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Analysis of Heavy Metals Concentration and Its Impact on Hepatic Indexes in Clarias gariepinus from Ibi, Gidin-Dorowa, and Donga Rivers in Taraba State, Nigeria

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Abstract

Exposure to heavy metals, which are particularly detrimental to human health, has increased as a result of anthropogenic activities and modern industry. Increased levels of heavy metals in African catfish (*Clarias gariepinus*) can be a good sign that human activity has contaminated an aquatic ecosystem. The study aimed to evaluate the levels of heavy metals and their potential effects on hepatic indexes in *Clarias gariepinus* collected from three different rivers (Ibi, Donga, and Gindin Dorowa) in Taraba State, Nigeria. The fish samples were collected from the three different rivers during the dry season. The gills were removed from the fish and subjected to oven drying and grinding before being analyzed for heavy metal concentrations. Blood samples were also collected from the fish for liver biomarkers analysis. The heavy metal concentrations (specifically Pb, Cd, Zn, As, and Hg) were determined using Micro Plasma Atomic Emission Spectroscopy (MP-AES) and compared to the maximum levels specified by the World Health Organization (WHO). The results showed that zinc had the highest mean concentration in all three river samples. However, all heavy metal concentrations in the gills of the fish were found to be below the maximum allowed limits advised by standard bodies, indicating that the gills were safe for consumption. Also, the liver biomarker analysis showed higher levels of ALP, total bilirubin, and albumin activity in the fish from Gindin-Dorowa compared to Donga and Ibi. However, all liver biomarker values fell within the reference standards, indicating that the fish from the three rivers were free from heavy metal toxicity. In conclusion, the study suggests that the *Clarias gariepinus* samples from the three rivers in Taraba State, Nigeria, had concentrations of heavy metals within safe limits, as determined by the WHO. The liver biomarker analysis further supported the absence of heavy metal toxicity in the fish.

Keywords: Heavy Metals, Hepatic indexes, *Clarias gariepinus*, Rivers**,** Taraba State, Nigeria

INTRODUCTION

Human exposure to heavy metals has significantly increased over the course of several centuries due to the rates of hazardous material emission from various sectors. The most frequent heavy metals that cause human poisoning have been mercury, lead, chromium, cadmium, and arsenic. Poisonings that are either acute or chronic may accompany exposure to water, air, or food. These heavy metals bioaccumulate in the body and have a variety of harmful effects on various tissues and organs. The cellular processes of growth, proliferation, differentiation, damage repair, and apoptosis can all be impacted by heavy metals. Similar pathways for these metals to cause toxicity, including ROS production, weakened antioxidant defense, enzyme inactivation, and oxidative stress, are revealed by comparing the mechanisms of action. However, some of them bind to particular macromolecules in a selective manner. Within this framework, ferrochelatase and aminolevulinic acid dehydratase interact with lead. Genomic instability is a result of some hazardous metals, including chromium, cadmium, and arsenic. Trace metals that are heavy or poisonous are at least five times denser than water. They often don't degrade further into less dangerous components; instead, they build up in the areas where they are discharged (Kennicutt *et al.,* 1998). They are bioaccumulative and stable (cannot be digested by the body). On sometimes, they reach people higher up the food chain (Fergosson, 1990). While some metals are necessary for biota, they can be exceedingly dangerous when present in high concentrations. At a certain amount of exposure, heavy metals are non-biodegradable and extremely damaging to aquatic life, plants, and people's health (Mustafa *et al*., 2006). Some heavy metals, like copper or cobalt, are necessary for enzymatic function at low concentrations, but at greater quantities, they act as enzyme inhibitors. Other metals, like cadmium and lead, are poisonous even at low doses and serve no biological purpose (Bryan, 1976).

According to Kheradmand *et al.* (2006), heavy metals can be divided into three categories: possibly hazardous (arsenic, cadmium, lead, mercury, etc.); probably essential (nickel, vanadium, cobalt); and necessary (copper, zinc, iron, manganese). Because they inhabit diverse tropic levels and range in size and age, fish have been recognized as useful indicators of heavy metal contamination in aquatic systems (Burger *et al.,* 2002). One of the most important indicators for determining the amounts of metal pollution in freshwater systems is fish (Rashed, 2001). Additionally, fish consumption by humans is common in many regions of the world, and contaminated fish may be harmful to human health. Studies on heavy metals in rivers, lakes, fish, and sediments have received significant attention in the environmental field, particularly over the past ten years (Zmen *et al*., 2004; Begüm *et al*., 2005; Ztürk *et al.,* 2008; Praveena *et al.,* 2008). Approximately 70 well-known trace elements, including heavy metals, are needed by the human body. However, there are 12 hazardous heavy metals that operate as toxic interference with the body's enzyme systems and metabolism, including lead, mercury, aluminum, arsenic, cadmium, nickel, and chromium. The presence of metal contaminants in freshwater upsets the delicate balance of the aquatic ecosystem, making it imperative to regularly monitor the amounts of heavy metals in aquatic habitats.

MATERIALS AND METHODS

Sampling Locations

The study samples were collected in three separate places: **Ibi River, Donga River, and Gidin Dorowa River**

Sample Collection

During the dry season in February, this investigation was conducted. To assess the levels of lead, cadmium, chromium, zinc, and arsenic, samples of *Clarias gariepinus* were taken from the three Rivers.

Experimental procedure

From the Ibi, Donga, and Gidindorora Rivers, mature catfish samples weighing between 1-1.5 kg were collected. Gills were removed from fish samples using stainless steel dissection kits after the fish were slaughtered and brought to the lab. Prior to digestion and analysis, fish organ was oven-dried at 80^0C for 48 hours, ground separately in a porcelain mortar and pestle, packed in labeled plastic bags, and stored at -10^0C. Using the organic extraction technique described by (sreedivi *et al.*, 1992), fish organ was treated and digested. A 50ml kjedhal flask was filled with 1g of the milled sample. Nitric acid (10 ml), perochloric acid (2 ml), and sulfuric acid (2 ml) were added in a 5:1:1 ratio to the sample in the flask. The flask's contents were heated gently within a hood.

Ashing

Each organ sample weighed 2 grams and was placed in a platinum dish before being placed in a muffle furnace. The temperature was raised to roughly 55^0C for 4-5 hours, and once the sample had entirely turned to ash, it was removed and allowed to cool in a desiccator.

Digestion of Samples

25ml of digesting acid (Aqua regia HCl: HNO_3, 3:1) was applied to 2.00g of the ash-prepared samples (muscles) in a kjeldal flask. Allow to cool, then transfer the digest into a 100ml volumetric flask. Make up to mark with distilled water, and filter using Whatman No. 1 filter paper. Swirl and heat gently at first until frothing stops, then more forcefully until a clear light yellow solution results. After that, the filtrate was transferred to the AAS (Bulk Scientific, VPG 20, La Vegas, USA). For the measurements, the wavelength characteristics of each heavy metal were established using the air acetylene integrated flame mode (all heavy metals) and a hollow cathode lamp of each desired metal was put into the instrument. Standard for each metal was obtained through extrapolation from the calibration curve of the standard. The aforementioned steps in this section were performed in accordance with the recommendations from the analytical methods for atomic absorption spectrometry (Perkin Elmer, 1996).

Liver Function Test (LFT)

The liver function enzymes (ALT, ALP, AST, total bilirubin, total protein, and albumin) were measured in the blood samples. In Taraba State, samples were taken from the Rivers

Ibi, Donga, and Gidin Dorowa and processed using a semi-automatic analyzer and clinical chemistry reagent kits.

Heavy Metals Analysis

Atomic absorption spectrometer (Shimazu- AA- t300) analysis was done on the concentrations of the heavy metals (Cd, Zn, As, Hg, and Pb) after digestion. The AAS values were given as µg/g, which were then converted to mg/kg in the final results. Analytical-grade reagents were utilized throughout.

RESULTS

Heavy Metals Composition in Fish Gills Samples from River Ibi, Donga and Gidin-Dorowa

Table 1 shows the concentrations of heavy metals in the gills of Clarias gariepinus from river Donga, Ibi and Gindin-Dorowa. Zn and Cd were present in the gills from the three rivers, Pb was only present in the gills of the fish sample from Gidin Dorowa at a concentration of (0.014mg/kg), which is significantly different from Ibi and Donga. Hg and As were both found to be absent in all the gills samples from the three locations. There was a significant ($p < 0.05$) difference among the Zn with the highest found in Gidin Dorowa (12.65mg/kg) followed by Ibi (9.140 mg/kg) and the least Donga (7.52 mg/kg). However, there is a significant ($p < 0.05$) difference between the Cd content of sample from river Ibi (0.165 mg/kg) when compared with that of Gidin Dorowa (0.063 mk/kg) and Donga (0.03 mg/kg).

Table 1: The Concentrations of Heavy Metals in the Gills of *Clarias gariepinus* from Donga, Ibi and Gidin Dorowa Rivers in Taraba State, Nigeria.

Heavy metals	LOCATIONS		
	Donga (mg/kg)	Ibi (mg/kg)	Gindin Dorowa (mg/kg)
Lead	$0.000^{a}\pm0.000$	$0.000^{a}\pm0.000$	$0.014^{b}\pm0.021$
Zinc	$7.750^{a}\pm0.077$	$9.140^{b}\pm0.014$	$12.65^{c}\pm0.000$
Arsenic	$0.000^{b}\pm0.000$	$0.000^{b}\pm0.000$	$0.000^{b}\pm0.000$
Cadmium	$0.037^{b}\pm0.070$	$0.165^{b}\pm0.007$	$0.063^{a}\pm0.045$
Mercury	$0.000^{b}\pm0.000$	$0.000^{b}\pm0.000$	$0.000^{b}\pm0.000$

N=3; Results are expressed as Mean± Standard deviation(SD). Means having the same letters in a column are not significantly different (p<0.05)

Liver Biomarkers Activities

As displayed in Table 2, the result of liver function test shows that blood sample from river Gidin-Dorowa has the highest concentration of ALP, Total bilirubin and albumin (7.12 U/L, 0.06 mg/dL and 1.90g/dL respectively) when compared with Donga and Ibi. The highest concentration of ALT was recorded in blood sample from Ibi (1.19 U/L) when compared with Gidin-Dorowa (0.47 UL) and Donga (0.43 U/L), while Donga has the highest concentration of AST (7.60 U/L) and direct bilirubin (0.70 mg/dL), followed by Ibi (1.19 U/L and 0.20 mg/dL respectively). However, there is no significant ($p < 0.05$) difference between direct and indirect bilirubin concentrations in the blood samples from the three rivers.

Table 2: Effect of Heavy Metals on Hepatic indexes in Clarias gariepinus from Ibi, Donga and Gidin Dorowa Rivers inTaraba State, Nigeria.

Parameters/Locations	Donga	Ibi	Gidin Dorowa
ALT (U/L)	$0.43^a±0.06$	$1.19^b±1.27$	$0.47^a±0.52$
ALP (U/L)	$6.35^b±5.30$	$2.10^a±1.41$	$7.12^b±1.44$
AST (U/L)	$7.60^b±2.12$	$1.19^b±1.27$	$0.47^a±0.52$
Total bilirubin (mg/dL)	$0.02^a±0.02$	$0.05^a±0.07$	$0.06^a±0.07$
Direct bilirubin(mg/dL)	$0.70^a±0.14$	$0.20^a±0.07$	$0.19^a±0.12$
Total protein(g/dL)	$0.10^a±0.13$	$0.05^a±0.07$	$0.08^a±0.02$
Indirect bilirubin(mg/dL)	$0.05^a±0.07$	$0.05^a±0.04$	$0.01^a±0.01$
Albumin (g/dL)	$1.10^a±1.41$	$0.14^a±0.10$	$1.90^b±1.35$

N=3; Results are expressed as Mean± Standard deviation(SD). Means having the same letters in a column are not significantly different (p<0.05)

DISCUSSION

Given that they occupy many food chain levels, fish are effective indicators of the extent of heavy metal contamination in aquatic systems (Karadede-Akin et al., 2007). The aquatic ecology is significantly impacted by heavy metals. Table 1 illustrates the findings of a study on the concentrations of heavy metals in the gills of Clarias gariepinus from Donga, Ibi, and Gindin-Dorowa rivers. Pb was present in the gills of fish samples from Gindin-Dorowa at a concentration of (0.0145mg/kg), whereas, it was absent from Ibi and Donga at a concentration of (0.00mg/kg), which was significantly different ($p < 0.05$). The Food and Agricultural Organization (FAO) and World Health Organization (WHO) reported that the results from the three rivers were all within the acceptable levels (0.5 mg/kg, respectively) (FAO, 2005; WHO, 2005). Every organ and system in the body is susceptible to lead, which is a possible human carcinogen. According to the Center for Hazardous Substance Research (CHSR), 2009, exposure to high levels of lead can seriously harm the kidney and brain and finally result in death. Pb is a hazardous environmental pollutant that has drawn attention because of the serious threats it poses to human health (Afshan et al., 2014). Gidin-Dorowa (12.65 mk/kg)>Ibi (9.140 mk/kg)>Donga (7.52 mk/kg) but the values in Donga are lower than the permissible limits, the values in Ibi was slightly above the permissible limits, and the values in Gidin-Dorowa was above the permissible limits (8.0 mg/kg respectively), according to data from (WHO, 2005). Particularly when given orally, zinc has been reported to be generally harmless. Zinc is a necessary element, but higher concentration may be toxic to fish (Buthelezi et al., 2000). However, high level of zinc intake will result in over toxicity symptoms such as fatigue, nausea, and epigastric pain. As was not discovered in the gills of fish samples from the three separate rivers at a concentration of (0.00mg/kg), which is not statistically ($p<0.05$) different. This amount is below the permitted limits (2.0 mg/kg, respectively), according to data from FAO/WHO (2004). Both lung and other malignancies may be brought on by arsenic (NRC 2000; IARC 2004). The king of poisons and poison of kings are two well-known nicknames for it (Gupta et al., 2017). Cd was discovered in the gills of fish samples from Gidin Dorowa at concentrations of (0.0636 mg/kg), Donga (0.037 mg/kg), and Ibi (0.165 mg/kg), with no appreciable difference ($p < 0.05$) between the three. According to data from (WHO, 2011), the values in Donga and Ibi are below the acceptable limits whereas Gidin Dorowa is only slightly above it (0.05 mg/kg, respectively). Gidin Dorowa and Ibi's findings, however, are greater than the mean value of 0.065 mg/kg reported by Akaninyene et al. (2016). The presence of

Cd in contaminated water may interfere with vital bodily functions, leading to short or long-term illnesses (Jiang et al., 2015; Richter et al., 2017; Cao et al., 2018). Muscle soreness, fever, and lung damage can all be brought on by acute inhalation exposure (high amounts over a short time). The fish samples from the three rivers did not have Hg in their gills. The acceptable limit of mercury is reported by (WHO/FAO, 2004) to be 0.108 mg/kg. Mercury vapour inhalation may be lethal and has negative effects on the lungs, kidneys, neurological, digestive, and immune systems. According to Olsen et al. (1997), the skin, eyes, and digestive system are corrosive to the inorganic salts of mercury.

Gidin Dorowa had higher levels of ALP, total bilirubin, and albumin activity (7.12 U/L, 0.06 mg/dL, and 1.90 g/dL, respectively) when compared with Donga and Ibi. Blood samples from Ibi (1.19 U/L) had the highest level of ALT when compared with Gidin-Dorowa (0.47 U/L) and Donga (0.43 U/L), while Donga has the highest concentration of AST (7.60 U/L) and total protein (0.70 mg/dL), followed by Ibi (1.19 U/L and 0.20 mg/dL respectively). However, the ranges of all liver biomarkers are within the reference standards, indicating that the fishes from the three rivers are free from heavy metal toxicity

CONCLUSION

The study's findings showed that Pb was only found in the gills of the fish sample from Gidin Dorowa, Zn and Cd were present in the gills from all three rivers. The variations in all heavy metals concentrations in the fish gills and liver parameters from the three locations are below the permitted limits and the reference standard.

REFERENCES

Abdullah, M. (H). 2008. Heavy metals (Cd, Cu, Cr, Pb and Zn) in Meretrixmeretrixroding, water and sediments from estuaries in Sabah, North Borneo. International Journalof Environment and Science Education **2:** 69–74.

Abou El-Naga, E.H., EL-Moselhy, K.M., Hamed, M.A.2005. Toxicity of cadmium and copper and their effects on some biochemical parameters of marine fish Mugilseheli. Egyptian Journal of Aquatic Research **31**.2:60-71.

Adakole, J.A. 2000. The effects of domestic, agricultural and industrial effluents on the water quality and biota of Bindare stream, Zaria- Nigeria. Ph.D Thesis. Dept. of Biological Sciences. Ahmadu Bello University, Zaria. **25**6pp.

Adefemi, S. O., Asaolu S. S. and Olaofe O. 2008. Determination of heavy metals in Tilapia mossambicuisfish, associated water and sediment from Ureje dam in South-Western Nigeria. Research Journal of Environmental Science **2**.2:151-155.

Ademoroti, C.M.A. 1996. Environmental Chemistry and Toxicology. Ibadan: Foludex Press Ltd. **215**pp.

Adeniyi, A.A and Yusuf, K. A. 2007. Determination of heavy metals in fish tissues, water and bottom sediments from Epe and Badagry Lagoons, Lagos, Nigeria.Environmental Monitoring Assessment **37**: 451-458.

Adhikari, S., Ghosh, L. and Ayyappan, S. 2006. Combined effect of water pH and alkalinity on the accumulation of lead, cadmium and chromium in Labiorohito(Hamilton). International journal of environment science and technology **3**.3:289-296.

Agency for toxic substances and disease registry (ATSDR) 2001. Surface Water, Sediment, and Biota Human Exposure Pathway Analysis for Churchill County:Fallon Leukemia Project, Fallon, Churchill County, Nevada. Atlanta, GA:Agency for Toxic Substances and Disease Registry.

Akaninyene, P.J., Eyo, V.O, Andem, B.A. and Udo, J. (2016). Assessment of some heavy metals in the tissues (gills, liver and muscle) of Clariasgariepinusfrom Calabar River, Cross River State, South-eastern Nigeria, Journal of Coastal Life Medicine; 4(6): 430-434.

Alam, M.G.M., Tanaka A., Allison G., Laurenson, L.J.B., Stagnitti, F. and Snow, E. 2016. A comparison of trace element concentrations in cultured and wild carp (Cyprinuscarpio) of lake Kasumigaura, Japan. Ecotoxicology and environmental safety **53**:348-354.

Albert, J.S. and Crampton, W.G.R. 2005. Electroreception and Electrogenesis in The Physiology of Fishes. 3rd ed. D.H. Evans and J.B. Claiborne. Eds. CRC Press. 431–472.

Alexander, D. E. 1999. Encyclopedia of Environmental Science. Springer. ISBN 0-412- 74050-8.

Allen, P. 1994. Mercury accumulation profiles and their modification by interaction with cadmium and lead in the soft tissues of the cichlid Oreochromisaureusduring chronic exposure. Bulletin of Environmental Contamination Toxicology **53**:684 - 692.

ATSDR (Toxicological Profile for Lead). 2001. US Department of Health and Human Services, Public Health Service **205**-93- 0606.

Baijot, E., Bouda, S. and Quedraogo. L. 1997. Physical, chemical and biological characteristics of reservoir in Burkina Faso. Quagadogo: C. T. A. Publication.39-48.

Baldisserotto, B., Chowdhury, M. J. and Wood, C. M. 2005. Effects of dietary calcium and cadmium on cadmium accumulation, calcium and cadmium uptake from the water, and their interactions in juvenile rainbow trout. Aquatic Toxicology **72**:99–117.

Barange, M., Field, J.G., Harris, R.P., Eileen, E., Hofmann, E.E., Perry, R.I. and Werner, F. 2010. Marine Ecosystems and Global Change. Oxford University Press. ISBN 9780199558025.

Barron, M. G. and Albeke, S. 2000. Calcium control of zinc uptake in rainbow trout Aquatic Toxicology **50**:257–264.

Basa, S.P. and Rani, U..A. 2003.Cadmium induced antioxidant defensemechanism in freshwater teleost Oreochromismossambicus(Tilapia). Ecotoxicology andEnvironmental Safety **56**.2:218-221.

Batvari, B.P., Kamala-Kannan, K., Shanthi, R., Krishnamoorthy, K.J. and Jayaprakash, M. 2007. Heavy metals in two fish species (Carangoidelmalabaricusand Belonestronglurus) from Pulicat Lake, North of Chennai, Southeast Coast of India.Environmental Monitoring Assessment **145**:167-175.

Bebianno, M.J., Geret, F., Hoarau, P., Serafim, M.A., Coelho, M.R., Ginassia-Barelli, M. and Romeo, M. 2004. Biomakers in Ruditapes decussates: a potential bio- indicator specie.Biomakers**9**:305-330.

Burger J., Gaines K.F., Shane, B. C., Stephens, W.L., Snodgrass, J., Dixon, C., McMahon, M., Shukla, S., Shukla T. And Gochfeld, M. 2002. Metal levels in fish from the Savannah river: potential hazards to fish and other receptors. EnvironmentalResearch **89**: 85-91.

Burger, J. S. and Gochfeld, M. 2005. Mercury in Commercial Fish: Optimizing Individual Choices to Reduce Risk. Environmental Health Perspectives **113**: 266-271.

Bury, R.A., Walker, P.A. and Clover, C.N. 2003.Nutritive metal uptake in teleost fish. Journal of experimental biology **206**:11-23.

Calabrese, E.J., Canada, A.T. and Sacco, C. 1985. Trace elements and public health. Annals of Revolution of Public Health **6**:131-146.

Campbell, K. R. 1994. Concentrations of heavy metals associated with urbanrunoff in fish living in storm water treatment ponds. Archive of Environmental ContaminantToxicology **27**:352-356.

Campbell, D. 1987. A Review of the Biology and Culture of Tilapia guineensis. ARAC Working Paper ARAC/WP/3/87 African Regional Aquaculture Centre, Port Harcourt, Nigeria.

Campbell, P.G.C., Twiss, M.R. and Wilkinson, K.J. 1997. Accumulation of naturalorganic matter on the surfaces of living cells: Implications for the interaction of toxic solutes with aquatic biota. Canadian Journal of Fisheries and Aquatic Science **54**:2543- 2554.

Campbell, N. A., Brad W. and Robin J. H. 2006. Biology: Exploring Life. ISBN 0-13- 250882-6. Boston, Massachusetts: Pearson Prentice Hall.

Chapman, D. Ed., 1996. Water quality assessments. A guide to the use of biota sediments and water in environmental monitoring. 2nd ed. London: Chapman andHall. 626pp.

Chapman, J.L. and Reiss, M.J. 1998. Ecology: Principles and Applications. 2nd. ed. Berkeley, CA: University of California press. ISBN **0**-521- 58802-2

Chatterjee, S., Chattopadhyay, B. and Mukhopadhyay, S.K. 2006. Trace metals distribution in the tissues of cichlids (O. Niloticus and O. Mossambicus) collected from wastewater fed fish ponds in East Calcutta Wetlands, a Ramsar site. ActaichthyolPiscat**36**.2:119-125.

Chen, C.J., Hsueh, Y.M., Tseng, M.P., Lin, Y.C., Hsul, I., Chou, W.L., Chiou, H.Y.,Wang, I.H., Chou Y.L., Tseng, C.H. and Liou, S.H. 2000. Individual susceptibility toarseniasis. In: Arsenic Exposure and Health Effects IV. W.RChappell, C.O. Abernathy and R.L. Calderon. Eds. Oxford, UK: Elsevier. 135-143.

Chilmonczyk, S. 1992. The thymus in fish: development and possible function in the immune response. Annual Review of Fish Diseases **2**:181 200.

Chinni, S., and Yallapragda, R. 2000. Toxicity of copper, zinc, cadmium and lead to penaeusindicuspostlarvae: Effects of individual metals. Journal of environmental biology **21**: 255-258.

Christensen, V and Pauly, D. Eds. 1993. Trophic models of aquatic ecosystems.The World Fish Centre, issue 26 of ICLARM Technical Reports , vol. **26**ofICLARMconference proceedings. ISBN 9789711022846.

Chukwu, O. 2008. Analysis of Groundwater Pollution from Abattoir Waste in Minna, Nigeria. Research Journal of Diary Science **2.4**:74-77.

Cid, B.P., Boia, C., Pombo, L. and Rebelo, E. 2001. Determination of trace metals in fish species of Ria de Aveiro (Portugal) by electrothermal atomic absorption spectrometry. Food Chemistry **75**.93:100.

Cipriano, R. C. 2001. Furunculosis and Other Diseases Caused ByAeromonassalmonicida. Fish Disease Leaflet **66**. U.S. Department of theInterior.

Davenport, J. 2008. Challenges to Marine Ecosystems. Proceedings of the 41st European Marine Biology Symposium Volume **202** of Developments in hydrobiology.ISBN 9781402088070.

Deekay, S.N., Abowei, J.F.N. and Chindah, C. 2010a. Some physical and chemicalparameters of Luubara creek, Ogoni land, Niger Delta, Nigeria. Research Journal ofEnvironmental and Earth Science 2.4:199-207. . and Alfred, J.F. 2010b. Seasonal variation of some physical and chemical parameters of Luubara creek, Ogoni land, Niger Delta, Nigeria. Research Journal of Environmental and Earth Science **2.4**: 207-215.

De Graaf, G.J. and Janssen, H. 1996. Artificial reproduction and pond rearing of the African catfish Clariasgariepinus in Sub-Saharan Africa. FAO Fisheries TechnicalPaper. No. **362**. FAO, Rome, Italy. 73 pp.

DFID. 1999. A simple methodology for water quality monitoring. G.R. Pearce, M.R. Chaudhry and S. Ghulum Eds. Department for International Development, Walling ford.

Dickson, M.D. and Leung, K.M. 1998. Mercury and organo chlorine exposure from fish consumption in Hong Kong. Chemosphere **37.5**: 991-1015.

Downing, J.A., Prairie, Y.T., Cole, J.J., Duarte, C.M., Tranvick, L.J., Striegel, R.G., McDowell, W.H., Kortelainen, P., Melack, J.M., Middleburg, J.J. 2006. The global abundance and size distribution of lakes, ponds and impoundments. Limnology andOceanography **51**: 2388-2397.

Duffus, J. H. 2002. ""Heavy metals" a meaningless term? (IUPAC Technical Report)" Pure and Applied Chemistry **74**:793-807. doi:10.1351/pac200274050793

Dupler, D. 2001. Heavy metal poisoning. Gale Encyclopedia of Alternative Medicine. Farmington Hills, MI: Gale Group.

Department of Water Affairs and Forestry (DWAF). 1996. Water QualityGuidelines for Domestic Use. Vol**. 1**, 2nd Ed., DWAF, Pretoria.

Earnshaw, A. and Greenwood, N. 1997. Chemistry of the elements. 2nd ed. Oxford: Butterworth-Heinemann. 1600pp.

Ebrahimi, M. and Taherianfard, M. 2011. The effects of heavy metals exposure on reproductive systems of cyprinid fish from Kor River. Iranian Journal of FisheriesSciences **10**:13-24.

Edokpayi, C.A. and E.C. Osimen. 2001. Hydrobiological studies on Ibiekuma River at Ekpoma, Southern Nigeria after Impoundment: The faunal characteristics. AfricanJournal of Science and Technology **1**:72-81.

Eisler, R. 1988. Lead Hazards to Fish, Wildlife and Invertebrates: A Synoptics Review. US Fish and Wildlife Service, Washington, DC.

Ekpo, K.E., Asia, I. O., Amayo, K. O. and Jegede, D. A. 2008. Determination of lead, cadmium and mercury in surrounding water and organs of some species of fish from Ikobariver in Benin city, Nigeria. International journal of physical sciences 3.**11**:289-292.

Ela, W.P. 2007. Introduction to Environmental Engineering and Science. 3rd ed.New York: Prentice Hall Inc. ISBN 0-**13**-148193-2

Elson, M. and Haas, M.D. 2003. Toxic Minerals and Heavy metals (Excerpted from a cookbook for all season) 2003 ed. California. 44 Environment Agency Japan. 1975. Quality of the environment in Japan. Tokyo: Ministry of finance printing Bureau. 33-40

Fergosson, J.E. 1990. The Heavy Elements Chemistry. Environmental Impact and Health.**10**: 3-5.

Fernandes, C., Fontaínhas-Fernandes, A., Cabral, D. and Salgado, M. A. 2008. Heavy metals in water, sediment and tissues of Liza saliensfrom Esmoriz–Paramos lagoon, Portugal. Environmental Monitoring Assessment **136**: 267–275.

FEPA (Federal Environmental Protection Agency) 1991. Guidelines and standards for Environmental Pollution Control in Nigeria.

FEPA (Federal Environmental Protection Agency) 2003: Guidelines and Standards for Environmental Pollution Control in Nigeria. 239pp

Filipovic, V. and Raspor, B. 2003. Metallothionein and metal levels in cytosol of liver, kidney and brain in relation to growth parameters of Mullussurmuletusand Lizaauratafrom the eastern Adriatic sea. Water Resources 37.**13**:3253-3262.

Food and Agricultural Organization (FAO). 1983. Compilation of legal Limits for Hazardous Substance in Fish and Fishery Products. Food and Agricultural Organization Fisherycircular. **466**.5-100.

Fox, G. A., Weseloh, D.V., Kubiak., T.J. and Erdman, T. C. 1991.Reproductive outcomes in colonial fish eating birds- a biomarker for developmental toxicants in great lakes food chains: historical and ecotoxicological perspectives. Journal of Great Lakes Research 17.**2**:152-157.

Gagnaire, B., Thomas-Guyon, H. and Renault, T. 2004. In vitro effects of cadmium and mercury on pacific oyster, Crassostreagigas(Thunberg), haemocytes. Fish andShellfish Immunology **16**:502-512.

Haffor, S.A. and Al-Yed, M.I. 2003.The effect of lead bioaccumulation on haem biosynthetic enzymes in fish. Journal of Environmental biology 24.**3**:271- 280.

Haines, T. A. and Brumbaugh, W. G. 1994. Metal concentration in the gill, gastro-intestinal tract and carcass of white suckers (Catostomuscommersoni) in relation to lake acidity. Water, Air and Soil Pollution **73**:265–274.

Hansen J.D. and Zapata A.G. 1998. Lymphocyte development in fish and amphibians. Immunological Reviews **166**: 199–220.

Hartman, K. H., Yanong, P.E., Pouder, D.B., Petty, B.D. Francis-Floyd, R. and Riggs,

A.C. 2004. Koi Herpes Virus (KHV) Disease. Fact Sheet VM-**149**. University ofFlorida Institute of Food and Agricultural Sciences.

Harrison, R. Ed. 2001. introduction to all forms of pollution. Pollution: Causes, Effects, and Control. Royal Society of Chemistry Comprehensive (579-page).

Harvey, S. 1975: Heavy metals. In: Pharmacological Basis of Therapeutics. 5th ed.L.S. Goodman and A. Gilman. Eds. New York: Macmillan. 924-941.

Heath, A.G. 1987. Water pollution and Fish physiology. Florida, USA: CRC press.215

Helfman G., Collette B. and Facey, D. 1997. The Diversity of Fishes. Blackwell Publishing. 375pp. ISBN 0-86542-256-7

Henry, F., Amara, R., Courcot, L., Lacouture, D. and Berthon, M.L. 2004. Heavy metals in four fish species from the French coast of the Eastern English Channel and Southern Bight of North Sea. Environment International **30**: 675–683.

Hightower, J. 2008. Diagnosis Mercury: Money, Politics and Poison. Island Press.77

Hogan, M. 2010. Heavy metal. Encyclopedia of Earth. National Council forScience and the Environment. E. Monosson and C. Cleveland. Eds. Washington DC:CRC Press. 1350pp.

Holdgate, M.W. 1979. A perspective of environmental pollution. In: Heavy metals in soils. B.J. Alloway. Ed. London: Black and Son Ltd. 109-256pp.

Horwitz, R. J., Ruppel, B., Wisniewski, S., Kiry, P., Hermanson, M. and Gilmour, C.1995. Mercury concentrations in freshwater fishes in New Jersey. Water Airand SoilPollution **80**:885– 888.

HSDB. 2009. Hazardous Substances Data Bank. National Library of Medicine. http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB and search on CAS number.

Hutzinger, O. 1980. The handbook of environmental chemistry. Vol. **2**. Part A. Reactions and processes. Berlin: Springer Verlag. 307 .

Jain, C.K. and Sharma, M.K. 2001. Distribution of trace metals in the Hindon river system, India. Journal of Hydrology (Amsterdam) **253**:81-90.

Jarup, L., Berglund, M., Elinder,C.G., Nordberg, G. and Vahter, M. 1998. Health Effects of Cadmium Exposure-A Review of the Literature And a Risk Estimate. Scandanevian Journal of Work and Environmental Health. **24** .1:1-51

Jezierska, B. and Witeska, M. 2001. Metal Toxicity to Fish. WydawnictwoAkademiiPodlaskiej, Siedlce 318 Pp.

Jezierska, B. and Witeska, M. 2006. The metal uptake and accumulation in fish living in polluted waters. Soil and Water Pollution Monitoring, Protection and Remediation 3.**23**:107-114.

sJoyeux, J.C., Filho, E.A.C. and De Jesus, H.C. 2004. Trace metal contamination inEstuarine Fishes from Vitoria bay, ES, Brazil. Brazilian Archives of Biotechnology **47.5**:765- 774.

Kakulu, S.E., Osibanjo, O. and Ajayi S.O. 1987. Trace metal content of fish and shellfishes of the Niger Delta area of Nigeria. Environmental International **13**:247-251.

Kenneth Barbalace. (nd). Zinc facts, Chemical and physical properties of Zinc. (Accessed February 2011) from http://www.britannica.com/ EBchecked/topic/87955/zinc-Zn.

Kennicutt, M.C., Wade, T.L. and Presley, B.J. 1992. Assessment of sediment contamination in Casco Bay. Casco Bay Estuary Project. Texas A&M University **113** pp.

Khaled, A. 2004. Heavy metal concentrations in certain tissues of five commercially important fishes from El-MexBay, Al-Exandria , Egypt. pp 1- 11.

Khalid, R.A., Gambrell, R.A. and Patrick W.H. 2008. Chemical transformation of heavy metals. D.C. Adriano and I.L. Jr. Bristbin. Eds. US Department of Energy. DoeSymposium Series. 133-147.

Kheradmand, K., Kamali, K., Fathipour, Y., Barzegar, M. and Goltapeh, E.M. 2006.Effect of pigmy mite Pediculasterfletchmanni(Acari: Siteroptidae) on mineral elements of button mushroom Agaricusbisporous. Pakistan Journal of Biological Science **9**: 2177–2180.

Clariasgariepinus, from the Olifants River, Mpumalanga, South Africa. Water South Africa **25**: 99-110

Krishnani, K. K., Azad, I. S., Kailasam, M., Thirunavukkarasu, A. R., Gupta, B. P.,Joseph, K. O., Muralidhar, M. 2003. Acute toxicity of some heavy metals to latescalcarifer fry with a note on its histopathological manifestations. Journal of EnvironmentalScience and Health **38.4**: 645-655.

Kutcher, T., Storelli, P.N. and Zack, O. 2006. Development of the zebra fish lymphatic system requires VegFcsignalling. Current Biology **16**: 1244–1248.

Labonne, M., Othman, D.B. and Luck, J.M. 2001. Lead isotopes in muscles as tracers of 168 metal sources and water movements in a Lagoon (Thau Basin, S. France). ChemicalGeology **181**: 181-191.

Landrigan, P.J., Schecter, C.B., Lipton, J.M., Fahs, M.C. and Schwartz, J. 2002. Environmental pollutants and diseases in American children: estimates of morbidity, mortality, and costs for lead poisoning, asthma, cancer, and developmental disabilities. Environmental Health Perspective **110**:721–728.

Lansche, A. M. and Miller, E. B. and sun, A.B. 1956. Lead and zinc pigments andzinc salts. Ecology and Natural Resources Collection **1**:725-737.

La Roche, G., 1972. Biological effects of short-term exposures to hazardous materials. In: Control of Hazardous Material Spills. Proceedings of 1972 National Conference onControl of Hazardous Material Spills, 21--23 March 1972, Houston, Texas. Graphics Management Corporation of Washington, D.C. 199-206.

Lawson, E. O. 2011. Physico-Chemical Parameters and Heavy Metal Contents of Water from the Mangrove Swamps of Lagos Lagoon, Lagos, Nigeria. Advances in BiologicalResearch **5.1**: 08-21.

Lee, B.G., Grimscom, S.B., Lee, J.S., Choi, H.J., Koh, C.H., Luoma, S.N. and N.S. Fisher. 2000. Influences of dietary uptake and reactive sulfides on metal bioavailability from aquatic sediments. Science **287**: 282-284.

Malik, N., Biswas, A.K., Qureshi, T.A., Borana, K., and Virha, R. 2008. Bioaccumulation of heavy metals in fish tissues of a freshwater lake of Bhopal. Environmentalmonitoring assessment

Manahan, S.E. 1992. Toxicological chemistry.2nd ed. Michigan, USA: Lewis publishers incorporated. . 2005. Environmental Chemistry. CRC Press. ISBN1-56670-633-5.

Mann, K.H. and Lazier, J.R.N. 2006. Dynamics of marine ecosystems: biological- physical interactions in the oceans. Wiley-Blackwell. ISBN 9781405111188Mansour, S.A. and Sidky, M.M. 2002. Ecological studies: Heavy metals contaminatingwater and fish from FayoumGov, Egypt. Food chemistry **78**:15-22.

Marcovechio, J.E. 2004. The use of Micropogoniasfurnieri and Mugilliza as bio-indicators of heavy metals pollution in La Plata river estuary, Argentina. Science of the totalenvironment **323**:219-227.

Mayers, T.R. and Hendricks, J.D. 1984. Histopathology. In Fundamental of aquatic toxicology. G.M. R. and S.R. Petrocelli. Eds. Washington Dc: Hemisphere. 413pp.

Mazlin, B. M., Ahmad, Z. A., Vikneswaran, M. and Sarva, M. P. 2009. Assessmentlevels of heavy metals in penaeusMonodonand oreochromissppin selected Aquaculture ponds of high densities development area. European journal ofscientificresearch **30.3**:348-360.

McAllister, D.E., Hamilton, A.L. and Harvey, B. 1997. Global freshwater biodiversity; Striving for the integrity of freshwater systems. Sea Wind **11**:1- 140.

McConchie, D.M., Mann, A.W., Lintern, M.J., Longman, D., Talbot, V., Gabelish, A.J. and Gabelish, M.J. 2008. "Heavy Metals in Marine Biota, Sediments, and Waters from the Shark Bay Area, Western Australia". Journal of Coastal Research **4.1**:37 – 58.

Mechenich, C. and Andrews, E. 2006. Interpreting Drinking Water Test Results. In L. a. H. R. University of Wisconsin Cooperative Extension- Wisconsin Department of Natural Resources- Wisconsin Department of Industry.

Mendil, D., Uluozlo, O.D., Hasdemir, E., Tuzen, M., Sari, H. and Suicmez, M. 2005.Determination of trace metals levels in seven fish species in lakes in tokat, Turkey. Food chemistry **90**:175-179.

Milligan, D.L., Babish, J.G. and Neuhauser, E.F. 2001 Noninducibility of cytochrome P450 in the earthworm Dendrobaenaveneta. Comparative Biochemistry andPhysiology **85**:85-87.

Mohan, D., Gaur, A., and Choudhary, D. 2007. Study of limnological and microbiology of NayaTalab Jodhpur (Rajasthan). Proceedings of DAE-BRNS National Symposiumon Limnology (NSL). 19-21st February 2007. Udaipur. 64-68.

Moiseenko, T. I., Kudryavtseva, L. P., Rodyushkin, I. V., Dauvalter, V. A., Lukin, A.A., and Kashulin, N. A. 1995. Airborne contamination by heavy metals and aluminium in the freshwater ecosystems of Kola subarctic region (Russia). Science of the TotalEnvironment **160.161**:715–727.

More, T. G., Rajput, R. A. and Bandela, N. N. 2003. Impact of heavy metals on DNAcontent in the whole body of freshwater bivalve, Lamelleidenmarginalis. EnvironmentScience Pollution Research **22**: 605-616.

Mortimer, E. and Charles, M. 1975. Chemistry: A Conceptual Approach. 3rd ed. New York: D. Van Nostrad Company.

Moss, B., Johnes, P. and Phillips, G. 1996. "The monitoring of ecological quality and the classification of standing waters in temperate regions". Biological Reviews **71**.2: 301–339.

Moustakas, A. and Karakassis I. 2005. "How diverse is aquatic biodiversity research?". Aquatic ecology **39**: 367-375.

Mustafa, S. and D.E. Nilgun. 2006. Copper(II)-rubeanic acid co-precipitation system for separation-preconcentration of trace metal ions in environmental samples for their flame atomic absorption spectrometric determinations. Journal of HazardousMaterials B**137**: 1035- 1041.

National academy of sciences-National research council (NAS-NRC) 1974. drinking water and health. Washington DC: National academic press. 1:1939

National Environmental Standards Regulations Enforcement Agency (NESREA). 2011. Guidelines and standards for Environmental Pollution Control in Nigeria.

Nathaniel, I. T., Salami, A. T. and Olajuyigbe, A. C. 2000. Environmental Features of Nigerian Economic Exclusive Zone (EEZ): Ibino and Bonny as case study. AfricanJournal of Environmental studies **1.1**: 9-17.

Ndiokwere, C.L. 2004: Chemistry and Environment. University of Benin, InauguralLecture Series 73

Nemerow, N.L. 1986. Streams, Lakes, Estuary and Ocean Pollution. New York: Van Nostrand Reinhold. 381-398.

Ney, J. J. and Van Hassel, J. H. 1983. Sources of variability in accumulation of heavy metals by fishes in a roadside stream. Archive of Environment Contamination Toxicology**12**:701–706.

Nogawa, k., Kobayashi, E., Okubor, Y. And Suwazono, Y. 2004. Environment cadmium exposure, adverse effects and preventive measures in Japan. BioMetals**17**.581-587.

Obasohan, E.E., Oronsaye, J.A., and Obano, E.E. 2008. Heavy metal concentrations in Malapteruruselectricusand Chrysichthysnigrodigitatusfrom Ogbariver in Benin City, Nigeria. African Journal of Biotechnology **5**.10: 974- 982.

Odum, E.P. 1971 .Fundamentals of ecology. 3rd ed. London: W.B. Sanders. 547.

Olaifa, F.E., Olaifa, A.K., Adelaja, A.A. and Owolabi, A.G. 2004. Heavy metal contamination of Clariasgariepinusfrom a lake and fish farm in Ibadan, Nigeria.African Journal of Biomedical Research **7**:145-148.

Olowu, R.A., Ayejuyo, G. O. , Adejoro, I. A. , Denloye, A. A. , Babatunde, A. O. and Ogundajo, A. L. 2009. Determination of heavy metals in fish tissues, water and sediment from Epe and badagry Lagoons, Lagos, Nigeria. E-Journal ofchemistry **7.1**:215-221.

Pagenkopf, G. K. 1983. Gill surface interaction model for trace-metal toxicity to fishes: role of complexation, pH, and water hardness. Environment Science and Technology**17**:342–347.

Papagiannis, L., Kagalou, L., Leonardos, J., Petridis, D. and Kalfakakou, V. 2004. Copper and zinc in four freshwater fish species from lakePamvotis (Greece). EnvironmentInternational **30**: 357–362.

Pattee, O.H. and Pain, D.J. 2003. Lead in the environment. In: Handbook of ecotoxicology. 2nd ed. D.J. Hoffman, B.A. Ratter, G.A. Burton jnr. and J. Cairns jnr. Eds. BocaRaton, Florida: Lewis publishers. 373-408.

Payne, A. I. 1978. Gut pH and digestive strategies in estuarine grey mullet (Mugilidae) and tilapia (Cilchlidae). Journal of Fish Biology **13**: 627–629.

Petr, T. 1978. Tropical man-made lakes - their ecological impact. Archive of Hydrobiology**81**:368-385.

Pelgrom, S. M. G. J., Lamers, L. P. M., Lock, R. A. C., Balm, P. H. M. and WendelaarBonga, S. E. 1995. Interactions between copper and cadmium modify metal organ distribution in mature tilapia, Oreochromismossambicus. Environmental Pollution**90**:415- 423.

Philippart, J-Cl. and Ruwet, J-Cl. 1982. Ecology and distribution of tilapias. in: Thebiology and culture of tilapias. ICLARM Conference Proceedings 7. R.S.V. Pullin and R.H. Lowe-McConnell. Eds. International 1 Centre for Living Aquatic Resources Management, Manila, Philippines. 15–59.

Phillips, D.J.H. 1990. Arsenic in aquatic organisms: a review emphasizing chemical speciation. Aquatic Toxicology **16**: 151–186.

Playle, R. C., Gensemer, R. W., and Dixon, D. G. 1992. Copper accumulation on gills of fathead minnows: influence of water hardness, complexation and pH of the gill microenvironment. Environmental Toxicology and Chemistry**11**:381–391.

Pote, J., Haller, L., Loizeau, J.L., Bravo, A.G., Sastre, V. and Wildi, W. 2008. Effects of a sewage treatment plant outlet pipe extension on the distribution of contaminants in the sediments of the Bay of Vidy, Lake Geneva, Switzerland. Bio-resourcesTechnology **99**:7122–7131.

Praveena, S. M., Radojevic, M., Abdullah, M. H. and Aris, A. Z. 2008. Application ofSediment Quality Guidelines in the Assessment of Mangrove Surface Sediment in Mengkabong Lagoon, Sabah, Malaysia. Iranian Journal of Environmental HealthScience and Engineering **5**:35-42.

Proti, S. 1989. Metals in Fish and Sediments from the River Kolbacksan. Water System **7**: 26- 27.

Rasheed O.A. 2011. Urban agricultural production: heavy metal contamination of Amaranthuscruentus L. grown on domestic refuse landfill soils in Ibadan, Nigeria. Journal of Food and Agriculture. **15.2**: 131-139.

Reid, S.D. and Mcdonald, D.G. 1991. Metal binding activity of the gills of rainbow trout (Oncorhynchusmykiss). Canadian Journal of Fisheries and Aquatic Science **48**:1061-1068.

Reilly, Sadik, O.A. 1990. Heavy metals contaminants in some Nigerian marine fishes of commercial importance. National institute for oceanography and marine research technicalpaper.No.63. ISBN 978-2345-063.

Sanders, M.K., Nowson, A.C., Kotowicz, A.M., Briffa,K., Devine, A. and Reid, I.R. 2009. Calcium and bone health: position statement for the Australian and New Zealand Bone and Mineral Society, Osteoporosis Australia and the Endocrine Society of Australia. The Medical Journal of Australia **190.6**: 316-320.

SadinAmerica. 2008. The reality of Aluminium poisoning. Accessed January 2011 from http:// www.knowthelies.com

Sanstead, H.H. 1976. Interaction of cadmium and lead with essential minerals. Effects and response relationships of toxic metals. G.F. Nordberg. Ed. Amansterdam:Elsevier. 511-525.

Sawyer, C.N., Mccarty, P.L. and Parkin, G.F. 1994. Chemistry for environmental engineering and science. 4th ed. New York: McGrawhill.

Saxena, M., Saxena, H., Kaur, P. and Kaur, K. 2009. Effect of heavy metal pollutionof water on response of fish lymphocytes to mitogenic stimulation. The Internet Journalof Veterinary Medicine **5.2**: 387-395.

Sreenivasa, R.A.O., Chary, N. S., Chandra S. K., Kamala, C. T. and Suman Raj, D. S. 2003. Fractionation studies and bioaccumulation of sediment-bound heavy metals in Kollerulake by edible fish 2003. Environment International **29**: 1001-1008.

Stagg, R. M., and Shuttleworth, T. J. 1982. The accumulation of copper in PlatichthysflesusL. and its effects on plasma electrolyte concentrations Journal of Fish Biology **20**:491–500.

Standard Organisation of Nigeria (SON). 2007. Nigerian standard for drinking water quality. Staniskiene, B., Matusevicius, P., Budreckiene, K.A. and Skibniewska, K.A. 2006. Distribution of Heavy Metals in Tissues of Freshwater Fish in Lithuania. Polish Journal of Environmental Studies **15.4**:585-591.

Stewart, H. 1975. Heavy metals. In: Pharmacological Basis of Therapeutics. 5th ed. L.S. Goodman and A. Gilman. Eds. New York: Macmillan. 924-941.

Storelli, M. M., Storelli, A., D'ddabbo, R., Marano, C., Bruno, R. and Marcotrigiano, G. O. 2005. Trace elements in loggerhead turtles (Carettacaretta) from the eastern Mediterranean Sea: Overview and evaluation. Environmental Pollution **135**:163–170.

Sun, B., Zhao, F.J., Lombi, E. and McGrath, S.P. 2001. Leaching of heavy metalsfrom contaminated soils using EDTA. Environmental pollution **113.2**:111-120. Suski, C.D., Killen, S.S., Keiffer, J.D., and Tufts, B.L. 2006. The influence of environmental temperature and oxygen concentration on the recovery of large- mouth bass from exercise. Implications for live-release angling tournaments. Journal of Fish Biology**68**:120-136.

Svobodova, Z. 1993. Water quality and fish health. Rome: Food and Agriculture Organisation of the United Nations.

Swingle, H.S. 1969. Relationship and dynamics of balanced and unbalanced fish population. Alabama Polytechnic Institute of Agriculture and Experimental Station, 34-67. Teodorovic, N., Djukic, S., Maletin, B., Miljanovic , O. and Jugovac N. 2000. Metal pollution index: proposal for freshwater monitoring based on trace metal accumulation in fish. Tiscia**32**: 55-60.

Terra, B.F., Araujo, F. G., Calza, F.C., Lopes, R.T. and Teixeira, T.P. 2008. Heavymetals in tissues of three fish species from different trophic levels in a tropical Brazilian river. Water, Air and Soil pollution **187**:275-284.

Terra, N.R., Feiden, I.R., Fachel, J., Lemos, C.T. and Nunes, E.A. 2009. Ecotoxocological evaluation of sediment and water samples from Sinos River, Rio Grande do Sul, Brazil, using Daphnia magna and V79 cells. ActaLimnologicaBrasiliensia, **20**: 65-74.

Thivierge, B. and Frey, R. 2006. "Heavy Metal Poisoning." Gale Encyclopedia of Medicine. 3rd ed. Encyclopedia.com. 18 Oct.2011.<http://www.encyclopedia.com.

Tüzen, M. 2003. Determination of heavy metals in fish samples of the Mid-Dam Lake Black Sea (Turkey) by graphite furnace atomic absorption spectrometry. FoodChemistry **80**:119–123.

Umeham, S.N. 1989. Some aspects of the physicochemical limnology of lake Chad (Southern sector). Journal of aquatic sciences **4**:21-26.

UNEP/FAO/IAEA/IOC. 1984. Reference methods for marine pollution studies no.8 Rev. 1

Unohia, C.G. 2001. Studies on the physico–chemical characteristics and productivity of concrete reservoir. Global Journal of Agricultural Science **1. 2**: 23-56.

U.S. Department of Public Health and Human Services (DPHHS). 2005. Toxicological Profile for Zinc (update). Atlanta, GA: Public health Service. 1-2.

U.S.EPA. 1994. Methods for the determination of metals in environmental samples: Supplement 1. U.S. Environment Protection Agency. EPA600R94111.

United States Geological Survey (USGS). 2009. Denver, CO. "Ground Water and Surface Water: A Single Resource." USGS Circular 1139 US national imageryand mapping Agency, 2005.

Van den Broek, J.L., Gledhill, K.S. and Morgan, D.G. 2002. Heavy metal concentration in the mosquito Gambusiaholbrooki, in the Manly Lagoon Catchment. In: UTS Freshwater Ecology Report. Department of Environmental Sciences, University ofTechnology, Sydney.

Veltrop, J.A. 1993. Importance of dams for water supply and hydropower. In:Water for Sustainable Development in the Twenty-first Century. A.K. Biswas, M. Jellalli andG.E. Stout. Eds. Delhi: Oxford University Press. 104-115.

Voigt, H. R. 2004. Heavy metal concentrations in four-horn sculpinTriglopsisquadricornis(L.) (Pisces), its main food organism SaduriaentomonL. (Crustacea), and in bottomsediments in the Archipelago Sea and the Gulf of Finland (Baltic Sea). Proc. Estonian Acad. Sci. Biol. Ecol. **56. 3:** 224.238

Vosyliene, M.Z. and Jankaite, A. 2006. Effects of heavy metals model mixture on Rainbow trout biological parameters. Ekologija**4**:12-17.

Ward, T.J., Correll, R.L. and Anderson R.B. 1986. Distribution of Cd, Pb and Zn amongst the marine sediments, sea grasses and fauna, and the selection of sentinel accumulators, near a Pb smelter in South Australia. Australian Journal of Marineand Freshwater Research **37**:567-585.

WHO. 2008. Major types of Water Pollutants, Common Diseases TransmittedThrough Contaminated Drinking Water and Measuring Water Quality. Accessed March 2011 http://www.who.int/water_sanitation_health/en/ - WHO water sanitation website

WHO. 2008. "World Health Organization. Safe Water and Global Health". http://www.who.int/features/qa/70/en/. Retrieved February 2011.

Wildianarko, B., Vangestel, C.A.M., Vreweij, R.A. and Vanstraalen, N.M. 2000. Associations between trace metals in sediment, water and guppy, poecilia reticulate (peters), from urban streams of Semerang, Idonesia. Eco- toxicology andEnvironmental Safety **45**:15-35.

Wimmer, U., Wang, Y., Georgiev, O. and Schaffner, W. 2005. Two major branches of cadmium defence in the mouse: MTF-1/metallothionein and glutathione. Nucleicacids research **33.18**:5715-5727.

Woodford, C.2006. Water pollution: An introduction- Causes, effects, types and solutions http://www.explainthatstuff.com/waterpollution.html. Retrieved February 2011

Yamazaki, M., Tanizaki, Y. and Shimokawa, T. 1996. Silver and other trace elements in a freshwater fish, Carasiusauratuslangsdorfii, from the Asakawa River in Tokyo, Japan. Environmental Pollution **94**:83–90.

Yang, H. N., and Chen, H. C. 1996. Uptake and elimination of cadmium by Japanese eel, Anguilla japonica, at various temperatures. Bulletin of Environmental ContaminationToxicology **56**:670– 676.

Yielmaz, A. B. 2003. Levels of heavy metals (Fe, Cu, Ni, Cr, Pb and Zn) in tissue of Mugilcephalusand Trachurusmediterraneusfrom Iskenderun Bay, Turkey. Environment Research **92**: 277-281.

Yilmaz, F. 2007. Heavy metal levels in two fish species Leuciscuscephalusand Lepomisgibbosus. Food Chemistry **100**: 830-835.

Zapata, A.G., Chiba, V. and Vara, A. 1996. Cells and tissues of the immune system of fish. In: The Fish Immune System: Organism, Pathogen and Environment