications. As a result, they are able to enter into the aquatic environment and food chains of humans and animals from a Variety of anthropogenic sources as well as from natural sources (Al-yousuf *et al.*, 2000). The main sources of contamination include; mining wastes, landfill leaches, municipal wastewater, urban runoff, and industrial waste waters particularly from electroplating, electronic and metal finishing industries. Many aquatic environments face metal concentrations that exceed water quality criteria designed to protect the environment, animals and humans. The problems are exacerbated because metals have the tendency to be transported with sediments, are persistent in the environment and can bio-accumulate in the food chain (ATSDR, 2007).

3.2 Levels of Lead, Zinc and Chromium in Fish Species

The results of the mean concentrations of Pb, Zn and Cr in African characid (*Clarias gariepinus*) and African arowana (*Heterotis niloticus*) are presented in Table 1.

Table 1: Mean Concentrations (mg/kg) of Pb, Zn and Cr

Fish Specie	Pb	Zn	Cr
African Characid	1.0525±0.46	1.155±0.04	1.31±0.41
African Arowana	0.860 ± 0.22	2.365±0.23	23.733±1.26
WHO/FAO	**1**	**100**	**0.005 -0.15**
EU	**0.3**		
NAFDAC	**2.0**	**50**	
FDA			**12 – 13**

KEY

WHO: World Health Organization

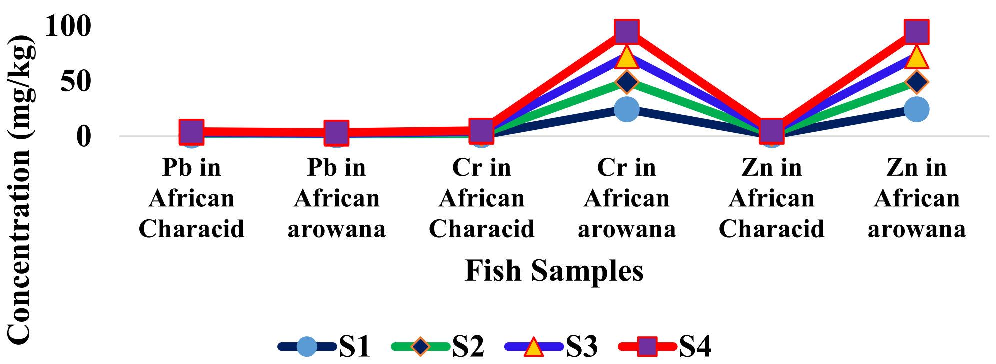
EU: European Union

NAFDAC: National Agency for Food, Drug Administration and Control

FDA: Food and Drug Agency

The mean concentrations of lead, zinc and chromium in African characid (*Clarias gariepinus*) and African arowana (*Heterotis niloticus*) fish species are shown in **Figure 1**

Figure 1: Concentrations of Lead, Chromium and Zinc in African Characid (*Clarias gariepinus*) and African Arowana (*Heterotis niloticus*) Fish Species



3.2.1 Lead

The mean concentrations of Pb in African characid (*Clarias gariepinus*) and African Arowana (*Heterotis niloticus*) in this study were 1.0525±0.46 and 0.860 ± 0.22 mg/kg respectively. The permissible limits for Pb in fish set by WHO/FAO is 1mg/kg The NAFDAC and European Union values are 2.0 and 0.3mg/kg respectively. Ojaniyi *et al.*(2021) reported the concentrations of Pb in cat fish in (*Clarias garipinus*), African arowana (*Heterotis niloticus*), and African mottled eel (*Anguilla labiate*) were 0.276±0.003, 0.394±0.1 and 0.299±0.061 mg/kg respectively. In another report, Yuguda *et al.*,(2022) gave Pb concentration in catfish and tilapia as 1.163±0.071 and 0.431±0.102 mg/kg respectively. The Pb concentration in gills of *Synodontis schall* was 0.50±0.12 mg/kg (Elinge *et al.*, 2019). A higher value of 2.38 ± 0.02 – 5.84 ± 0.04 mg/kg for Pb in catfish *(Clarias gariepinus*) was reported by Hagras *et al*., (2018).

Concentrations of Pb in the environment are largely increased by anthropogenic activities such as base metal mining, battery manufacturing, lead based paints and lead-gasoline (Abadi *et al.*, 2014; Krishnani *et al.*, 2003; Kennedy 2011). Lead poisoning can happen if a person is exposed to very high levels of lead over a short period of time. When this happens, a person may experience the following: abdominal pain, constipation, tiredness, headache, irritability, and loss of appetite, memory loss, pain or tingling in the hands and or feet and weakness (ATSDR, 2005). However, lead poison can easily be overlooked because these symptoms may occur slowly or may be caused by other things. Exposure to high levels of lead may cause anemia, weakness and kidney and brain damage. Very high lead exposure can cause death. Lead can cross the placenta barrier, which means pregnant women who are exposed to lead also expose their unborn children. Lead can damage a developing baby's nervous system (ATSDR, 2005). Even low level of lead exposures in developing babies have been found to affect behavior and intelligence. Lead exposure can cause miscarriage, stillbirths, and infertility (in both men and women). Generally, lead affects children more than it does adults. Children tend to show signs of severe lead toxicity at lower levels than adults (NIOSH, 1995).

3.2.2 Zinc

The mean values of Zn in this study for African characid (*Clarias gariepinus*) and African arowana (*Heterotis niloticus*) are1.155±0.04 mg/kg and 2.365 ± 0.23 mg/kg respectively. These values are below the permissible limits of 50 and 100 set by NAFDAC, Nigeria and WHO. The concentrations of Zn in *Synodontis schall*, 0.60±0.2- 0.15±0.00 mg/kg and 0.47±0.14 - 0.28±0.0 mg/kg in *Synodontis membranaceus* reported by Elinge *et al.,* (2019) were lower than the Zn levels reported in this study. Similarly, Ojaniyi *et al.* (2021) reported that concentrations of Zn in cat fish (*Clarias garipinus*), African arowana (*Heterotis niloticus*) and African mottled eel (*Anguilla labiate*) were 0.245±0.04, 1.242±0.03 and 0.556±0.008 mg/kg respectively. In another report Jafiya *et al*. (2022) gave the concentrations of Zn in *Oreochromis niloticus, Clarias gariepinus* and *Syndontis schall* as; 8.22±2.86 - 14.46±3.99, 11.09±3.12 - 13.45±3.32 and 8.34±8.98 - 11.48±10.98 mg/kg respectively. El-Ishaq *et al.* (2016) also reported Zn concentrations in African catfish (*Clarias gariepinus* and tilapia (*O. niloticus*) as 2.03±1.2 - 3.58±1.69 and 0.46±0.46 - 2.74±1.54 mg/kg respectively. Very high concentrations of 74.5 and 71.2 mg/kg of Zn in *Tilapia guineensis* and *Sarotherodonmelanotheron* were reported by Owhonda *et al*. (2016).

Zinc is an essential trace element, a micronutrient in every living organism. Zn is found in almost every cell to be involved in nucleic acid synthesis (Tabari et al., 2010). Zinc is known as a cofactor to more than 300 enzymes that involved in RNA and DNA metabolism. Zn is also important in the structure stabilization of a large amount of proteins (Chasapis *et al.,* 2012; and Song *et al.,* 2010). When exceeding amounts are present, Zn becomes toxic (Krishna *et al,*2014), but a deficiency of Zn can lead to several disorders (Scherz and Kirchhoff, 2006) such as results in poor pregnancy outcomes (King, 2000; Uriu-adams, & Keen,2010) and development of chronic diseases, including cardiovascular disease (Messner *et al.,* 2009; Afridi *et al.,* 2009) and also cause cancer (Kazi *et al.,*2010).

3.2.3 Chromium

The mean value of Cr for African characid (*Clarias gariepinus*) in this study, 1.31±0.41 is greater than the recommended value of 0.05 – 0.15mg/kg set by the World Health Organization (WHO) and Food and Agricultural Organization (FAO), but less than 12 – 13mg/kg set by Food and Drug Agency (FDA). However, the result for African arowana (*Heterotis niloticus*), 23.733±1.26 mg/kg is greater than recommended values of WHO/FAO and FDA.

Elinge *et al.,* (2019) reported the concentration of Cr in *Synodontis schall*, 0.13±0.09 mg/kg is less than the result for African characid (*Clarias gariepinus*), which is in consonance with the concentration Cr for *Synodontis membranaceus*, 0.16±0.03 -1.39±0.95mg/kg. These values are much less than the result for African arowana (*Heterotis niloticus*). The Cr concentration in *Tilapia guineensis,* 10.5mg/kg and *Sarotherodon melanotheron,* 10.3mg/kg are above the results for arowana (*Heterotis niloticus*) (Owhonda *et al*., (2016). Ojaniyi *et al.* (2021) reported that concentrations of Cr in cat fish (*Clarias garipinus*), 0.001±0.002 mg/kg, African arowana (*Heterotis niloticus*),0.000±0.000 mg/kg and African mottled eel (*Anguilla labiate*), 0.001±0.002 mg/kg are much lower than the results for African characid (*Clarias gariepinus*) and African arowana (*Heterotis niloticus*) obtained in this study. Yuguda *et al.* (2022) reported Cr concentration in Catfish, 2.066±0.222-2.882±0.230 mg/kg and Tilapia, 0.439±0.034 - 1.973±0.183 mg/kg, which are much lower than the result for African arowana (*Heterotis niloticus*) in this study.

Chromium is an essential nutrient metal necessary for metabolism of carbohydrates. Chromium will find its way into the aquatic ecosystem through effluents discharged from leather tanneries, textiles, metal fishing, electroplating dyeing, mining, printing industries, ceramics, photographic and pharmaceutical industries (WHO, 2011). Poor treatment of these effluents can lead to the presence of Cr (IV) in the surrounding water bodies, where it is commonly found at potentially harmful levels to fish (Rohasliney *et al.,* 2014). The physicochemical parameters of a given water body especially surface waters determines the stability of chromium. The most stable forms of chromium are the oxidation states trivalent Cr (III) or (Cr^{3+}) and the hexavalent Cr (VI) or (Cr^{6+}). The hexavalent chromium (Cr^{6+}) is considered to be toxic (i.e carcinogenic) because of its powerful oxidative potential and ability to cross call membranes (Ashraf *et al.*, 2010). Fish assimilate Cr by ingestion, gill uptake or by accumulation in the tissues mainly through the liver and kidney. The concentration found in fish and other aquatic organisms are often higher and at lethal doses than those found in the environment (Karadede *et al.,* 2010). The overall toxic impact on organs like gill, livers, kidneys, heart may seriously affect the catabolic, anabolic and physiological activities which may deter the optimal growth and behavior of fish. Common toxic effect of Chromium in fish include: anatomical, histological, hematological and morphological alterations, inhibition and reduction in growth, and impaired immune function (Yilmaz *et al.,* 2007).

Chromium in man causes mucosal irritation, phytotoxic corrosion, irritation of the central nervous system which is followed by depression and in rare cases of death (Weber *et al.* 2013).

4. Conclusion

The mean concentrations of lead (Pb), zinc (Zn) and chromium (Cr) in African characid (*Clarias gariepinus*) and African arowana (*Heterotis niloticus*) determined in this study were within the limits set by the World Health Organization (WHO), Food and Agricultural Organization (FAO) and National Agency for Food, Drug Administration and Control (NAFDAC).

Acknowledgement
The authors are grateful to Mal. Idris Baba of Chemistry Research Laboratory, Yobe State University, Damaturu for his invaluable contribution in the sample analysis.

Authors' Contributions
Dagari M.S.: Conceptualization, design and supervision of the research work; Editing of the write-up
Bala U.M.: Undertaking the research work, write-up and data analysis.

References

Abadi, D. R.V., Dobaradaran, S., Nabipour I., Lamani, X. and Ravanipour, M. (2014). Comparative investigation of heavy metal, trace, and macro element contents in commercially valuable fish species harvested off from the Persian Gulf. *Environ. Sci*.

Afridi, H. I., Kazi T. G., Kazi N., Kandhro G. A., Baig J. A., Jamali M. K. and Shah A. Q. (2011). Interactions between Cadmium and Zinc in the Biological Samples of Pakistani Smokers and Nonsmokers Cardiovascular Disease Patients. *Biol Trace Elem Res*. 139:257-268,

Agbugui M. O., Abhulimen E. F., Inobeme, A. and Olori, E. (2019). Biodiversity of Fish Fauna in River Niger at Agenebode, Edo State, Nigeria, *Egyptian Journal of Aquatic Biology and Fisheries*, 23(4): 159-166.www.ejabf.journals.ekb

Agbugui, M. O., Oniye, S. J., Auta, J. and Abeke, F. O. (2011). Growth performance and feed utilization of fingerlings of *Clarias gariepinus* (Teguels) fed processed *Pauletia monandra* (Kurz) seed meal. *Journal of Aquatic Sciences*, 26 (1): 21-27.

Allen-Gill SM, Martynov VG (1995). Heavy metals burdens in nine species of freshwater and anadromous fish from the Pechora River, *Northern Russia. Sci. Total Environ,* 160-161:653-659.

Al-yousuf MH, El-shahawi MS, Al-ghais SM (2000). Trace Metals in Liver, Skin and Muscle of *Lethrinus lentjan* Fish Species in Relation to Body Length and Sex. *Journal of Science Total Environment*.;14(7): 247-256.

Ashraf, M. A., Maah, M. J., Yusoff, I., Wajid, A. and Mahmood K. (2010). Sand mining effects, causes and concerns: A case study from Bestari Jaya, Selangor, Peninsular Malaysia. *Scientific Research and Essays,* 6(6):1216–1231.

ATSDR (2007).Toxicological Profile for Lead. Goergia: Agency for Toxic Substance and Disease Registry,US Department of Health and Humans Services

ATSDR (2005). Lead toxicity. Georgia: Agency for Toxic Substances and Disease Registry, U.S. Department of Health and Human Services

Atuma SO, Egborge ABM (1986). Insecticide and Metals in Nigeria Surface Water- Warri. Inter. J. Environ. Stud. 27:39-142.

Azamana, F., Hafizan Juahira, Kamaruzzaman, Y., Azman, A., Mohd -Khairuln Amri Kamarudina, Mohd Ekhwan Torimana, Ahmad Dasuki Mustafaa, Mohammad Azizi Amrana, Che Noraini Che Hasnama, Ahmad Shakir Mohd Saudia (2015). Heavy Metal in Fish: Analysis and Human Health-A Review. *Jurnal Teknologi,* 77:(1) 61–69 | www.jurnalteknologi.utm.my | eISSN 2180–3722

Chasapis, C. T., Loutsidou, A., Spiliopoulou, C. A. and Stefanidou, M. E. (2012). Zinc and Human Health: An Update. *Arch Toxicol*., 86: 521-534.

Elinge, C. M., Obaroh, I. O., Muhammad, A., Yanah, Y. M. and Abdullahi, L. Y. (2019). Determination of some heavy metals in three selected Fish species from river Zamare, Nigeria International *Journal of Fisheries and Aquatic Studies*, 7(4):385-387.

El-Ishaq, A., Akinsola R.O. and Hussaini I. (2016). Determination of Some Trace Elements Cu, Fe, Pb And Zn in the Gills, Muscle and Tissues of *Clarias gariepinus* and *Oreochromis niloticus* Found Along River Yobe. *Journal of Medical and Biological Science Research.* Vol. 2(1): pp. 27-32.

Federal Environmental Protection Agency (FEPA), (1991). Guidance and Standards for Environmental Pollution in Nigeria. FEPA, Lagos, Nigeria, 1-10.

Hagras, A. E., Elbaghdady, H. A. M. and Gouda, A. M. R. (2018). Assessment of Water Quality and Heavy Metals in Water, Sediments, and Some Organs of African Catfish (Clarias gariepinus) in El-Serw drain, Nile Delta, Egypt. *International Journal of Environment*, 07(04):124-141.

Jafiya, L., Akogwu, A., Sabo J. S. and Osunlaja, A. A. (2022). Assessment of Heavy Metals in Some Edible Fish Species of the Komadugu-Yobe River, Gashua, Yobe State, North-East Nigeria: Threat to Public Health *International Journal of Biological and Pharmaceutical Sciences Archive,* 04(01): 001–011.

Karadede, H., Oymak, S. A. and Ünlü, E. (2010). Heavy metals in mullet, Liza abu, and catfish, Silurus triostegus, from the Ataturk Dam Lake (Euphrates) *Turkey Environment International,* 2004(30):183-188.

Kazi T. G., Wadhwa S. K., Afridi H. I., Kazi N., Kandhro G. A., Baig J. A., Arain M. B. (2010). Interaction of Cadmium and Zinc in Biological Samples of Smokers and Chewing Tobacco Female Mouth Cancer Patients. *Journal of Hazardous Materials*. 176: 985-991, doi:10.1016/j.jhazmat.2009.11.139

Kennedy, C. J. (2011). The Toxicology of Metals in Fishes.

King, J. C. (2000). Determinants of Maternal Zinc Status during Pregnancy. *Am J Clin Nutr*. 71: 1334-1343.

Krishna, P., Jyothirmayi, V. and Madhusudhana, R. K. (2014). Human Health Risk Assessment of Heavy Metal Accumulation through Fish Consumption, from Machilipatnam Coast, Andhra Pradesh, India. *International Research Journal of Public and Environmental Health,* 1(5): 121-125.

Krishnani, K. K., Azad, I. S., Kailasam, M., Thirunavukkarasu, A. R. and Gupta, B. P. (2003) Acute toxicity of some heavy metals to Lates calcarifer fry with a note on its histopathological manifestations. *J Environ Sci Health A.,* 38:645-655

KYBP (2006).Komadugu Yobe Basin Water Audit Report by Afremedev Consultancy Services Limited for FMWR IUCN-NCF Komadugu Yobe Basin Project, Kano, Nigeria.

.Messner, B., Knoflach, M., Seubert, A., Ritsch, A., Pfaller, K., Henderson, B., Bernhard, D. (2009). Cadmium is a Novel and Independent Risk Factor for Early Atherosclerosis Mechanisms and in Vivo Relevance. *Arterioscler Thromb Vasc Biol*. 1392-1398.

NIOSH (1995). *Report to Congress on Workers'* Home Contamination Study Conducted Under the Workers' Family Protection Act. USA: National Institute for Occupational Safety and Health.

NPC (2006).National Population Commission, http://www.population.gov.ng

Ogwuegbu, MO; Ijioma, MA (2003). Effects of Certain Heavy Metals on the Population Due To Mineral Exploitation. In: International Conference on Scientific and Environmental Issues In The Population, Environment and Sustainable Development in Nigeria, University of Ado Ekiti, Ekiti State, Nigerian p.8-10.

Ojaniyi, O. F., Okoye, P. A. C., Omokpariola, D. O. (2021). Heavy Metals Analysis and Health Risk Assessment of Three Fish Species, Surface Water and Sediment Samples in Ogbaru Axis of River Niger, Anambra State, Nigeria. *Asian Journal of Applied Chemistry Research,* 9(1): 64-81.

Osman, A; Wuertz, S; Mekkawy, I; Exner, H; Kirschbaum, F (2007). *J. Environ. Toxic.* 22 (4): 375- 389

Owhonda N.K., Ogali R.E., Ofodile S.E. (2016). Assessment of Chromium, Nickel, Cobalt and Zinc In Edible Flesh of Two Tilapia Fish Species Found in Bodo River, Rivers State, Nigeria, *J. Appl. Sci. Environ. Manage.*, 20(3):560-564.

Rasheed, MN (2001). Egypt monitoring of environmental heavy metals in fish from Nasser Lake, *.Environ. Int.,* 27: 27-33.

Ravera, RC; Beone, GM; Dantas, M; Lodigiani, P (2003). Trace Element Concentrations in Freshwater Mussels and Macrophytes as Related to Those in Their Environment, *J. Lim.*, 62 (1): 61-70.

Rohasliney, H., Tan, H. S., Noor-Zuhartini, Md, M., Tan, P.Y. (2014). Determination of Heavy Metal Fishes from the lower reach of Kelantan River. Kelantan, Malaysia. *Tropical Life Sciences Research*. 25(2):21-39.

Scherz, H., and Kirchhoff, E. (2006). Trace Elements in Foods: Zinc Contents of Raw Foods-A Comparison of Data Originating from Different Geographical Regions of the World. *Journal of Food Composition and Analysis*. 19: 420- 433.

SINEO (2013). Operating Manual of Master 40 Microwave Digester.

Song, Y., Elias, V., Loban, A., Scrimgeour, A. G. and Ho, E. (2010). Marginal Zinc Deficiency Increases Oxidative DNA Damage in the Prostate after Chronic Exercise. *Free Radical Biology and Medicine*. 48: 82-88

Sivaperumal, P; Sankar, TV; Nair, PGV (2007). Heavy metal concentrations in fish, shellfish and fish product from internal markets of India vis-à-vis international standards. *Food Chem.* 102 (61): 612-620.

Svobodova, Z; Celechovska, O; Kolara, J; Randak, T;Zlabek, V (2004). "Assessment of Metal Contamination in the Upper Reaches of the Ticha Orlice River," *Czech J. Anim. Sci.*, 49 (4): 458-641.

Tabari, S., Saravi, S.S.S., Bandany, G.A., Dehghan, A. and Shrodekhe M. (2010). Heavy metals (Zn, Pb, Cd and Cr) in fish, water and sediments sampled form Southern Caspian Sea, Iran. Toxicology and Industrial Health. 26(10). https://doi.org/10.1177/07482337 10377777.

Uriu-adams, J. Y., and Keen, C. L. (2010). Zinc and Reproduction: Effects of Zinc Deficiency on Prenatal and Early Postnatal Development. *Birth Defects Research* (Part B). 89: 313-325

Wakawa LD, Suleiman AA, Ibrahim Y, Adam LI. Tree Species Biodiversity of a Sahelien Ecosystem in North-East Nigeria. Bartın Orman Fakültesi Dergisi, 2017; 19(2): 166-173.

Weber, P., Behr, E. R., Knorr, C. D. L., Vendruscolo, D. S., Flores, E. M.,M., Dressler, V. L. and Baldisserotto, B. (2013). Metals in the water, sediment, and tissues of two fish species from different trophic levels in a subtropical Brazilian river. *Microchemical Journal*. 106(1):61-66.

WHO (2011). Guide lines for drinking water quality, 4th Edition. Witczak, A. and Abdel-Gawad, H. (2014). Assessment of health risk from organochlorine pesticides residues in high-fat spreadable foods produced in Poland. *J Environ Sci Health* 49:917-28, doi:10.1080/03601234.2014.951574.

Yilmaz F., Ozdemir N., Demirak A., Tuna A. L. (2007). Heavy metal levels in two fish species Leuciscus cephalus and Lepomis gibbosus. *Food Chem*. 100:830-835.

Yuguda, U., Jones, A. N., Ibrahim, U. A. and Yadima, S. G. (2022). Determination of Heavy Metals Concentration in Water, Fish Species and Human Urine Associated with Chronic Kidney Disease in Gashua, Yobe State, Nigeria. *FUW Trends in Science & Technology Journal*, 7(1):168 – 179.