International Journal of Innovative Agriculture & Biology Research 8(2):50-59, April-June, 2020

© SEAHI PUBLICATIONS, 2020 www.seahipaj.org ISSN: 2354- 2934

Human Health Risk Assessment of Nutrients via Consumption of *Oreochromis niloticus* (Nile Tilapia Fish)

A.S. Achide* & **D.A. Bako**

Department of Basic Sciences,
College of Agriculture, Science and Technology, P.M.B 33, Lafia, Nasarawa State, Nigeria
***Email of Corresponding author: achidesamson@gmail.com/gistwitachide@yahoo.com**

ABSTRACT
The human health risk assessments of nutrients through consumption of *Oreochromis niloticus* (Nile Tilapia Fish) were investigated. The data of nutrients concentrations of the fish was collected from Shabu river in Lafia, Nasarawa State and were analyzed for Iron (Fe), Zinc (Zn), Lead (Pb) and Copper (Cu) concentrations using USEPA maximum tolerable limits of contaminants in fish. The results of the findings reveals that the Estimated Daily Intake for Cu in both Adult and Child account for 20% concentration of the analyzed nutrients in Gills and Bones with an estimated risk level of 30% for Gills and 29% for Bones. The levels of distribution for Fe, Zn and Pb in the fish parts were minimal with the highest 9% in Bones. These level of essential nutrients found in fish may compliment of the requirement of these nutrients in non-animal nutrition on consumption.
Keywords: Minerals, Contamination, Health Risk Assessment, Estimated Daily Intake (EDI), and Target Hazard Quotient (THQ)

1.0 INTRODUCTION

Minerals are chemical constituents used by the body in many ways. Although they yield no energy, they have important roles to play in many activities in the body (Malhotra, 1998; Eruvbetine, 2003). Minerals are inorganic elements, present in all body tissues and fluids and their presence is necessary for the maintenance of certain physicochemical processes essential to life. Every form of living matter requires these inorganic elements or minerals for their normal life processes (Ozcan, 2003). Minerals may be broadly classified as macro (major), micro (trace) elements and ultra trace elements. The macro-minerals include calcium, phosphorus, sodium and chloride, while the micro-elements include iron, copper, cobalt, potassium, magnesium, iodine, zinc, manganese, molybdenum, fluoride, chromium, selenium and sulfur (Eruvbetine, 2003). The macro-minerals are required in amounts greater than 100 mg/dl and the micro-minerals are required in amounts less than 100 mg/dl (Murray *et al.*, 2000). The ultra trace elements include boron, silicon, arsenic and nickel which have been found in animals and are believed to be essential for some of these animals. In this century, the significance and importance of mineral elements for human or animal nutrition cannot be overemphasized. The presence of mineral elements in animal feed is vital for the animals' metabolic process and with modern analytical techniques; the detection of these minerals as essential nutrients is still an active area of current research.

Mineral deficiencies or toxicity are a major public health problem in many developing countries, with the aged, infants and pregnant women especially at risk (Batra and Seth, 2002). Mineral elements play important roles in heath and diseases state of humans and domestic animals when taken in the right quantity. These minerals can have devastating consequences when it reaches a certain threshold limit in the body. There have been suggestions that the lack of adequate information about the composition of varied feed resources in some regions have been the major drawback to their utilization, rather than real shortage (Aletor and Omodara, 1994).

Fish are generally consumed for several purposes aimed at growth, development and maintenance of good health. The contamination of fish by metals in areas with high anthropogenic pressure is presently assuming a dangerous proportion for food quality, aquatic life and fish species are no exception (Ejaz ul Islam *et al.,* 2007). A significant proportion of developing countries like the Nigerian populations still rely on surface water for drinking, washing, swimming and fishing coupled with the accelerating growth of urban areas near aquatic environments combined with uncontrolled increases in industrial and agricultural activities, have raised serious concerns about the concentration of minerals (Rai, 2008; Wang *et al.,* 2010). Due to the capability of minerals (metals) to bioaccumulate in organic tissues when continuously exposed to their low concentrations may result in subsequent transfer to man through the food web (Paquin *et al.,* 2003). The risk of indirect metal contamination through feeding is a worldwide concern. In fact, this has been considered the main route of exposure for human beings and showed potential risk (Onsanit, *et al.,* 2012; Mallin *et al.,* 2011; Storelli, 2008).

Similarly, it is reported that people can be exposed to toxic chemicals that accumulate in fish taken from contaminated waters that are consumed (Han *et al.,* 1994; Svensson *et al.,* 1995).

Human health risk assessments are the characterization of potential adverse health effects of human exposures to environmental hazards (USEPA, 2012). Health risk assessment is an important tool that evaluates the consequences of human activities and weighs the adverse effects to public health against the contributions to economic development. Assessment of minerals in fish can be categorized into two major aspects:

a) **From the public health point of view;** to evaluate the potential health risks to human associated with consumption of fish from Shabu river to safeguard human health.

b) **From the aquatic environment view point;** to improve our knowledge on the biological status of the aquatic ecosystems as well as to improve our understanding of how the aquatic ecosystem adapts or changes according to the change in surrounding environmental conditions.

Considering the above facts, the present study was undertaken to assess the health risk associated with nutrients (Iron (Fe), Copper (Cu), Zinc (Zn), and Lead (Pb)) via consumption of an edible *Oreochromis niloticus* harvested from Shabu river in Nasarawa State and predict potential health consequences that can serve as scientific basics for decision making and policy development. This will help to minimize the risk of health population on individuals that depends on the Shabu river for their fish supply or water. In the current study Fe, Cu, Zn and Zn were chosen for human health risk assessment in fish due to their extremely toxic effects on the aquatic organisms and human health. Also human consumes the fish tissue while gills, bones and liver are considered as good environmental indicator of minerals contamination from water *(*Agemian *et al.,* 1980*)*. Thus fish muscle, gills, bones and liver are chosen to produce a representative health risk assessment of minerals content data which include Fe, Cu, Zn and Pb for contaminated Nile Tilapia Fish from Shabu river.

2.0 Theoretical Framework of Potential Human Exposure to Minerals via Consumption of Fish

Minerals in a risk assessment fall into one of these two categories;

(i) non-carcinogen and

(ii) carcinogen.

Non-carcinogenic minerals are assumed to have a threshold; a dose below which no adverse health effects will be observed where an essential part of the dose-response portion of a risk assessment includes the use of a reference dose (RfD). On the other hand, carcinogens are assumed to have no effective threshold. This assumption implies that there is a risk of cancer developing with exposures at low doses and, therefore, there is no safe threshold for exposure to carcinogenic minerals. Carcinogens are expressed by their Cancer Potency Factor (Lushenko, 2010). All consumption limits and risk factors will be calculated assuming, for adults a consumption rate of 227g and body weight 70kg while for children a consumption rate of 114g and body weight of 16kg (USEPA, 2000). A schematic diagram to understand the accumulation process which raises potential risk is shown in figure 1.

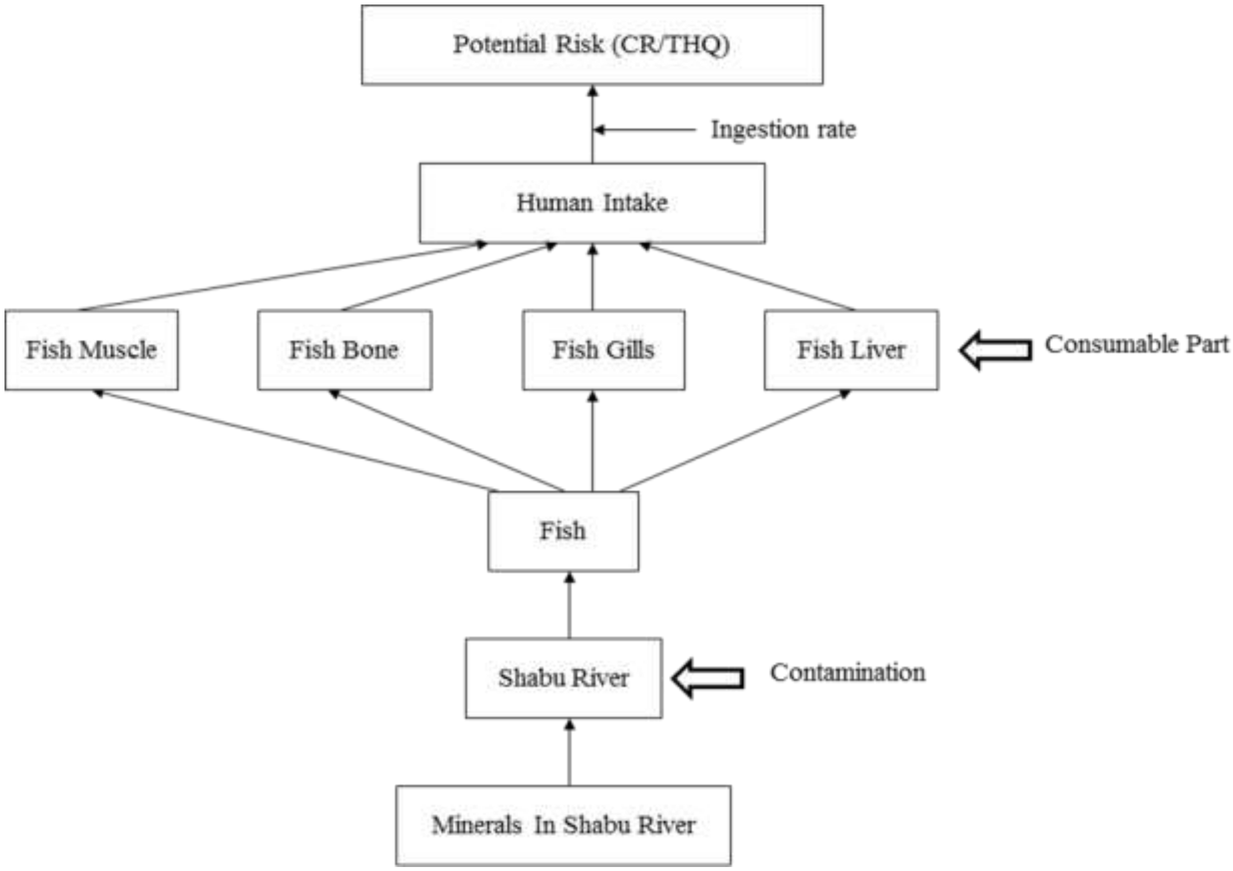

Figure 1: Schematic diagram of investigation process to access potential risk (CR: Cancer Risk; THQ: Target Hazard Quotient)

In the present study, the non-carcinogenic human risk assessment according to Onsanit *et al*, (2010) using the estimated daily intake (EDI) and reference dose (RfD) is estimated as;

$$EDI = \frac{C \times IR}{BW} \quad - \quad - \quad - \quad - \quad - \quad - \quad - \quad - \quad - \qquad (1)$$

Where C = average trace element concentration in organism muscle (μgg^{-1} wet weight), IR = Fish Ingestion Rate ($gday^{-1}$) per capita, and BW = average body weight of target population.
The Target Hazard Quotient (THQ) represents the ratio between the EDI and the RfD in Equation 2. It is also considered to be an estimate of the risk level (non-carcinogenic) due to pollutant exposure and not estimated risk (*Agusa et al., 2005*)

$$THQ = \frac{EDI}{RfD} \quad - \quad - \quad - \quad - \quad - \quad - \quad - \quad - \quad - \qquad (2)$$

A summation of the target hazard quotients for all minerals to which an individual is exposed is to be used in calculating the Hazard Index (USEPA, 2011).

$$HI = THQ_{Fe} + THQ_{Zn} + THQ_{Pb} + THQ_{Cu} \quad - \quad - \quad - \quad - \quad - \qquad (3)$$

Where HI is the hazard index; THQ_{Fe} is the target hazard quotient for Fe intake; THQ_{Zn} is the target hazard quotient for Zn intake; THQ_{Pb} is the target hazard quotient for Pb intake and THQ_{Cu} is the target hazard quotient for Cu intake. Carcinogenic risk was evaluated by target cancer risk (CR). The method for estimating CR was provided in USEPA Region III Risk-Based Concentration Table (USEPA, 2011) and the model is shown as:

$$CR = \frac{(C \times IR \times 10^{-3} \times CPSo \times EF \times ED)}{(BW \times AT)} \qquad - \quad - \quad - \quad - \quad - \qquad (4)$$

Where CR is the target cancer risk; C is the metal concentration in fish (μgg^{-1}); IR is the fish ingestion rate ($gday^{-1}$); CPSo is the carcinogenic potency slope oral, (mg/kg bw-day^{-1}); and AT is the averaging time carcinogens (days $year^{-1}$). The distribution of carcinogenic risk was estimated for Pb as this element for which an oral slope factor is derived. Table 3 shows the input parameters used in the health risk estimation. An averaging time of 365 d/yr for 70 yrs (i.e., AT = 25550dyr^{-1}) was used to characterize lifetime exposure for cancer risk calculation (USEPA, 2011). The USEPA has concluded that a lifetime cancer risk of 10^{-6} (1 in a million) or less can generally be considered as acceptable, whereas a lifetime risk of 10^{-3} or greater is considered serious and requires attention. Risk level between 10^{-6} to 10^{-4} (1 in 10,000) may also be up to standard but requires a case-specific judgment.

3.0 MATERIALS AND METHOD

Data Source

Oreochromis niloticus is one of the topmost favoured species of edible fish in Nigeria with a greater percentage supplied from natural water bodies and others from cultured ponds. This fish species can survive in bad environmental conditions because of their resistance to diseases (Zhou *et al.,* 1998), it is however considered here to be an ideal species of organism for an assessment study on the health effect of nutrients through consumption (Mokhtar *et al.,* 2009). Based on the (USEPA, 1989) Guidance, the ingestion dose is assumed to equal to the absorbed contaminant dose and that cooking has no effect on the contaminants (Chien *et al.,* 2002).

Therefore, in this study, data of nutrients concentrations for *Oreochromis niloticus*, collected from Shabu River in Lafia Nasarawa State, were obtained from Achide and Asheshi (2017) and which is presented in Table 1.

Table 1: Concentration of nutrient accumulation (mg/Kg dry weight) in tissues of fish

S/NO	SAMPLES	Fe	Zn	Pb	Cu
1	LIVER	0.013±0.035	0.050±0.030	0.001±0.048	0.110±0.046
2	GILLS	0.023±0.035	0.080±0.030	0.003±0.048	0.160±0.046
3	BONES	0.091±0.035	0.011±0.030	0.101±0.048	0.200±0.046
4	MUSCLE	0.052±0.035	0.030±0.030	0.015±0.048	0.101±0.046

Since the dietary intakes for humans are reported in terms of wet weight ingestion, the wet weight conversion is applied to conduct the risk assessment and the calculated values are presented in Table 2.

Table 2: Concentration of nutrient accumulation in analyzed tissues of fish

		Nutrients Concentration (µg/g w/w)			
S/NO	**Fish Body parts**	**Fe**	**Zn**	**Pb**	**Cu**
1	Liver	0.0052	0.0200	0.0004	0.0440
2	Gills	0.0104	0.0360	0.0014	0.0720
3	Bones	0.0324	0.0036	0.0360	0.0712
4	Muscle	0.0155	0.0104	0.0045	0.0300

Equations for converting between dry and wet weight concentrations was obtained from Ohio EPA (2008) and is presented below;

$$wet\ weight = (Dry\ weight)\left[1 - \left(\frac{(Percent\ moisture content)}{100}\right)\right] \quad - \quad - \quad (5)$$

Table 3: Summary of Input Parameters in the health Risk Estimation

Symbol	**Description**	**Unit**	**Value**
C	Average trace elements concentration in organism	µg/g wet weight	Presented in Table 2
IR	Fish Ingestion Rate	g/day	227g for Adult 114g for Children (USEPA, 2000)
Rfd	Reference dose	$\mu g g^{-1} day^{-1}$	Fe = 0.7 (USEPA, 2008) Cu = 0.04; Zn = 0.3 (USEPA, 2011) Pb = 0.003 (EC, 2004; Tu *et al.,* 2008)
BW	Average body weight of target Population	Kg	Adult = 70Kg Children = 16Kg (USEPA, 2000)
EF	Exposure frequency	days yr^{-1}	365
ED	Exposure duration	Yr	70
AT	Averaging time Carcinogens	days	Non carcinogens = 365 days yr^{-1} x ED
CPso	Carcinogenic potency slope, oral	$\mu g g^{-1}\ day^{-1}$	Pb = 0.009 (OEHHA, 2011)

Consolidated Table of OEHHA/ARB Approved Risk Assessment Health Values

4.0 RESULTS AND DISCUSSION

Table 4: Calculated values of EDI and THQ for Adults and Children in *Oreochromis niloticus*

Fish Parts	Metal	Rfd	EDI(Adult)	EDI(Child)	THQ(Adult)	THQ(Child)
Liver	Fe	0.7	0.01686286	0.03705000	0.0240898	0.0529286
	Zn	0.3	0.06485714	0.14250000	0.2161905	0.4750000
	Pb	0.03	0.00129714	0.00285000	0.0432381	0.0950000
	Cu	0.04	0.14268571	0.31350000	3.5671429	7.8375000
Gills	Fe	0.7	0.03372571	0.07410000	0.0481796	0.1058571
	Zn	0.3	0.11674286	0.25650000	0.3891429	0.8550000
	Pb	0.03	0.00454000	0.00997500	0.1513333	0.3325000
	Cu	0.04	0.23348571	0.51300000	5.8371429	12.8250000
Bones	Fe	0.7	0.10506857	0.23085000	0.1500980	0.3297857
	Zn	0.3	0.01167429	0.02565000	0.0389143	0.0855000
	Pb	0.03	0.01167429	0.02565000	0.3891429	0.8550000
	Cu	0.04	0.23089143	0.50730000	5.7722857	12.6825000
Muscle	Fe	0.7	0.05026429	0.11043750	0.0718061	0.1577679
	Zn	0.3	0.03372571	0.07410000	0.1124190	0.2470000
	Pb	0.03	0.01459286	0.03206250	0.4864286	1.0687500
	Cu	0.04	0.09728571	0.21375000	2.4321429	5.3437500

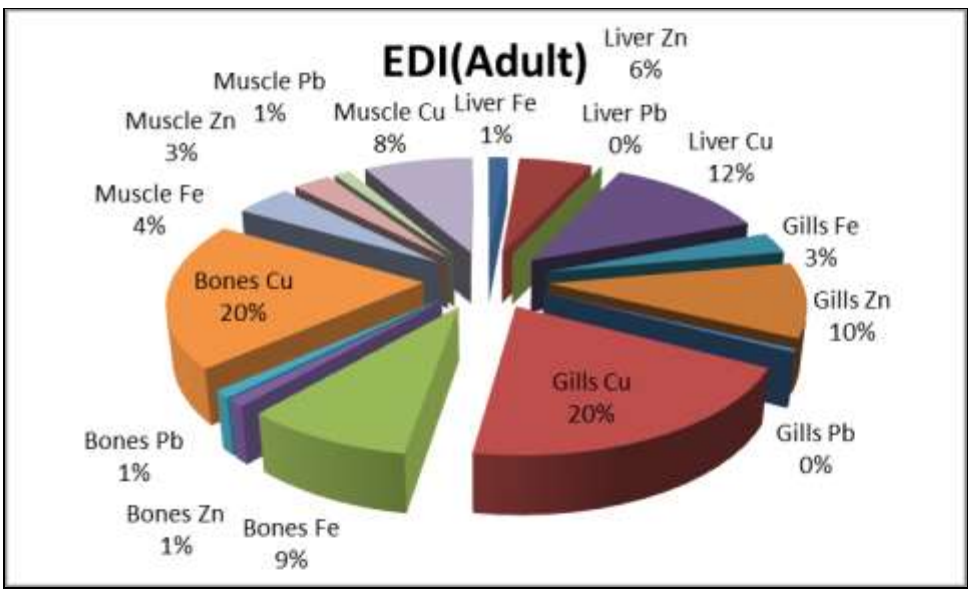

Figure 1: Percentage distribution of EDI (Adult)

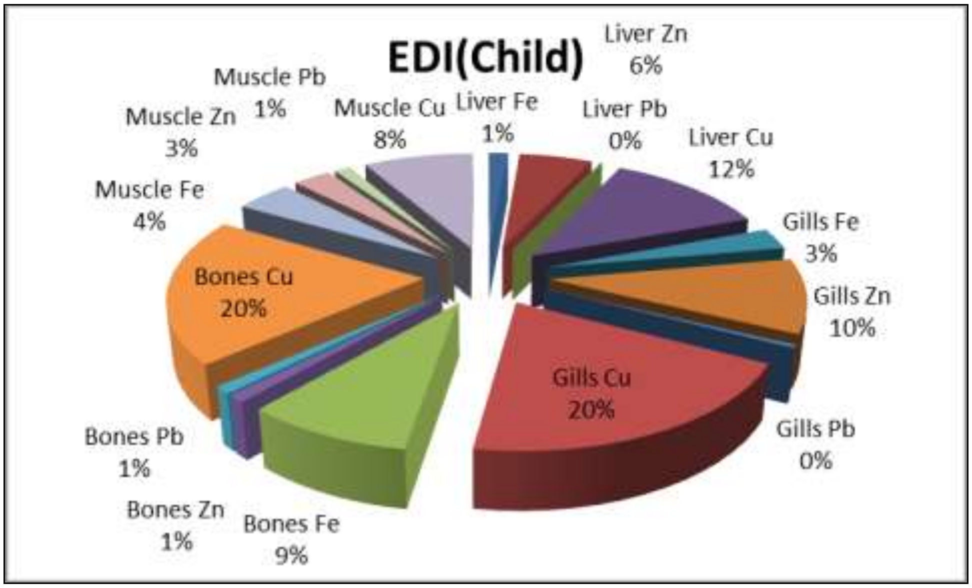

Figure 2: Percentage distribution of EDI (Child)

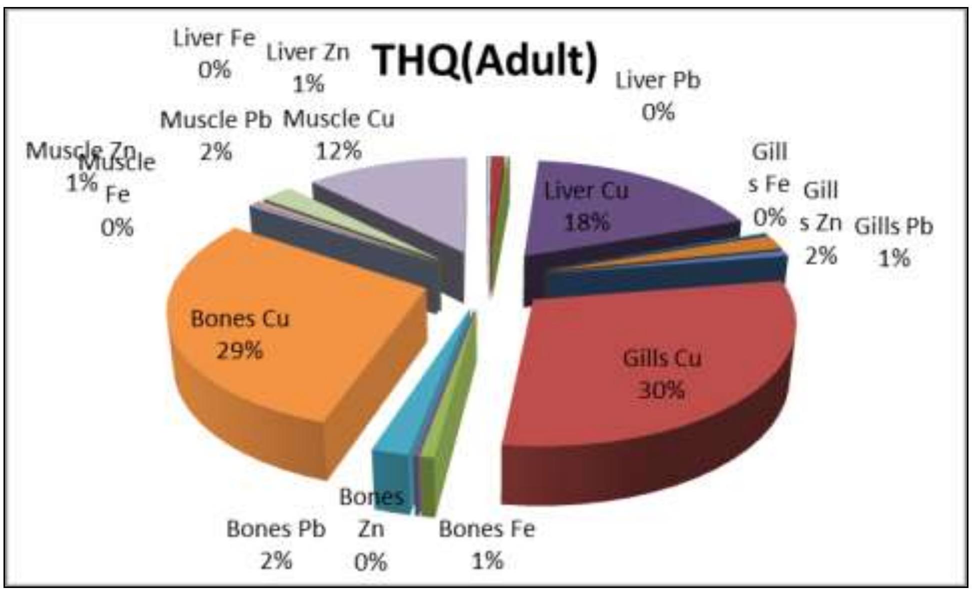

Figure 3: Percentage distribution of THQ (Adult)

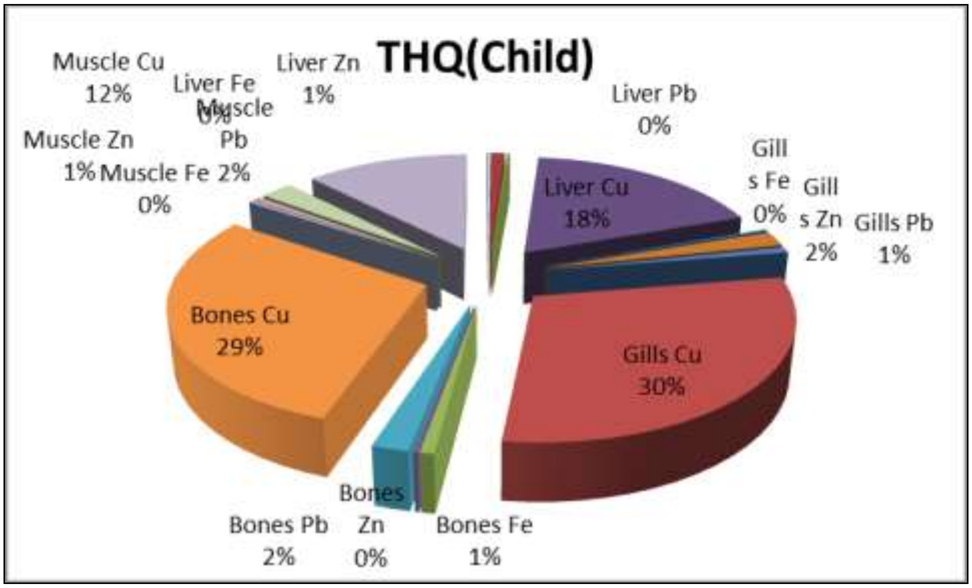

Figure 4: Percentage distribution of THQ (Child)

4.1 Non-carcinogenic Risk Assessment

A human risk assessment for consuming contaminated fishes were performed for Fe, Zn, Pb and Cu using USEPA maximum tolerable limits of contaminants in fish. Metal concentrations were used to estimate adverse non-carcinogenic health risk. Table 4 displays the calculated values of EDI and THQ for potential health risks (non-carcinogenic effects) associated with the consumption of *Oreochromis niloticus* fish contaminated with (Fe, Zn, Pb and Cu) for adults and children. THQ larger than 1 implies that the estimated exposure exceeded the USEPA reference dose for the contaminant of interest. Copper has THQ values greater than 1 in all the fish parts for both the child and adult. For Lead (Pb), THQ value for the muscle was above 1 indicating high risk of adverse health effects from consumption of fish by a Child. It can be suggested that fish meal intake by a child should be reduced.

4.2 Carcinogenic Risk Assessment

Out of the entire contaminant mineral investigated, only inorganic Pb is classified as carcinogenic element to humans (Vieira *et al*, 2011). The target carcinogenic effects derived from lead intake are calculated using Equation (4) and the carcinogenic risk values associated with the ingestion of Pb through consumption of *Oreochromis niloticus* was estimated to be 5.81×10^{-6} mg/kg/day, 4.08×10^{-8} mg/kg/day, 1.05×10^{-6} mg/kg/day and 1.31×10^{-7} mg/kg/day in liver, gills, bones and muscle respectively. According to the U.S. EPA (1989) the acceptable risk levels for carcinogenic risks range from 10^{-4} to 10^{-6}; which means that when the level of carcinogenic health effects is at 10^{-6} for individual toxic metals, it will result in relatively negligible cancer risks (USEPA 2010). The results of the present study revealed that the potential carcinogenic risks are still within the acceptable risk levels for carcinogenic risks range introduced by (U.S. EPA 1989).

5.0 CONCLUSION

The main reasons in developing this present health assessments, intends to get a preliminary data which would represent local conditions while assessing the inherent health risk to human from consuming locally caught fishes.

Most THQ values for evaluated fish parts are below 1, which means the intake of minerals by consuming these fish parts is not likely to cause any appreciable health risks on the human body (Adult and Child). While, in case of Cu the calculated values of THQ for all fish parts exceed the limit of 1 in all fish parts of both the child and adult. Also Lead (Pb) THQ value in the muscle exceed the limit of 1 indicating high risk of adverse health effects from consumption of fish by a Child. Considering the findings from this study, further research should be carried out on the assessment of reliability of fish fins as a non – destructible bio monitoring organs of metal pollution.

REFERENCES

Achide, S.A., and Asheshi, O.O. (2017). Bioaccumulation of Heavy Metals on Some Organs of Oreochromis Niloticus (Nile Tilapia Fish). International Journal of Applied Science and Mathematical Theory. ISSN 2489-009X, 3(1):31-37.

Agemian, H, Sturtevant, D., and Austen, K. (1980). Simultaneous acid extractions of six trace metals from fish tissue by hot-block digestion and determination by atomic-absorption spectrometry, Analyst, 105: 125-130.

Agusa, T., Kunito, T., Yasunaga, G., Iwata, H., Subramanian, A., Ismail, A., and Tanabe, S. (2005). Concentrations of trace elements in marine fish and its risk assessment in Malaysia, Marine Pollution Bulletin, 51: 896-911.

Aletor, V.A. and Omodara, O.A. (1994). Studies on some leguminous browse plants, with particular reference to their proximate, mineral and some endogenous anti-nutritional constituents. Anim. Feed Sci. Technol. 46: 343-348.

Batra, J. and Seth, P.K. (2002). Effect of iron deficiency on developing rat brain. Indian J. Clin. Biochem. 17(2): 108-114.

EC (2004). Assessment of the dietary exposure to arsenic, cadmium, lead and mercury of the population of the EU member states. (Reports on Tasks for Scientific Cooperation).European Commission.

Ejaz ul Islam, Yang, X.E., He, Z.L. and Mahmood, Q. (2007). Assessing potential dietary toxicity of heavy metals in selected vegetables and crops. J. Zhejiang Univ. Sci, 8: 1 -13.

Eruvbetine, D. (2003). Canine Nutrition and Health. A paper presented at the seminar organized by Kensington Pharmaceuticals Nig. Ltd., Lagos on August 21, 2003.

Greene, R and Crecelius, E. (2006). Total and inorganic arsenic in Mid-Atlantic marine fish and shellfish and implications for fish Advisories. Integ. Environ. Asses. Manage. *2*: 344–354.

Han, B.C., Jeng, W.L., Hung, T.C. and Jeng, M.S. (1994). Copper intake and health threat by consuming seafood from copper-contaminated coastal environments in Taiwan. *Environmental Toxicology and Chemistry*, **13:** 775-780.

Lushenko, M.A. (2010). A risk assessment for ingestion of toxic chemicals in fish from Imperial beach California. MSc Thesis, Faculty of San Diego State University.

Malhotra, V.K. (1998). Biochemistry for Students. Tenth Edition. Jaypee Brothers Medical Publishers (P) Ltd, New Delhi, India.

Mallin, M., McIver, M., Fulton, M. and Wirth, E. (2011). Elevated levels of metals and organic pollutants in fish and clams in the Cape Fear River watershed. *Arch Environ Contam Toxicol*, **61:** 461- 471.

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. *European Journal of Scientific Research*, **30:** 348-360.

Murray, R.K., Granner, D.K., Mayes, P.A., and Rodwell, V.W. (2000). Harper's Biochemistry, 25th Edition, McGraw-Hill, Health Profession Division, USA.

OEHHA (2011). Adoption of the revised air toxics hot spots program technical support document for cancer potency factors.

OhioEPA (2008). Ecological risk assessment guidance document. Lazarus Government Center, 50 West Town St., Suite 700, Columbus: Division of Environmental Response and Revitalization.

Onsanit, S., Chen, M., Ke, C., and Wang, W.X., (2012). Mercury and stable isotope signatures in caged marine fish and fish feeds. J. Hazard. Mater. 203–204, 13 – 21.

Onsanit, S., Ke, C., Wang, X., Wang, K.J., and Wang, W.X. (2010). Trace elements in two marine fish cultured in fish cages in Fujian province, China, Environmental Pollution, 158: 1334 - 1342.

Ozcan, M. (2003). Mineral Contents of some Plants used as condiments in Turkey. Food Chemistry 84: 437- 440.

Paquin, R.R., Farley, K., Santore, R.C., Kavvadas, C.D., Mooney, K.G., and Winfield, R.P. (2003). Metals in aquatic systems: A review of exposure, bioaccumulation, and toxicity models. Society of Environmental Toxicology and Chemistry (SETAC), Pensacola.

Rai, P.K. (2008). Heavy metal pollution in aquatic ecosystems and its phytoremediation using wetland plants: an ecosustainable approach. Int. J. Phytoremediation 10: 133 - 160.

Storelli, M.M. (2008). Potential human health risks from metals (Hg, Cd and Pb) and polychlorinated biphenyls (PCBs) via seafood consumption: Estimation of target hazard quotients (THQs) and toxic equivalents (TEQs). *Food and Chemical Toxicology*, **46:** 2782-2788.

Svensson, B.G., Nilsson, A., Jonsson, E., Schütz, A., Akesson, B. and Hagmar, L. (1995). Fish consumption and exposure to persistent organochlorine compounds, mercury, selenium and methylamines among Swedish fishermen. *Scandinavian Journal of Work, Environment & Health*, **21:** 96-105.

Tu, N.P.C., Ha, N.N., Ikemoto, T., Tuyen, B.C., Tanabe, S. and Takeuchi, I. (2008). Regional variations in trace element concentrations in tissues of black tiger shrimp *Penaeus monodon* (*Decapoda: Penaeidae*) from South Vietnam. *Marine Pollution Bulletin*, **57:** 858-866.

USEPA, US Environmental Protection Agency (1989). Risk Assessment Guidance for Superfund. Vol. I. Human Health Evaluation Manual (Part A), Interim Final. EPA 540/1–89/002United States Environmental Protection Agency, Washington, DC.

USEPA, US Environmental Protection Agency (2000). *Guidance for assessing chemical contaminant data for use in fish advisories. Vol. II. Risk assessment and fish consumption limits*. 3rd ed. Washington DC: USEPA. EPA 823-B-00-008.

USEPA, US Environmental Protection Agency. (2000). Guidance for Assessing Chemical Contamination Data for Use in Fish Advisories. Vol. II. Risk Assessment and Fish Consumption Limits EPA/823-B94-004 United States Environmental Protection Agency, Washington, DC.

USEPA, US Environmental Protection Agency (2008). *Provisional Peer Reviewed Toxicity Values (PPRTV) for Iron and Compounds (CASRN 7439-89-6)*. Derivation of Chronic and Subchronic Oral RfDs. Superfund Health Risk Technical Support Center, National Center for Environmental Assessment, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, OH. April 1.

USEPA, US Environmental Protection Agency (2010). A Guide to Health Risk Assessment, California Environmental Protection Agency. Office of Environmental Health Hazard Assessment. http://www.oehha.ca.gov

USEPA, US Environmental Protection Agency (2011). USEPA regional screening level (RSL) summary table. Washington, DC.

USEPA, US Environmental Protection Agency (2012). Waste and cleanup risk assessment.

Vieira, C., Morais, S., Ramos, S., Delerue-Matos, C., and Oliveira, M. (2011). Mercury, cadmium, lead and arsenic levels in three pelagic fish species from the Atlantic Ocean: intra-and inter-specific variability and human health risks for consumption, Food and Chemical Toxicology, 49: 923-932.

Wang, Y., Chen, P., Cui, R., Si, W., Zhang, Y., and Ji, W. (2010). Heavy metal concentrations in water, sediment, and tissues of two fish species (Triplohysapappenheimi,Gobiohwanghensis) from the Lanzhou section of the Yellow River, China. Environ. Monit. Assess. 165: 97-102.

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 Research*, **32:** 3331-3340.