https://chemclassjournal.com/
ChemClass Journal Vol. 9 Issue 2 (2025); 736-742
e-ISSN:3092-8214 p-ISSN:3092-8206
doi.org/10.33003/chemclass-2025-0902/193

Assessment of the Metal Uptake and Accumulation in Fishes Living in Polluted Water of Abuloma River, Rivers State, Nigeria

Okorie Edmund

Chemistry Unit, Department of Science Laboratory Technology, School of Technology, Federal Polytechnic Idah P.M.B. 1037 Idah, Kogi State Nigeria.

(*) Corresponding author: okorie.edmund@gmail.com

Abstract

Some heavy metals - lead, manganese, copper, nickel, zinc, chromium, iron, cadmium, cobalt and arsenic (Pb, Mn, Cu, Ni, Zn, Cr, Fe, Cd, Co and As) contents in selected fishes from Abuloma River in Rivers State of Nigeria was studied after dry ashing using the Flame Atomic Absorption Spectrometric technique. From the analysis, Pb, Zn and Fe were identified in all the fish samples with concentration range of 0.024-0.160 µg/g (Pb); 0.246-2.779 µg/g (Zn) and 0.346-1.047 µg/g (Fe). Ni, Cd and Co were not detected in the fish samples. Mn, Cu, Cr and As were found in some of the fish samples with the concentration range of 0-0.144 µg/g (Mn); 0-0.276 µg/g (Cu); 0-0.063 µg/g (Cr) and 0 - 9.167 µg/g (As). The concentration observed for As, was far higher than the recommended permissible limits by Food and Agricultural Organisation; which is 0.002 µg/g. The pollution index (Pi) analysis indicates a very high index for As in Mullet fish (1194.5), Sika fish (3222) and Stock fish (4583.5); while the Pi for Pb > 1 also indicates severe pollution. Hence, these fish species from Abuloma River could be considered as unfit for consumption.

Keywords: Abuloma River, FAAS, Heavy metals, Water pollution, fish.

Introduction

The increasing industrial activity in Rivers State, as the major site of Nigeria's oil industries has resulted in the pollution of their water bodies with heavy metals. Heavy metal pollution in rivers has been observed as a serious concern as it is increasing steadily throughout the world each year. This is due to the release of pollutants from the various sources of industrial, agricultural and mining waste such as leaching of minerals and soil erosion as well as anthropogenic activities either directly or indirectly into the aquatic system. This has resulted in disruption in the ecological balance of different systems [1].

Fish is an aquatic organism of high economic value that responds to environmental change. Thus, it is extremely suitable to be utilized as an indicator for pollution studies. Moreover, fish is a good bio accumulator as it has the optimum size for analysis, and a long lifespan and it is easily obtained in large quantity to be sampled for accumulated metals. Generally, this accumulation depends on metal concentration, time of exposure, way of metal uptake, environmental conditions such as water, temperature, pH, hardness, salinity and intrinsic factors (fish age, feeding habit, size). Various metals show different affinity to fish tissues. Most of them accumulate mainly in liver, kidney and gills. Metals distribution in various organs is time related. Accumulation of metals in various organs of fish may cause structural lesions and functional disturbance [2].

The bioaccumulation of heavy metals in different tissues of aquatic organisms leads to several harmful effects. It may have genotoxic, mutagenic, Immuno-suppressive and cytotoxic effects. It may also result in histopathological changes, abnormalities in fish reproduction and public health hazard for human consumption such as polluted fish [3]. The main threats for fish consumers are associated with exposure to cadmium, mercury, arsenic, and lead [4]. For human beings, there are several different sources of heavy metal pollution such as rechargeable nickel-cadmium batteries and cigarette smoking, which are considered as the major sources for cadmium exposure; inducing serious effects such as renal damage and bone fracture [5].

Rivers State, located in the South-South geopolitical zone of Nigeria, is economically significant as the center of Nigeria's oil industry. Oil extraction and transportation throughout the water bodies of this state, is one of the nation's main pollution sources of polluted waters in Rivers State. Many industries and cities, which surround the state are another pollution sources. Cities and industrial wastes and pollution enter the water bodies and pollute them. There are different fish species in these polluted waters. The aim of this study is to evaluate the concentration of selected heavy metals - lead, manganese, copper, iron, zinc, chromium, nickel, arsenic, cadmium and cobalt, accumulated by fishes living in polluted water of Abuloma river, Rivers State, Nigeria, to ascertain their safety for consumption.

Materials and Methods

Sample collection

Four different species of fish namely: Catfish, Sika fish, Stock fish and Mullet were bought from local fishermen at Abuloma River, Rivers State, Nigeria. The fishes were further subjected to preparation and analysis.

Sample preparation

The muscle tissue of each of the different species of fish was ground using a mortar and pestle into smaller pieces and oven dried at 60 ºC until constant weight was reached (i.e. no moisture content in the samples). 1 g each of the dried fish samples was weighed into pre-weighed porcelain crucibles and transferred into a muffle furnace where they were ashed at 600 ºC for two hours. The ashed samples were removed from the furnace and allowed to cool in a desiccator.

The cooled ashed samples were carefully transferred into four different 100 cm^3 beakers. Then 10 cm^3 of nitric acid was added to each of the samples for digestion and then placed on a water bath at 99 ºC to boil for 30 minutes. The samples were allowed to cool. The cooled solubilised sample was further filtered using a filter funnel and filter paper into a 1000 cm^3 volumetric flask, and the filtrate was made up to the mark with distilled water and stored in sample containers. The filtrates of each of the fish samples were analysed using Atomic Absorption Spectrophotometer, AAS 500F (PG instruments LTD, UK) to determine the concentration of the following heavy metals in each of the samples: Pb, Mn, Cu, Fe, Zn, Cr, Ni, As, Cd, Co.

Metal pollution index

The metal pollution index (Pi) is applied to assess the contamination of metals among the different organs of the fish samples under investigation [6].

The Pi is calculated by the following equation:

$$Pi = Ci/Csi$$

where, Pi is the monomial pollution index of metal i; Ci is the content of metal i in the fish samples (µg/g of wet weight); Csi is the threshold value of metal i in the fish samples.

The Pi value is divided into four pollution levels. Pi < 0.2 suggests no significant pollution, 0.2 < pi < 0.6 indicates minor pollution, 0.6 < pi < 1 represents a moderate pollution, and pi > 1 illustrates a severe pollution [6].

Results and Discussion

The result of the metal uptake and accumulation in fishes living in polluted water of Rivers State, Nigeria, are shown on Table 1, while the pollution index analysis is indicated on Table 2.

Table 1: Concentration of selected heavy metals in fish species from Abuloma River (µg/g)

	Parameters									
Samples	**Pb**	**Mn**	**Cu**	**Ni**	**Zn**	**Cr**	**Fe**	**Cd**	**Co**	**As**
Mullet	0.160±0	0.144±0	0.168±0	ND	0.571±0.001	0.036±0	0.346±0.001	ND	ND	2.389±0.0
Sika fish	0.052±0	ND	ND	ND	0.246±0.001	ND	0.674±0.001	ND	ND	6.444±0.002
Catfish	0.235±0	0.001±0	ND	ND	0.457±0.001	0.054±0.01	1.047±0.002	ND	ND	ND
Stockfish	0.024±0	ND	0.276±0	ND	2.779±0.001	0.063±0	0.510±0.002	ND	ND	9.167±0.001
FAO Limits [7]	0.0035	0.2	0.5	0.005	1.0	0.05	0.8	0.007	-	0.002

ND = Not Detected

Table 2: Pollution index of selected heavy metals in fish species from Abuloma river

	Parameters									
Samples	**Pb**	**Mn**	**Cu**	**Ni**	**Zn**	**Cr**	**Fe**	**Cd**	**Co**	**As**
Mullet	45.71	0.72	0.34	0	0.57	0.72	0.43	0	0	1194.5
Sika fish	14.86	0	0	0	0.25	0	0.84	0	0	3222.0
Catfish	67.14	0.01	0	0	0.46	1.08	1.31	0	0	0
Stockfish	6.86	0	0.55	0	2.78	1.26	0.64	0	0	4583.5

The result indicates a Pb concentration of 0.160 ±0.0 µg/g for Mullet fish, 0.052 ±0.0 µg/g for (Sika fish), 0.235±0.0 µg/g (Catfish) and 0.024 ±0.0 µg/g (Stockfish). For Mn, the observable concentrations were 0.144±0.0 µg/g (Mullet fish) & 0.001±0.0 µg/g (Catfish). Mn was not detected in Sika and Stockfish. For Cu analysis, the observed concentrations are 0.166 ±0.0 µg/g (Mullet) and 0.273±0.0 µg/g (Stockfish). Cu was not detected in Sika fish and Catfish, while Ni, Cd and Co were not detected in the fish samples. Zn was detected in all the samples with the following concentrations: 0.571±0.001 ug/g (Mullet), 0.246±0.001 µg/g (Sika fish), 0.457±0.001 ug/g (Catfish) and 2.779±0.001 µg/g (Stockfish). For Cr determination in the fish species, the observed concentration are: 0.036±0.0 ug/g (Mullet), 0.054±0.0 µg/g(Catfish), and 0.063±0.0 µg/g (Stockfish). However, Cr was not detected in Sika fish. The Fe observed in the various fish samples occurred in Mullet fish (0.346±0.001 µg/g), Sika fish (0.674±0.001 µg/g), Catfish (1.047±0.002 µg/g) and Stockfish (0.51±0.002 µg/g). Surprisingly, an elevated concentration of As was detected in three of the four fish samples. The observed concentrations are 2.389±0.0 µg/g (Mullet fish), 6.444±0.002 µg/g (Sika fish) and 9.167±0.001 µg/g (Stockfish). As was not detected in Catfish.

From the results obtained, Pb was far above the limit prescribed by Food and Agricultural Organisation (FAO). The highest concentration of Pb was recorded in Catfish (0.235±0.0 µg/g) and this might be attributed to anthropogenic factors. Lead is a chemical element from the heavy metals category and it is one of the most ubiquitous and useful known metal to humans [8]. Even though it has no essential role in the living organism, Pb is detectable in practically all phases of the inert environment and in all biological systems [9].

Manganese indicated a low concentration far below the observable limit by FAO (0.2 µg/g). The observable Mn could be from natural sources. Copper concentration was also found to be very low compared to the prescribed concentration by FAO (0.5 µg/g). Ni, Cd and Co were not in any way detected and is therefore an indication that no anthropogenic source with Ni, Cd and Co were discharged into the Abuloma River. Zinc concentrations were also found to be low compared to the FAO limit of 1.0 µg/g.

Thus, the highest concentration of observed Zn is 2.78 µg/g in Stockfish. This is an indication that Zn may bioaccumulate in fish with time. Zinc wastes can have a direct toxicity to fish at increased waterborne levels [10]. Fisheries can be affected by either Zn alone or more often together with Cu and other metals [11][12]. The main target of water borne Zn toxicity are the gills [10], where the Ca^{2+} uptake is disrupted leading to hypocalcemia and eventually, death [13].

For Cr and Fe, the observed concentration was slightly above the FAO limits. Cr is an essential nutrient metal necessary for metabolism of carbohydrates [14]. Chromium enters into the aquatic ecosystem through effluents discharged from leather tanneries, textiles, electroplating, metal finishing, mining, dyeing and printing industries, ceramics, photographic and pharmaceutical industries [15][16]. Poor treatment of these effluents can lead to the presence of Cr in the surrounding water bodies, where it is commonly found at potentially harmful levels to fish [17][18][19].

The observed concentration of As is far above the limits prescribed by FAO in the Mullet, Sika and Stock fishes. The As concentration in the fish species are grossly unacceptable. The riverine area where the fishes are sampled is a reservoir of industrial discharge. It is, therefore, not surprising that the As concentration is high in these aquatic species. Arsenic reach aquatic ecosystem by a variety of sources including manufacturing companies, mineral or strip mines, smelting operations and electric generating stations (power points). One major agricultural source of As is the manufacture and use of Arsenical defoliants and pesticides. It also has been used to kill aquatic plants in order to reduce the difficulty encountered during hook and line fishing areas over grown with aquatic vegetation [11].

Arsenic compounds in the third oxidation state (Arsenites) are absorbed fairly rapidly into fish and are more toxic than Arsenic compounds in the oxidation static V (Arsenates) [20]. Acute exposures can result in immediate death because As induces increases in mucus production causing suffocation, or direct detrimental effects on the gill epithelium. Chronic exposures can result in the accumulation of metalloid to toxic levels and it is responsible for several disease conditions [21].

Pollution index analysis

The pollution index results indicate a minor to no significant pollution for Mn, Cu, Ni, Zn, Cd and Co. A severe pollution occurred with Zn and Cr in Stockfish. Cr and Fe also showed a severe pollution in Catfish. Very severe pollution was observed with Pb in Mullet, Sika fish, Catfish and Stockfish, while As showed a very severe pollution index in Mullet fish, Sika fish and Stockfish.

Conclusion

From the results obtained, the Mullet, Sika and Stockfishes are not recommended for human consumption due to the objectionable high concentration of Pb and As observed. These elevated concentrations are as a result of massive industrial activities taking place in the study area which ends up polluting the water body as a result of their effluent discharges. The Catfish, however, was not affected by the As absorption, though further studies may be required to ascertain the suitability of the Catfish obtained from Abuloma river for human consumption.

Conflicting interests

There is no conflicting interest in this work.

Authors contributions

The authors are solely responsible for the funding of this work.

Acknowledgement

The authors wish to acknowledge the Chemistry Laboratory of the Science Laboratory Technology Department, The Federal Polytechnic, Idah, for granting them access to their facilities.

References

[1] Siti, N.P., Mohd, K.S., Mohd, Y.A.S., Nur, A.Y., Nor, A.S., & Siti, A.A. (2018). Toxicity Effects of Fish Histopathology on Copper Accumulation. Tropical Agriculture Science, 42(2), pp. 519-540.

[2] Barbara, J., & Malgorzata, W. (2006). The Metal uptake and Accumulation in Fish Living in Polluted Waters. Soil and Water Pollution Monitoring, Protection and Remediation, 12, pp. 107-114. DOI: 10.1007/978-1-4020-4728-2_6.

[3] Matos, L., Cunha, A., Sousa, A.A., Maranhào, J.P.R., Santos, N.R.S,., Gonçalves, M.M.C., Dantas, S.M.M.M., Sousa, J.M.C.E., Peron, A.P., Silva, F.E.E.D., Alencar, M.V.O.B., Islam, M.T., Aguiar, R.P.S., Melo-Cavalcant, A.A.C., Bonecker, C.C., & Junior, H.F.J. (2017).The influence of heavy metals on toxicogenetic damage in a Brazilian tropical river. Chemosphere, 185, pp. 852-859. DOI: 10.1016/chemosphere.

[4] Khalifa, K.M., Hamil, A.M., Al-Houni, A.Q.A., Achacha, M.A. (2010). Determination of Heavy Metals in Fish Species of the Mediterranean Sea (Libyan Coastline) Using Atomic Absorption Spectrometry. Int. J. Pharmacol. Technol. Res., 2(2), pp. 1350-1354.

[5] Jan, A., Azam, M., Siddiqui, K., Ali, A., Choi, I., & Haq, Q. (2015). Heavy metals and human health: Mechanistic insight into toxicity and counter defense system of antioxidants. Int. J. Mol. Sci., 16, pp. 29592–29630. DOI: 10.3390/ijms161226183.

[6] Liu, Y., Fu, Q., Gao, J., Xu, W.G., & Qin, W.H. (2013). Concentrations and safety evaluation of heavy metals in aquatic products of Yancheng, Jiangsu province. Environ. Sci., 34, pp. 4081–4089. PMID: 24364334.

[7] Food and Agricultural Organisation (FAO). (1983). Complication of legallimits of hazardous substances in fish and fishery products. Food and Agricultural Organization of the limited nation, 102, pp. 764.

[8] Strungaru, S.A., Jitar, O., Plavan, G., & Nicoara, M. (2012). Lead Accumulation in the bodies of Rana Tadpoles. Anglele Stiintifice ale Universitatii "Alexandru Loan Cuza" Din Lasi, S., Biologie Animal, Tom LVIII.

[9] Stancheva, M., Makedonski, L., & Peycheva, K. (2014). Determination of Metal Concentrations of Most Consumed Fish Species from Bulgarian Black Sea Coast. Bulgarian Chemical Communication, 46 pp. 195 – 203.

[10] Hogstrand, C. (2011). Zinc. Academic Press, New York, USA.

[11] Sorensen, E.M.B. (1991). Metal Poisoning in Fish: Environmental and life Sciences Associated. Boca Raton: CRC Press Inc.

[12] Alabaster, J.S., & Lloyd, R. (1982). Water Quality Criteria for fresh water fish. London: FAO by Butter worth Scientific.

[13] Niyogis-Wood, C.M. (2006). Interaction between dietary calcium supplementation and chronic waterborne zinc exposure in Juvenile rainbow trout, Oncorhynchus Mykiss. Comp. Bio-Chem. Physiol., 143(1), pp. 94-102. DOI: 10.1016/j.cbpc.2005.12.007.

[14] Farag, A.M., May, T., Marty, G.D., Easton, M., & Harper, D.D. (2006). The effect of Chronic Chromium exposure on the health of Chinook salmon (Oncorhynchus Tshawytscha). Aquat., Toxicol., 76, pp. 246-257. DOI: 10.1016/j.aquatox.2005.09.011

[15] Arunkumar, R.I., Rajasekaran, P., & Michael, R.D. (2000). Differential effect of chromium compounds on the immune response of the African Mouth breeder, Orechromis Mossambicus (Peters). Fish Shellfish Immunol., 10, pp. 667-676. DOI: 10.1006/fsim.2000.0281

[16] Abbas, H.H., & Ali, F.K. (2007). Study the effect of Hexavalent Chromium on some biochemical, Cytotoxicological and histo pathological aspects of the Oreochrommis Spp., Fish. Pak. J. Biol. Sci.,10, pp. 3973 – 3982. DOI: 10.3923/pjbs.2007.3973.3982

[17] Sfakianakis, D.G., Renieri, E., Kentouri, M., & Tsatsakis, A.M. (2015). Effect of heavy metals on fish larvae deformities. A

Review Environ. Res., 137, pp. 246-255. DOI: 10.1016/j.envres.2014.12.014.

[18] Li, Z.H., Li, P., & Randak, T. (2011). Evaluating the toxicity of environmental concentrations of water borne chromium (VI) to a model teleost, Oncorhynchus Mykiss: a comparative study of in vivo and in vitro. Comp. Biochem. Physiol., 153(4), pp. 402-407. DOI: 10.1016/j.cbpc.2011.01.005.

[19] Pacheco, M., Santos, M., Pereira, P., Martinez, J.I., Alonso, P.J., Soares, M.J., & Lopes, J.C. (2013). EPR detection of paramagnetic chromium in liver of fish (Anguilia Anguilla) treated with dischromate (IV) and associated oxidative stress responses – contribution to elucidation of toxicity mechanisms. Comp. Biochem. Physiol., C157, pp. 132-140. DOI: 10.1016/j.cbpc.2012.10.009.

[20] Liao, C.M., Tsai, J.W., Ling, M.P., Laing, H.M., & Chou, Y.H. (2004). Organ-Specific toxicokinetics and dose-response of Arsenic in tilapia Oreochromis Mossambicus. Arch Environ. Contam. Toxicol., 47, pp. 502 – 510. DOI: 10.1007/s00244-004-3105-2.

[21] Hughes, M.F. (2002). Arsenic toxicity and potential mechanisms of action. Toxicol. Lett., 133, pp. 1-16. DOI: 10.1016/s0378-4274(02)00084-x.