Available online at www.pelagiaresearchlibrary.com

Pelagia Research Library

Advances in Applied Science Research, 2013, 4(2):181-189

ISSN: 0976-8610
CODEN (USA): AASRFC

Emergent pollution bio-monitoring triad (target species-tissues-analyte) for the aquatic environment of Chad lake

[1]Peter A. Gwaski, [2]Stephen S. Hati, [1]Naomi P. Ndahi and [1]Victor O. Ogugbuaja

[1]Department of Chemistry, University of Maiduguri, Maiduguri Nigeria
[2]Analytics Division, Stat-Data Pro+, Abuja Nigeria

ABSTRACT

This study attempted to develop a decisive tool for pollution bio-monitoring triad (target specie-tissue-analyte) at the Lake Chad region of Nigeria. Six prominent commercial food fish species (Polypterus ansorgii, Clarias anguillaris, Oreochromis niloticus, Synodontis nigrita, Bagrus docmac, Lates niloticus) were collected and tissues (Gills, Kidney, Liver, Lung and Muscle) harvested and prepared for metals (Cd, Cr, Cu, Fe, Mn, Ni, Pb, and Zn) analysis according to standard procedures. Metal determination was conducted by standard methods of flame atomic absorption spectrometry. Clarias anguillaris for Cd, Pb and Zn bio-monitoring was indicated, Oreochromis niloticus for Cu, Mn and Ni monitoring while Synodotis nigrita and Polypterus ansorgii were indicated for Cr and Fe respectively. However, Lates niloticus and Bagrus docmac indicated concern for tissue accumulation of metals, but did not show favourably high collective accumulation of any metal. On the question of target tissue, it was clearly indicated that the muscle tissue is a good candidate for Zn, Pb, Ni and Cu monitoring. The gill tissue revealed monitoring capacity for Mn, Fe and Cr, while liver tissue for Cd. The result of study suggested a high level of reliability on the use of Clarias anguillaris and Oreochromis niloticus as target species and confirmed the use of key tissues such as the muscle, gills and liver as pollution monitors of heavy metals. However, it is strongly suggested that further monitoring studies should be carried out with these species and tissues, at a different period to enable the calibration of the results of this study.

Key words: Target fish species, tissues, metal analyte, aquatic bio-monitoring

---

INTRODUCTION

Toxic contaminants enter surface waters through several anthropogenic activities, and may concentrate through aquatic food chains and accumulate in fish tissues. The bioaccumulation of these contaminants may rise to more than one million times the concentrations determined in the water column [1-2]. Therefore fish tissue monitoring serves as an important indicator of contamination in an aquatic environment; indicating sediments and water quality problems. Tissue contaminant monitoring enables regulatory agencies to detect levels of contamination in fish tissue that may be detrimental to human consumers. It is also useful in the management program of the aquatic environment from which the fish species are sampled [3-4].

However, on a broader note, the target species, tissue and analyte are a significant triad factors to be considered when embarking on aquatic pollution bio-monitoring program [5].

Heavy metals are typical contaminants studied in fish tissues for monitoring purposes world over [1, 6-9]. This study focuses on the Lake Chad region of Nigeria, a significant agricultural resource [10-11] in Nigeria. It is aimed at presenting not only the risk associated with the consumption of the commercial food fish analysed but to present a decisive monitoring tool for this aquatic environment. This was achieved by concisely outlining target specie-tissue-analyte triad for pollution monitoring purposes in this region.

MATERIALS AND METHODS

Lake Chad is located at the southern border of the Sahara desert, eastern expanse of the Sahel, 12:20-14:20N, 13:00-15:20E; 280m above sea level [10]. Six prominent commercial food fish species (*Polypterus ansorgii, Clarias anguillaris, Oreochromis niloticus, Synodontis nigrita, Bagrus docmac, Lates niloticus*) were collected from the Kwatan Dawashe portion of the Lake Chad region. Random composite sampling technique was used without discrepancies for sexes in species. Fishes were caught using gill nets and collected in a well labelled polytetrafluoroethylene (PTFE, Teflon) bags and transported to the laboratory. Sampling took place on a monthly basis for a period of 12 months (January–December, 2011). Tissue collection, dissection and harvest followed standard produce in FAO technical paper [12]. The fish species were identified by an expert at the Federal College of Freshwater Fish Technology, Baga Nigeria. A total of 216 samples were collected over the period of study. Gills, Kidney, Liver, Lung and Muscle tissues were analysed for heavy metals (Cd, Cr, Cu, Fe, Mn, Ni, Pb, and Zn). Tissues were prepared according to standard methods [13-14]. This consisted of weighing, drying of each separate tissues (10.0 g); dried at 105°C to constant weight, ashed at 550°C for 4 h in a muffle furnace, pulverized and digested with concentrated nitric acid and hydrogen peroxide (1:1 v/v). The clear solutions produced following filtration through Whatmann 541 filter paper were then subjected to the standard method of flame atomic absorption spectrophotometry (FAAS) determination of the heavy metals [15]. The Shimadzu atomic absorption spectrometer, AA-6800 operational with an ASC-6100 auto sampler and air-acetylene atomization gas mixture system was used for the analyses. Replicate determination was made and the results presented on a dry weight basis in micro gram per gram (mg/kg). Data analysis was performed using Analyse-it v2.26 statistical software for Microsoft Excel. Statistical significance was considered at 95% confidence interval, $P<0.05$.

RESULTS

Cadmium (Cd)

Figure 1 revealed that the highest concentration of Cd was recorded in the liver (0.40±0.02 mg/kg) of *Oreochromis niloticus.* Cd recorded the highest concentrations in the gills (0.08±0.00 mg/kg) of *Bagrus docmac*, kidney (0.05±0.01 mg/kg) of *Polypterus ansorgii* and lung (0.31±0.01 mg/kg) *Clarias anguillaris.* Generally, the results indicate that while the liver tissue accumulated more Cd than other tissues, *Clarias anguillaris* accumulated more Cd than other fish species. ANOVA results revealed that with the exception of *Clarias anguillaris v Bagrus docmac* and *Synodontis nigrita v Lates niloticus,* all other comparison for difference in Cd concentration in liver were significant.

Chromium (Cr)

Figure 2 revealed that the highest concentration of Cr (2.0±0.2 mg/kg) was recorded in the gills of *Synodontis nigrita.* Cr recorded the highest concentrations in the kidney, liver and lung of *Polypterus ansorgii*, (0.71±0.04, 0.92±0.05 and 0.84±0.06 mg/kg) respectively, again highest in the muscle of *Synodontis nigrita* (1.02±0.1 mg/kg). In general, the results indicated that while gills accumulate more Cr than other tissues, *Synodontis nigrita* accumulated more Cr than other species of fishes. ANOVA results revealed that with the exception of *Clarias anguillaris v Lates niloticus,* all other comparison for difference in Cr concentration in gills were significant.

Copper (Cu)

Figure 3 shows that Cu concentration was highest in the muscle (4.20±0.4 mg/kg) of *Oreochromis niloticus.* Cu also recorded the highest concentrations in the kidney and lung of this same species (0.59±0.05 and 0.60±0.02 mg/kg) respectively, but highest in the gills and liver of *Clarias anguillaris* (0.50±0.02 and 0.70±0.05 respectively mg/kg). On the whole, the results suggest that Cu accumulated more in muscles than other tissues, while *Oreochromis niloticus* accumulates more Cu than other fish species. ANOVA results show that all paired comparison of Cu concentration in muscle tissue was significant.

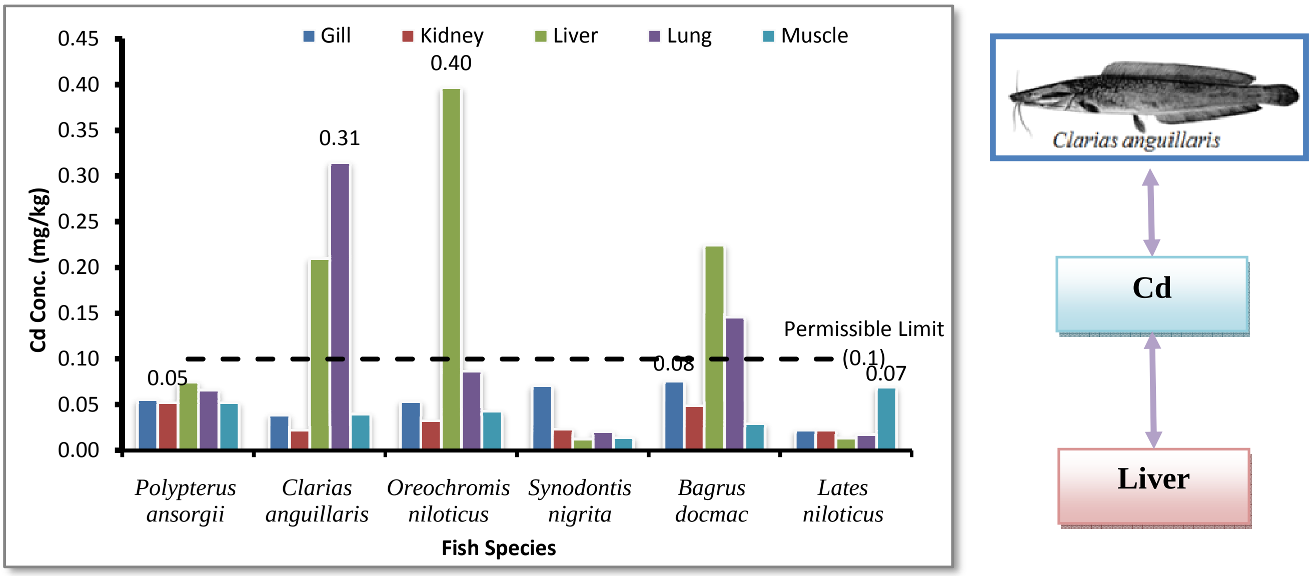

Figure 1: Cd in Tissues of Fish Species with outline of bio-monitoring triad

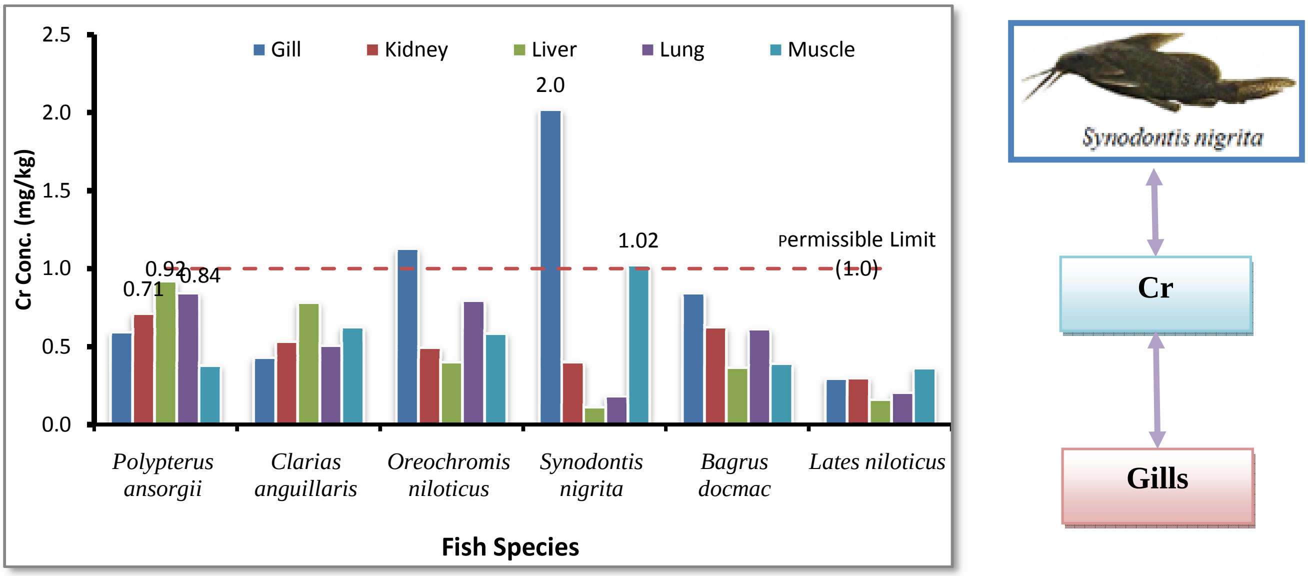

Figure 2: Cr in Tissues of Fish Species with outline of bio-monitoring triad

Iron (Fe)

Figure 4 revealed that the highest concentration of Fe was recorded in the gills (5.0±0.2 mg/kg) of *Synodontis nigrita*. Fe also recorded the highest concentrations in the kidney, liver and lung of *Polypterus ansorgii*, (2.0±0.1, 3.5±0.4 and 3.2±0.4 mg/kg respectively), but highest in the muscle of *Clarias anguillaris* (1.4±0.2 mg/kg). Generally, the results suggest that while gills accumulated more Fe than other tissues, *Polypterus ansorgii* accumulated more Fe than other fish species. ANOVA results revealed that with the exception of *Clarias anguillaris v Lates niloticus*, all other comparison for difference in Fe concentration in gills were significant.

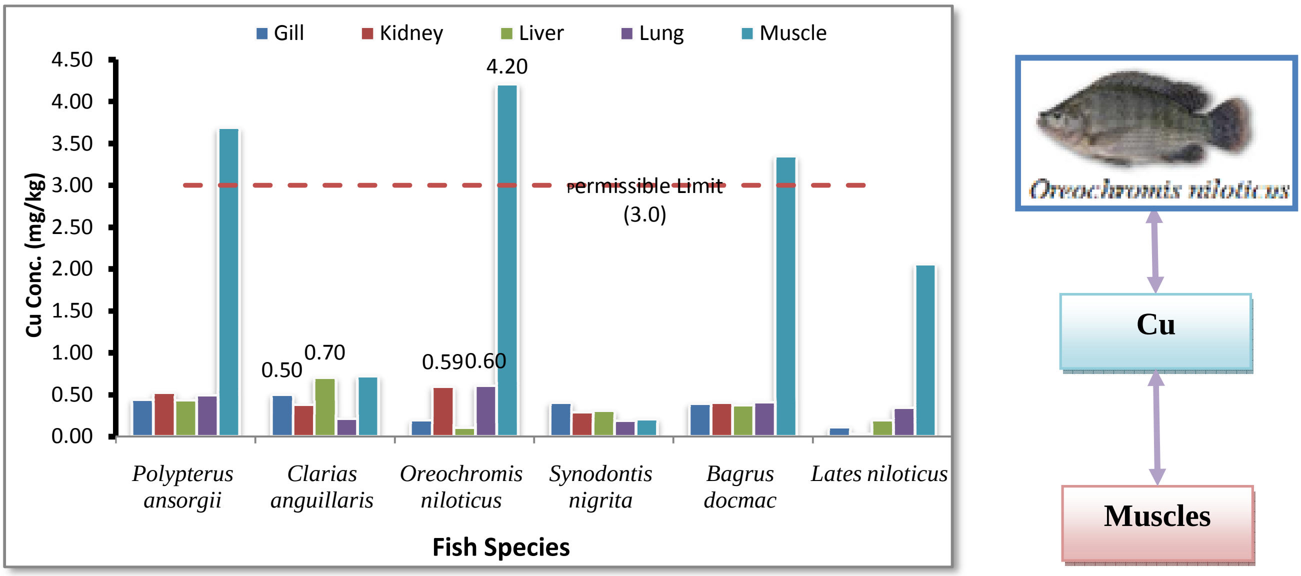

Figure 3: Cu in Tissues of Fish Species with outline of bio-monitoring triad

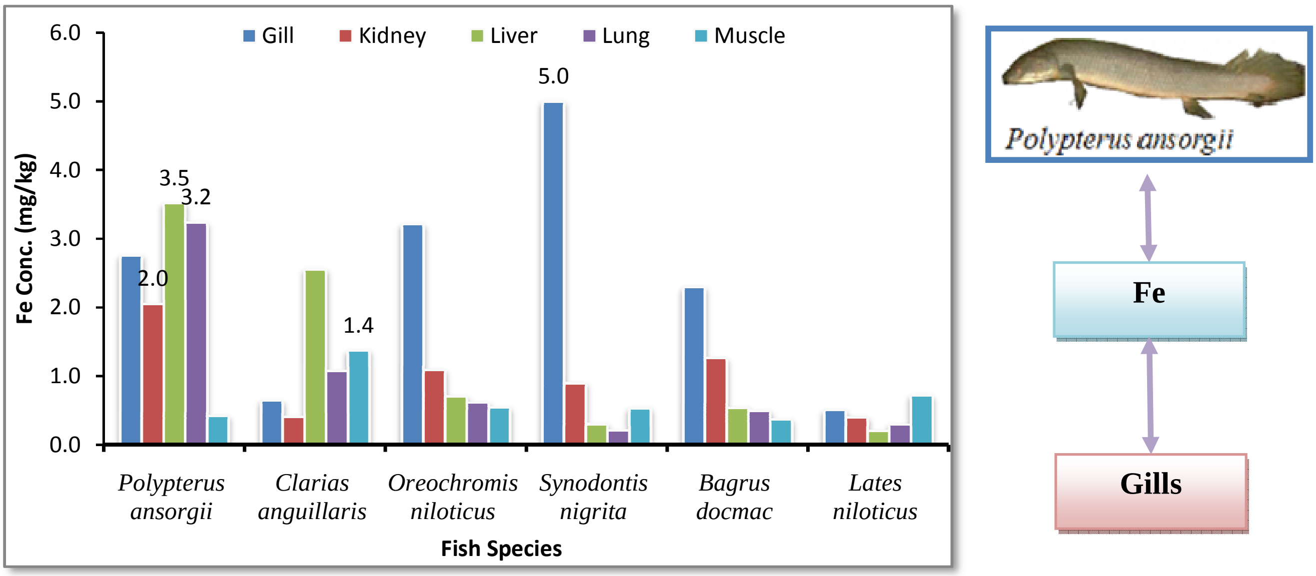

Figure 4: Fe in Tissues of Fish Species with outline of bio-monitoring triad

Manganese (Mn)
Figure 5 shows that the highest concentration of Mn was recorded in the gills (0.87±0.05 mg/kg) of *Polypterus ansorgii*. Mn recorded the highest concentrations in the kidney, lung and muscle of *Oreochromis niloticus*, (0.69±0.02, 0.80±0.05 and 0.69±0.02 mg/kg respectively), but highest in the liver of *Bagrus docmac* (0.76±0.05 mg/kg). On the whole, the results indicated that while gill tissue accumulated more Mn than other tissues, *Oreochromis niloticus* accumulated more Mn than other fish species. ANOVA results revealed that with the exception of *Oreochromis niloticus v Bagrus docmac*, all other comparison for difference in Mn concentration in gills were significant.

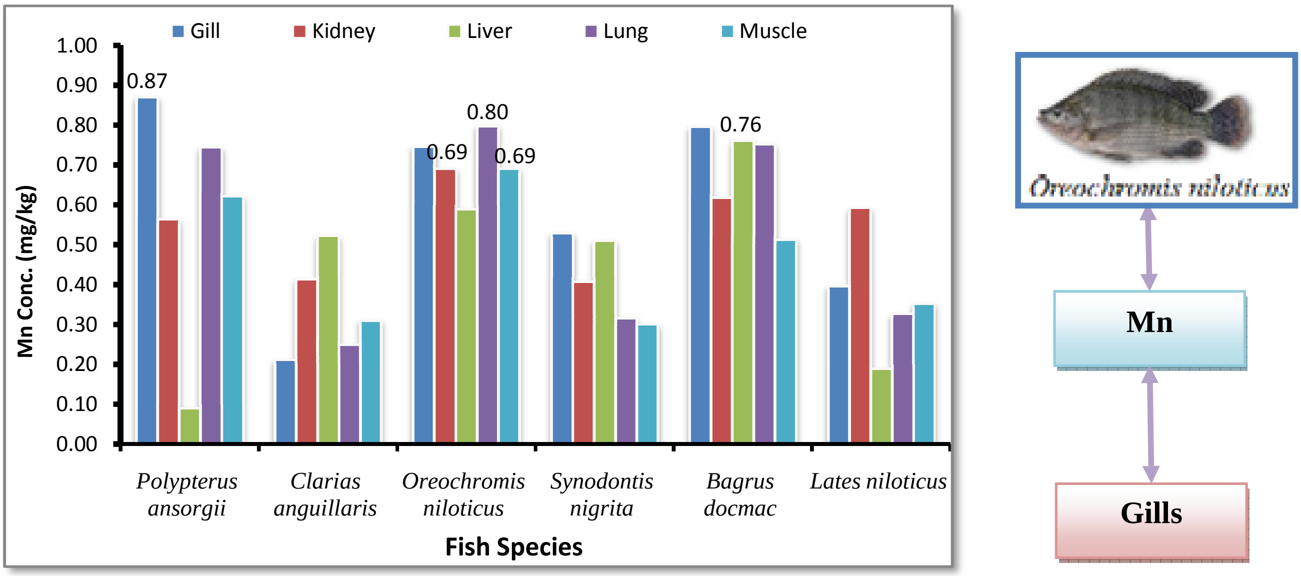

Figure 5: Mn in Tissues of Fish Species with outline of bio-monitoring triad

Nickel (Ni)
Figure 6 revealed that the highest concentration of Ni was recorded in the muscle (0.79±0.03 mg/kg) of *Oreochromis niloticus*, as well as in the liver (0.40±0.01 mg/kg) and lung (0.52±0.04 mg/kg). Ni recorded the highest concentrations in the kidney (0.36±0.05 mg/kg) of *Clarias anguillaris*, but highest in the gills (0.31±0.01 mg/kg) of *Synodontis nigrita*. Generally, the results indicate that while muscle tissue accumulated more Ni than other tissues, *Oreochromis niloticus* accumulates more Ni than other fish species. ANOVA results revealed that with the exception of *Polypterus ansorgii v Bagrus docmac* and *Synodontis nigrita v Lates niloticus* all other comparison for difference in Ni concentration in muscle was significant.

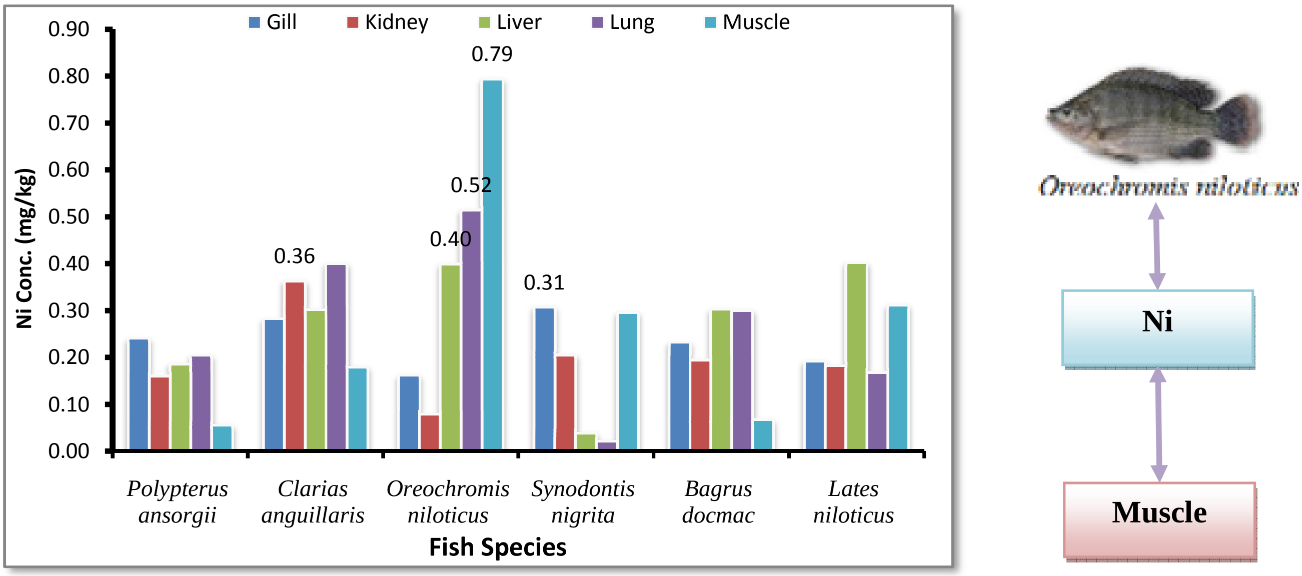

Figure 6: Ni in Tissues of Fish Species with outline of bio-monitoring triad

Lead (Pb)
Figure 7 shows that the highest concentration of Pb was recorded in the muscles (0.59±0.2 mg/kg) of *Lates niloticus*. Pb concentrations were highest in both gills (0.17±0.04 mg/kg) and kidney (0.09±0.00 mg/kg) of *Bagrus docmac*.

Similarly, Pb was highest in both liver (0.21±0.02 mg/kg) and lungs (0.17±0.04 mg/kg) of *Clarias anguillaris*. In general, the results suggest that while muscle accumulated more Pb than other tissues, *Oreochromis niloticus* accumulated more Pb than other fish species. ANOVA results showed that about 70% of all comparison for difference in Pb concentration in muscle was significant.

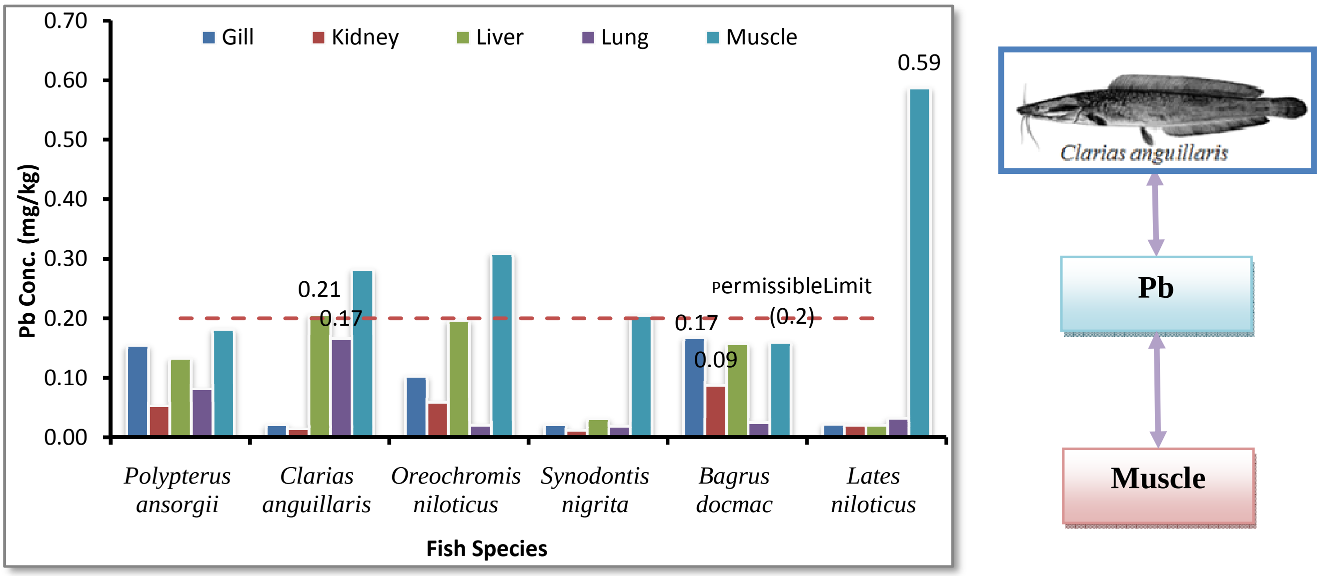

Figure 7: Pb in Tissues of Fish Species with outline of bio-monitoring triad

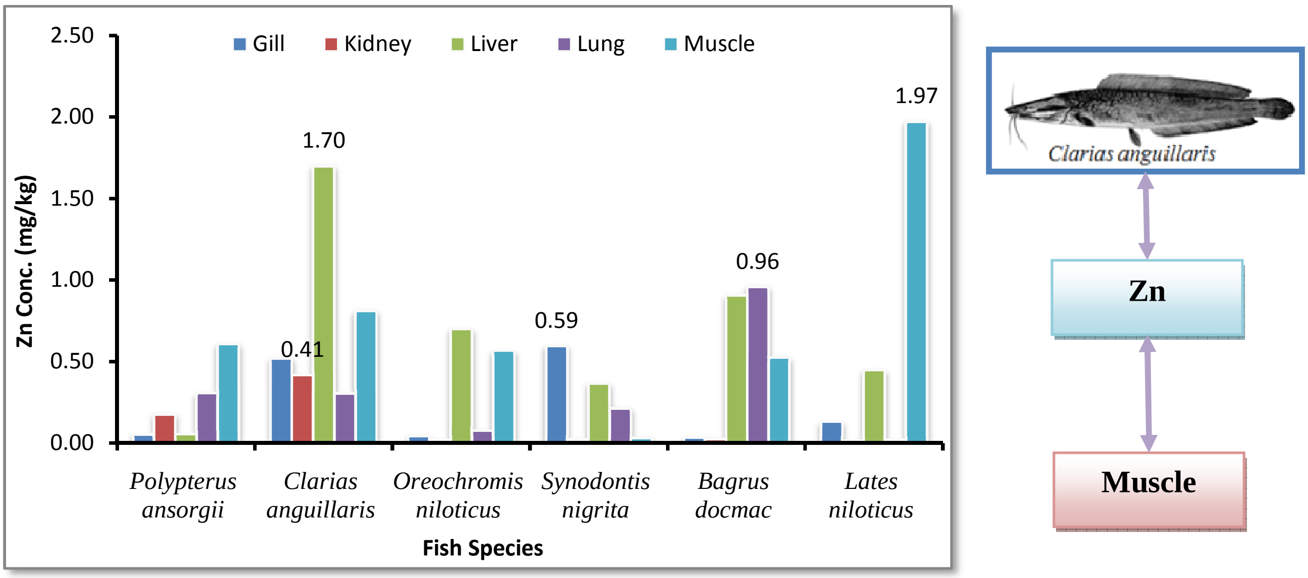

Figure 8: Zn in Tissues of Fish Species with outline of bio-monitoring triad

Zinc (Zn)

Figure 8 revealed that the highest concentration of Zn was recorded in the muscles (1.97±0.2 mg/kg) of *Lates niloticus*. Zn recorded the highest concentrations in the kidney and liver of *Clarias anguillaris* (0.41±0.03 and 1.70±0.01 mg/kg) respectively, but highest in the gills (0.59±0.02 mg/kg) of *Synodontis nigrita* and lung (0.96±0.05 mg/kg) of *Bagrus docmac*. Generally, the results suggest that while muscle tissue accumulated more Zn than other tissues, *Clarias anguillaris* accumulated more Zn than other fish species. ANOVA results revealed that with the exception of *Polypterus ansorgii v Oreochromis niloticus, Polypterus ansorgii v Bagrus docmac* and *Oreochromis niloticus v Bagrus docmac,* all other comparison for difference in Zn concentration in muscle were significant.

DISCUSSION

In establishing the pollution bio-monitoring triad for the study area of Lake Chad, an adjacent outline of target species and tissue in relation to the summary result of each metal is presented in this study. At a glance, the frequencies of occurrence of *Clarias anguillaris* for Cd, Pb and Zn monitoring were indicated. Similarly *Oreochromis niloticus* for Cu, Mn and Ni, while *Synodotis nigrita and Polypterus ansorgii* were indicated for Cr and Fe respectively. However, *Lates niloticus* and *Bagrus docmac* indicated concern for certain tissue accumulation of metals, but did not show favourably high collective accumulation of any metal.

On the question of target tissue, it was clearly indicated that muscle tissue is a good candidate for Zn, Pb, Ni and Cu monitoring. The gill tissue showed monitoring capacity for Mn, Fe and Cr, while liver tissue indicated Cd.

However, it is significant to note that although the results of this study shows significant variability in the accumulation of metals in the different tissues of fish species, which is principally dependent on the bioavailable metal concentrations in the abiotic components of their habitats [16-17]. It indicated that the generally high and broad concentration variations of Fe are very likely associated with the forms of agricultural practices, domestic waste load and the atypical Saharan dust loaded with this metals that are released into the Lake Chad [18]. However, reports [17, 19] have established that metal levels in fish typically follow the order: Fe > Zn > Pb > Cu > Cd > Hg. One reason for this is may have been drawn from the order of natural abundance of these metals. But strict conformity to this order are not usually observed from most studies, as observed from the order of this study, (Fe > Cu > Cr > Mn > Zn > Ni> Pb> Cd) and other studies [20-21].

Other factors responsible for variability in the accumulation of metals in the tissues of fish species include their feeding patterns or habits, ecological needs, metabolism, age and size of the fish [16, 20, 22]. Also the rates of uptake, storage and elimination [23-24], implying that metals which have high uptake and low elimination rates in the tissues of fish are expected to be accumulated to higher levels. According to studies [23, 25-26], the accumulation of non-essential metals may take place at very low environmental concentration since fish are not able to regulate their level by the physiological mechanisms in most organisms. For instance Cd and Pb have no known role in biological systems, whereas Cu and Zn are essential elements of enzymes or metalloproteins in fish metabolism [27-28].

It is well-known that the accumulation of metals in fish tissue is also dependent on the chemical nature of the metal. Attendant with this is the ionic strength and pH [29] of the aquatic environment. For instance acidic conditions provide for sufficient hydrogen ions to occupy many of the negatively charged surfaces, thus few spaces are left to bind heavy metals, hence the soluble phase contain more heavy metals. The soluble form of heavy metals is considered to be more harmful because it is more easily transported and accessible to aquatic organism [30]. Water hardness and salinity reduces uptake and accumulation of metals by the fish [19]. Temperature [31] as well as the presence of other metals has also been reported to influence accumulation of metals in fish. For instance the enrichment of water with calcium reduced copper accumulation in the gills [32] and gill damage reduced in the presence of Ni [33].

The result of this study indicated that a number of metals were beyond the permissible limits [34-35]. Such as Cd in liver and lung tissues of *Clarias anguillaris, Oreochromis niloticus* and *Bagrus docmac*, Cu concentrations recorded in the muscles of *Polypterus ansorgii*, *Oreochromis niloticus and Bagrus docmac and* Cr concentrations in the gill tissues of *Lates niloticus* and *Synodontis nigrita*. However, the accumulation of metals in liver, lung and gills of food fish do not directly affect human health because these are not edible parts, but predatory animals such as birds who consume the whole fish are at risk of excess metal contamination [36].

This study revealed that high metal accumulation in certain tissue of a particular species does not necessarily reflect on the cumulative potential hazard of the fish species. For instance Pb concentration in the muscle of *Lates niloticus* was more than twice the permissible limits, but *Clarias anguillaris* indicated the highest cumulative concentration of Pb. This occurrence of excessive levels is considered as potential hazards that can cause danger to both animal and human health [27-28].

In this study *Clarias anguillaris* and *Oreochromis niloticus* indicated proficiencies for bio-monitoring purpose, which may also be attributed to their feeding characteristics as metals interaction increases with bottom feeding fish rather than surface water fish species [37-38].

Muscle tissues indicated higher accumulation of most metals in this study. This is contrary to other studies [33, 36, 39-40] where muscles accumulation was least, but corresponds to other findings [30-41]. The concern for muscle tissue analysis is because they usually consist of the edible part of fish foods.

This study corroborates the assertions that gills are the main position of entry for the dissolved metals as a result they represent the target for the toxic action of metals [27]. However, the diversity of cell-types of the gills (chloride cells, mucus cell, pillar cells and undifferentiated cells) makes it complex to interpret the possible mechanisms of metal accumulation [42]. High metal accumulation in the gills may also be due to complexing of the elements with mucus left over between the lamella of gill tissue, which is difficult to remove entirely from the gills during preparation for analysis [43].

Liver tissue in this study showed considerable accumulation of Cd. It is reported to be a good water pollution monitor because their concentrations accumulated in this tissue are often comparative to those present in the environment. This is particularly true for copper and cadmium. Metal accumulation in the liver speedily increases during exposure, and remain high for a long time of cleansing, when other tissue are already cleared. Metals are stored in liver from producing metallothioneins, by metal detoxification mechanism in the body [16].

CONCLUSION

The study was conducted to establish a possibility of developing pollution bio-monitoring tool for the aquatic environment of the Lake Chad region of Nigeria. The result of study suggested a high level of reliability on the use of *Clarias anguillaris* and *Oreochromis niloticus* as target species. The study also confirmed the use of key tissues such as the muscle, gills and liver as pollution monitors of heavy metals. However, it is strongly suggested that further monitoring studies are carried with these species and tissues, at a different period to enable the calibration of the results of this study.

Acknowledgements
The authors are grateful to the staff of Federal College of Freshwater Fish Technology, Baga Nigeria and the staff of National Food Drug Administration and Control for their support in fish species identification, sampling and laboratory analysis.

REFERENCES

[1] EPA (U.S. Environmental Protection Agency), *Volume I, EPA-823/R-92-008a*, **1992.**
[2] EPA (U.S. Environmental Protection Agency), *Volume II, EPA-823/R-92-008b*, **1992.**
[3] Cunningham PA, Sullivan E, *NLFWA Questionnaire June*, **1999**.
[4] Cunningham PA, Whitaker CO, *NPDES and Nonpoint Source Monitoring Programs*, **1989.**
[5] EPA (U.S. Environmental Protection Agency), *Volume I, 3rd edition, EPA-823-B-00-007*, **1992.**
[6] Norrgren L, Petterson U, Orn S, Bergqvist *PA, Arc.Environ. Cont. Toxicol.*, **2000**, 38, 334-341.
[7] Bervoets L, Blust R, *Environmental Pollution*, **2003,** 126, 9-19.
[8] Begum A, Amin MN, Kaneco S, Onta, K, *Food Chemistry*, **2005,** 93, 439-443.
[9] Agarwal R, Kumar R, Behari JR, *Bulletin of Environmental Contamination and Toxicology*, **2007,** 78, 108-112.
[10] ILEC: International Lake Environment Committee, **2012**, http://www.ilec.or.jp/database/afr/
[11] Keith JO, Plowes DCH, *USAID Technical Paper* 47, **1997**.
[12] Dybern B, *FAO, Fisher. Tech*, **1983,** 212, 1-13.
[13] Daziel J, Baker C, *FAO Fish Tech.* **1983**, 212, 14-21.
[14] Vogel AI, *Vogel's Textbook of Quantitative Chemical Analysis,* (6th Edn), Pearson Edu Ltd, India, **2000**, pp 104-607.
[15] SC (Shimadzu Corporation), *Atomic Absorption Spectrometry Cookbook*, G10, **2000**, 1-32.
[16] Peakall D, Burger J, *Ecotoxicology and Environmental Safety*, **2003,** 56, 110-121.
[17] Marcovecchio JE, *Science of the Total Environment* **2004**, 323, 219-226.
[18] Hati SS, Dimari GA, Waziri M, Pindiga YN, *Terrestr Aquat Environ Toxico*, **2008**, 2, 30-33.

[19] Barbara J, Malgorzata W, *Soil and Water Pollution Monitoring, Protection and Remediation*, **2006**, 3–23.
[20] Bhupander K, Mukherjee DP, Sanjay K, Meenu M, Prakash D, Singh SK, Sharma CS, *Annals of Biological Research*, **2011**, 2, 125-134.
[21] Ambedkar G, Muniyan M, Advances in Applied Science Research, **2011**, 5, 221-225.
[22] Ishaq S. Eneji R, Sha'Ato, Annune PA, *Pak J Anal Environ Chem*, **2011**, 12, 25-31
[23] Heath AG, *Water pollution and fish physiology*, CRC Press, Florida USA, **1987**, pp 245.
[24] Langston WJ, *Toxic effects of metals and the incidence of marine ecosystem*, In: heavy metals in the Marine Environment (eds Plmess RW, Rainbow PS), CAC press, New York, **1990**, pp 256.
[25] Larsson A, Haux C, Spbeck M, *Ecotox. Environ. Saf.* **1985**, 9: 250-281.
[26] Mustafa K, Canli M, *Turk G Zool*, **2000**, 24, 429-436.
[27] Olsson PE, Kling P, Hogstrand C, *Mechanisms of heavy metal accumulation and toxicity in fish*, In: Langston WJ., Bebianno, M.J. (Eds.), Metal metabolism in Aquatic Environments, Chapman and Hall, London, **1998**, pp 321-350.
[28] Wright DA, Welbourn P, *Environmental Toxicology*, Cambridge press, Cambridge, **2002**
[29] Cogun HY, Kargin F, *Chemosphere*, **2004**, 55, 277–282.
[30] ATSDR, *Interaction profile for: Arsenic, cadmium, chromium, and lead*, US Department of Health and Human Services Public Health Service, Atlanta Georgia, **2004**, pp 103-155.
[31] Yang HN, Chen HC, *Bull Environ Contam Toxicol* **1996,** 56, 670–676.
[32] Playle RC, Gensemer RW, Dixon DG, *Environm Toxicol Chem*, **1992,** 11, 381–391.
[33] Senthamilselvan D, Chezhian A, Kabilan N, Sureshkumar T, *European Journal of Experimental Biology*, **2011**, 2, 198-205
[34] FAO, Food and Agriculture Organization, *FAO fishery circular*, **1983,** 464, 5-100.
[35] WHO, World Health Organization, *Environmental Health Criteria*, Geneva Switzerland, **1989,** 85, 22-34.
[36] Indrajith HAP, Pathiratne KAS, Pathiratne A, *Sri Lanka J. Aquat Sci*, **2008**, 13: 63-81.
[37] Coughtrey PJ, Thorne MC, *Rotterdam*, **1983**, 2, 191-217.
[38] Kersten M, Forstner U, *Cadmium in the Aquatic Environment*, Wiley, New York, **1987**, pp 51-88.
[39] Nwani CD, Nwachi DA, Okogwu OI, Ude EF, Odoh GE, *Journal of Environmental Biology*, **2010**, 31, 595-601.
[40] Mathana P, Thiravia Raj S, Radha Krishnan Nair C, Selvamohan T, *Advances in Applied Science Research*, **2012**, 6, 3703-3707
[41] Tóth T, Jaroslav A, Juraj T, Marek S, Július Á, Radovan S, *J Micro Bio Food Sci*, **2012**, 1, 837-847.
[42] Al-Weher SM, *Jordan Journal of Biological Sciences*, **2008**, 1, 41 – 46.
[43] Alvarado NE, Quesada L, Hylland K, Marigomez L, Soto M, *Aqutic Toxicol*, **2006**, 77, 64-77.
[44] Demirak AF, Yilmaz AL, Ozdemir N, *Chemosphere* **2005**, doi;10.1016/j.chemosphere.**2005**.09.033