AN ASSESSMENT OF HEAVY METAL CONTENTS IMPACT ON FISH SPECIES OBTAINED FROM KIRI DAM, ADAMAWA STATE

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Abstract: This work compared the heavy metals contents in four fish species obtained from Kiri Dam using Inductively Coupled Plasma Optical Emission Spectrophotometer (ICP-OES). The order of accumulation of heavy metals in the fish species investigated increase in sequence: **Zn > Cu > Ni > Cr > Mn > Pb > Cd > As.** The bioaccumulation factors of metals in the fish species studied indicated that *C. gariepinus* and *O. niloticus* recorded higher values than the other fish species. The result also showed that, the concentrations of the metals accumulated by the fishes differ with specie and metal type. The order of the accumulations of the metals in the organs of the fish species was; Stomach>Gills>Bones>Muscles. The Health Indices of the metals indicated that most of the metals were above the safety region and therefore, the consumption of fish from Kiri Dam could pose health problems for both children and Adults. Further work should be carried out on the levels of the metals during dry and wet seasons to advice the general public on the consumption of fishes from Kiri Dam.

Keywords: Heavy metals, sediments, fish, plants, Kiri Dam

Introduction

All over the world, there is an increasing impact of toxic pollutants on the environment especially the aquatic ecosystem; Nigeria is not left out. Municipal sewage, waste water works upstream; fishing as well agricultural run-offs from sugar cane plantation and factory are some of the commonest anthropogenic activities contributing to the pollution of Kiri Dam in Shelleng LGA of Adamawa State. It has been shown that the impact of pollution load is on the increase both in scope and magnitude (Ekeanyanwu *et al.*, 2010). Chemical pollutants from industries, mineral exploration and exploitation or from other miscellaneous anthropogenic sources are indiscriminately discharged into the water bodies without regard to the health of aquatic life (Milamand Onyia, 2007). Rapid industrialization and urbanization without proper planning and management; increase use of fertilizer and pesticide in agricultural revolution; inadequate consideration of environmental impact analysis of developmental projects and disposal of domestic; municipal, industrial waste and trace elements from mechanic and battery charger workshops; carwash and laundry washes near river banks are some of the commonest anthropogenic activities spear heading the environmental disaster (Badejo *et al.*, 2010).

Among environmental pollutants, heavy metals are of particular concern, due to bioaccumulation in aquatic ecosystem (Censi *et al.*, 2006). The pollution of the aquatic environment with heavy metals has become a worldwide problem in recent times because they are indestructible and most of them have toxic effects on organisms (Ekeanyanwu *et al.*, 2010). It has also been recognized for many years that the concentrations of heavy metals found in coastal areas, whether they are in the dissolved or particulate phase may be derived from a variety of anthropogenic and natural resources (Dalman *et al.*, 2006 and Milam *et al.*, 2012). Studies on heavy metals in rivers, lakes, fish and sediments (Öztürk *et al.*, 2008 and Pote *et al.*, 2008) have been a major environmental focus especially during the last decade. The presence of heavy metals in different foods constitutes a serious health hazards depending on their relative levels. The increasing load of heavy metals has caused imbalance in aquatic ecosystems and the biota growing under such habitats accumulated with high amounts of heavy metals (Cu, Zn, Cd, Cr, Pb, As and Ni etc), which in turn, are being assimilated and transferred within the food chains by the process of biomagnification (Kara *et al.*, 2003).

Materials and Methods

Study area

Kiri Dam was built to provide irrigation for the Savannah Sugar Company (SSC), a large-scale sugar cane processing company set up as a joint venture between the Nigerian Federal Government and the Common-Health Development Corporation (CDC), London. The CDC was the managing agent for the project, and the construction contract was awarded to NECCO a company largely owned by the government (Samuel, 1998).

The Kiri dam hosts municipal sewage and wastewater works from upstream as well agricultural wastes from farmlands during run-offs (Fig. 1). People within the upstream vicinity and in the catchment town draw water from the dam for drinking and some other domestic uses. Also the dam reservoir serves as the major source of fish as fishes are being caught and sold to the public in the State’s headquarter and the surrounding towns. The presence of a large number of marine animals like hippopotamus in the dam makes it a unique ecosystem for tourism purposes. Above all, the Government of Adamawa State recently signed an agreement with the Republic of Cameroun to actualize the proposal of the United States Trade Development Agency in October, 2008 on construction of a 35MW Hydro-electric power plant at the dam.

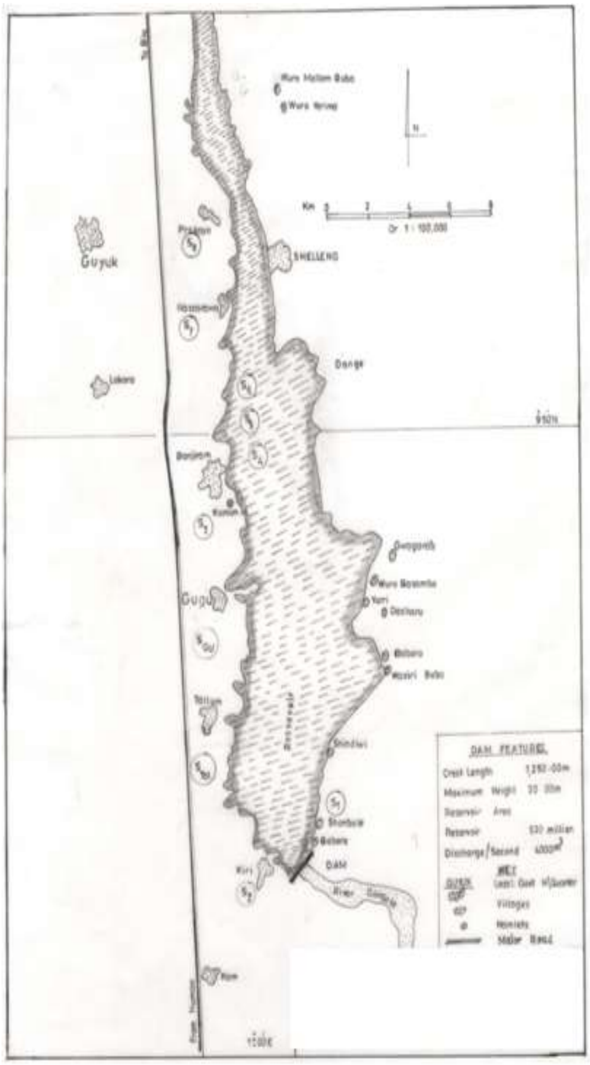

Fig. 1: Map of Kiri Dam showing sampling locations

Sampling and sample preparation

Fish samples

A total of twenty samples (five each of *Clarias gariepinus* (cat fish), *Synodontis batensisda*, *Oreochromis niloticus* (Tilapia) and *Heterotis niloticus* (African crap), respectively were bought from fishermen at the various dam sites within the period of six months. The fish samples were thoroughly washed and rinsed with deionized water to remove adhering contaminants. The fish samples were transported to the laboratory in ice flakes coolers. The lengths and weights of the fish samples were recorded. The gills and muscles of each fish were dissected out and placed in separate Petri dishes and were dried in an oven. These were then digested according to methods described by Van Loon (1980) and Du Preez and Steyn (1992). Samples of gills, bone, intestine and dorsal muscles weighing 0.5 g each was transferred into a digestion tube containing 35 mL of a mixture of nitric and perchloric acid (6:1) and were left overnight at room temperature. The next day, the samples were placed on a hot plate and heated at 135°C for 2 h. Excess nitric acid was added until most of the organic matter and fatty material were destroyed. The colourless liquor formed was slowly evaporated to dryness (prolonged baking avoided), cooled and dissolved in 5 mL of 20% nitric acid and diluted to 25 mL mark in a graduated cylinder with ultrapure water.

Sample analysis

The heavy metals; Cd, Cu, Cr, Pb, Mn, Ni, Fe, and Zn in sediments were analyzed with Inductively Coupled Plasma Optical Emission Spectrophotometer ICP-OES (Perkin Elmer 2004 Model 200 DV).

Statistical analysis

Each sample was analyzed in triplicate and the average values recorded. The data were tested for goodness of fit to a normal distribution, using a Kolmogorov–Smirnow one-sample test. Student's t tests were used to detect significant differences in fish's concentrations of heavy metals and As between samples collected and between body parts. Evaluations of significant differences among means were performed using one-way ANOVA followed by Tukey's post-hoc test, with $p < 0.05$ indicating statistical significance.

Results and Discussion

Heavy metal levels in parts of fish

The mineral elements and heavy metal contents of Catfish and *Synodontis* sp (benthic fishes), Tilapia and African carp (pelagic fishes) from Kiri-dam were shown in Figs. 2 – 10. The heavy metals analyzed in the fishes were arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), manganese (Mn), nickel (Ni), lead (Pb), and zinc (Zn) and the mineral elements were potassium (K), calcium (Ca), sodium (Na) and iron (Fe). The investigations of the muscles, gills, bones, and stomach organs/tissues of the fish species showed that all the fish species accumulated the heavy metals and higher concentrations of the mineral elements.

Concentrations of arsenic in fish samples

The concentrations of arsenic in muscles, gills, bones, and stomach of the five fish species studied are represented in Fig. 2. It was revealed that *O. niloticus* had the highest amount of arsenic in bones (33 mg/kg) followed by its bones of *C. gariepinus* (30 mg/kg) and in the gills of *S. batensisda* (27.5 mg/kg).

The result obtained showed significant difference ($p>0.05$) in arsenic concentrations in different body parts of both the pelagic and benthic fishes. From observation, the arsenic values in this study were seen to be higher than the WHO (1996) tolerance (permissible) limits. The result agreed with previous studies by Zhang *et al*. (2007) on analysis of As, Cu, and Hg in muscles and intestines tissues of some fishes in Gorge's Reservoir, China. This result warned the consumers of these fish species in the catchment of health risk as the result of As exposure. Heavy metals such as arsenic, cadmium, lead and chromium are said to be associated with mixture of waste water and sewage sludge (Mapanda *et al.*, 2007). Nyirenda *et al.* (2011) reported that long term exposure to inorganic arsenic in drinking water is mainly associated with skin cancer, as well as other skin lesions such as hyper keratosis and pigmentation changes (black foot disease). Chronic exposure to inorganic arsenic has the risk to several health effects, such as gastrointestinal tract, respiratory tract, skin, liver, cardiovascular system, hematopoietic system and the nervous system (Mandal and Suzuki, 2001).

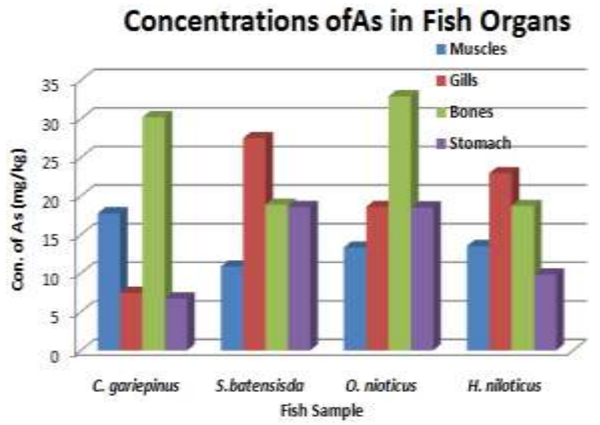

Fig. 2: Distribution of arsenic (mg/kg^{-1}) in organs of fish samples for Kiri Dam

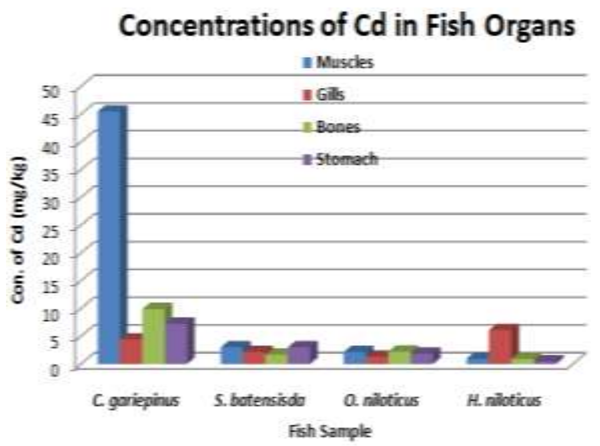

Fig. 3: Distribution of cadmium (mg/kg^{-1}) in organs of fish samples for Kiri Dam

Concentrations of cadmium in fish samples

The concentrations of cadmium in the body part of fish species investigated are represented in Fig. 3. From the result, catfish had the highest concentration of cadmium in the muscle (44 mg/kg), bones (10 mg/kg) and also stomach (7.3 mg/kg). African carp fish on the other hand, followed with 6.0 mg/kg in the gills. The lowest concentration of Cd among the fish species was detected in the stomach (0.45 mg/kg) of African carp fish. The cadmium concentrations in the fish species was in the following order: *C. gariepinus* > *S. batensisda* > *H. niloticus*> *O. niloticus.* The concentrations of cadmium detected in all the parts of the fish samples analysed were well above the tolerance limit (0.2 mg/kg) (WHO, 1996).

The concentrations of cadmium in *C. gariepinus* (muscles) may be due to its ability to survive in mud sediment with high Cd metal pollutant for a very long period and thus accumulating Cd in the body of this fish. Sediments had been known to act as the most important reservoir or sink of metals and other pollutants in aquatic environment (Ozturk *et al.*, 2009; Nyirenda *et al.*, 2011). Bioaccumulation of heavy metals may occur when benthic fishes feed on benthic invertebrates that ingest particulate matter (Milam and Onyia, 2007). Cadmium is known to be one of the most harmful heavy metals and is capable of inducing serious renal, hepatic and testicular injuries at even very low concentration (Adeyeye and Ayoola, 2010). The presence of cadmium in sediments and fish parts may be as a result of industrialization and other anthropogenic activities (Adefemi *et al.*, 2008).

Concentrations of chromium in fish samples

The concentrations of chromium in parts of the fish species investigated are represented in Fig. 4. There was a considerable variation (P>0.05) in chromium contents in different parts of fish sample. The concentrations of chromium detected were high in the stomach, bones muscles and gills of *C. gariepinus* followed by the organs of *S. batensisda*. The result revealed a regular distribution pattern of chromium concentration in muscles, gills, bones and stomach parts of the fish species which followed the sequence: *H. niloticus* <*S. batensisda*<*O. niloticus* >*C. gariepinus.* These observations may be due to difference in fish habitat, metabolism, anthropogenic activities and surrounding ecosystem status. The Cr levels were much less than those reported by Eisenberg and Topping (1986) and Zhang *et al.* (2007). The values were also far above the limits of 1.2 – 1.3 mg/kg (USFDA, 1993). Cr as Cr (VI) is carcinogenic to human (WHO, 1996). Excessive Cr exposure could affect the development of fetus in mothers and could also lead to DNA damage resulting to cancer and genetic mutations (Nyirenda *et al.*, 2011).

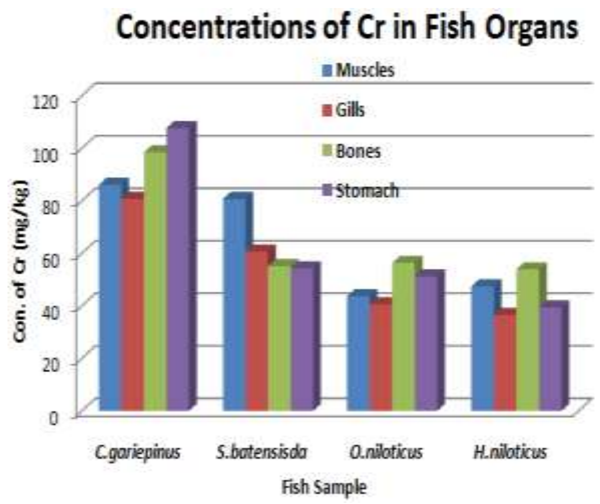

Fig. 4: Distribution of cromium (mg/kg^{-1}) in organs of fish samples for Kiri Dam

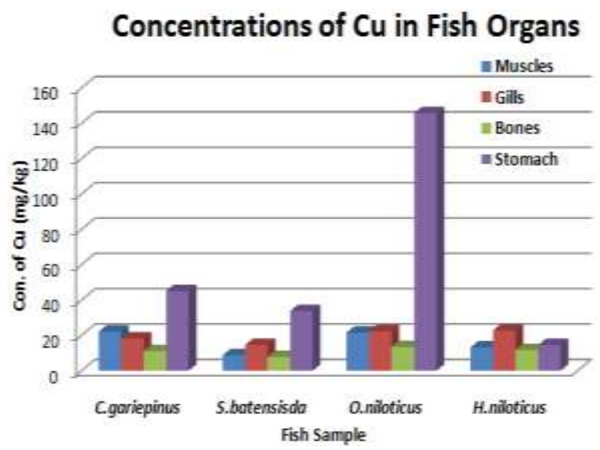

Fig. 5: Distribution of copper (mg/kg^{-1}) in organs of fish samples for Kiri Dam

Concentrations of copper in fish in fish samples

The concentration of copper in body parts of four fish species taken from Kiri dam is represented in Fig. 5. The highest concentration of copper among the fishes was detected in the stomach of *O. niloticus* followed by the stomach of *C. gariepinus* then stomach of *S. batensisda* andthe least was in the muscles of *H. niloticus*. The high concentrations of copper in the stomach and gills of the fish samples indicated that, the fish during feeding makes use of the gills and stores the particles in the stomach. Many studies have also demonstrated that diet is the most important route of Cu accumulation in aquatic animals (Sindayigaya *et al.,* 1994; Ibrahim and Said, 2010). However, Cu concentrations are lower than the values reported by Zhang *et al.* (2007); Adeyeye and Ayoola (2010); Ibrahim and Said (2010). The copper contents in the sample were much higher than WHO permissive limit (3.0 mg/kg). Excessive intake of Cu is said to be responsible for liver cirrhosis, dermatitis and neurological disorders (Zhang *et al.,* 2007).

Concentrations of manganese in fish samples

Figure 6 below represents the concentrations of manganese (Mn) in fish species studied. High manganese concentrations were detected in bones, stomach and gills parts of *C. gariepinus* followed by gills and bones of *H. niloticus* and the least was in *S. batensisda*. It would be noted that although the fish species had considerable concentrations of Mn in other parts, their muscles contents were very low with no significant difference (P<0.01) between the values. Manganese is an essential trace element which contributes to the well-being of the cells in humans and most at times acts as co-factor in some enzymatic reactions such as those involved in phosphorylation, cholesterol and synthesis of fatty acids.

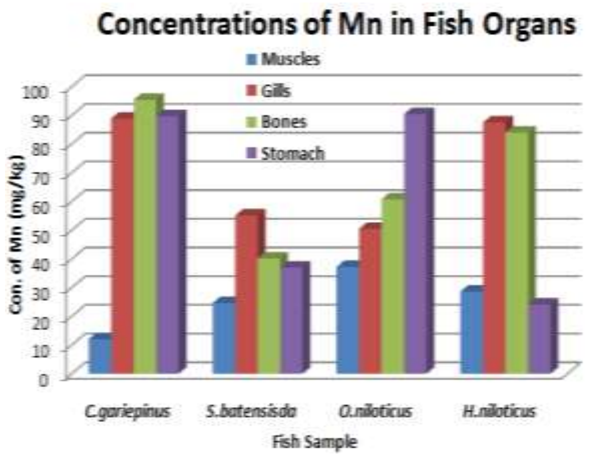

Fig. 6: Distribution of manganese (mg/kg^{-1}) in organs of fish samples for Kiri Dam

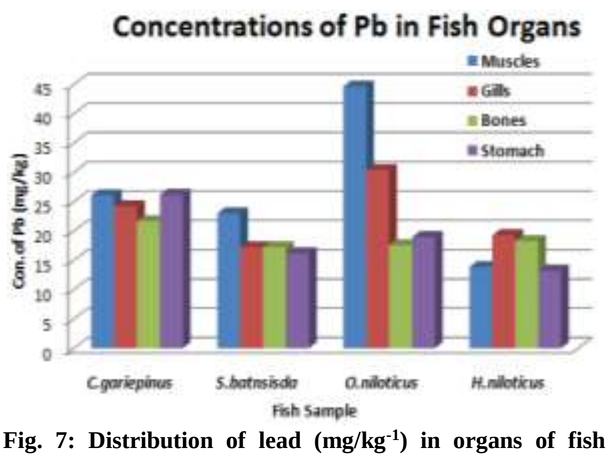

Fig. 7: Distribution of lead (mg/kg^{-1}) in organs of fish samples for Kiri Dam

Concentrations of lead in fish samples

The concentrations of lead in the four fish species studied are represented in Fig. 7. Highest concentrations of Pb were detected in muscles (45 mg/kg) of followed by gills (30 mg/kg) of Tilapia fish (*O. niloticus*). Muscles, stomach and gills of catfish also accumulated appreciable concentrations of Pb but African carps fish had lower concentrations. The concentrations of Pb obtained in this study is higher than the WHO (1996) value (0.2 mg/kg)

Concentration of zinc in fish samples

The concentrations of Zn in the four fish species is represented in Fig. 8. Zn was found in considerable amount in all the parts of the fish samples. High Zn conscentrations were detected in stomach and gills of the fish species, however, African carp fish predominated followed by *Synodontis* species and the lowest concentration was in catfish. Zn is an abundant mineral element and is found in most rocks and soils; it could be possible that the differences in Zn concentrations in the fish species within the sample areas of the Dam could have arisen from disparity in geological processes at work within the catchment (Milam and Onyia, 2007). This agrees with the recorded high concentrations of Zn in parts of Tilapia fishes that was the pelagic (Ibrahim and Said, 2011) but were contrary the work of Milam and Onyia (2007) that recorded higher Zn concentrations in the gills of benthic fishes than the pelagic. Toxicity due to excessive intake of Zn has been reported to cause electrolyte imbalance, nausea, anemia, lethargy and diarrhea and affects the hepatic distribution of other metals in fish (Zhang *et al.,* 2007; Adeyeye *et al.,* 2010). Thus, in processing fish for consumption, it is advisable to discard both gills and stomach (intestines) so as to reduce the risk of heavy metals consumption from contaminated fish.

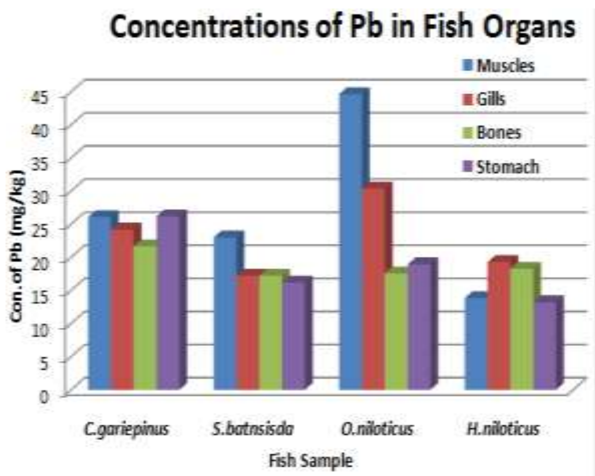

Fig. 8: Distribution of zinc (mg/kg^{-1}) in organs of fish samples for Kiri Dam

Concentration of nickel in fish

The concentrations of Ni in fish samples investigated from Kiri Damare represented in Fig. 9. Ni concentrations detected in fish parts were low in the samples collected from the dam. Lower concentrations of Ni were recorded in catfish and African carp while higher concentrations were recorded in stomach of Tilapia and African carp but the least concentration was in catfish (stomach). This agrees with the observations of Ozeomena (2010) but the results were lower than what was reported by Adeyeye and Ayoola (2010).

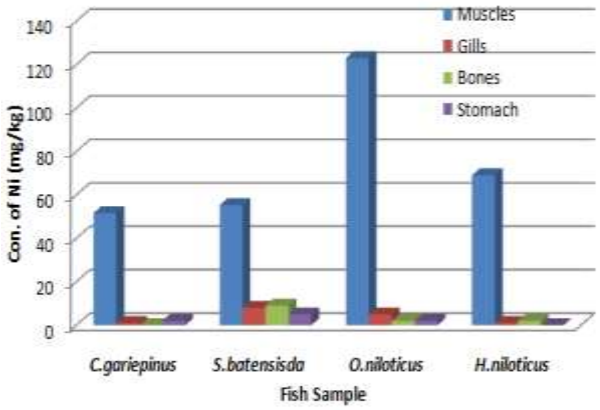

Fig. 9: Distribution of nickel (mg/kg^{-1}) in organs of fish samples for Kiri Dam

Table 1: Health risk estimates associated with heavy metals in fish species

Fish type			Heavy Metals				
			As	*Pb	*Cr	*Cu	*Cd
RfD			7.00E-03	4.0E-03	1.5	4.0E-02	1.0E-03
Catfish	ED	Children	0.0474	0.0695	0.229	0.0588	0.116
		Adult	0.0203	0.0298	0.0983	0.0252	0. 050
	HI	Children	6.77	17.375	0.153	1.47	116
		Adult	2.90	7.45	0.066	0.63	50
Synodontis	ED	Children	0.029	0.061	0.2154	0.0231	0.0065
		Adult	0.0124	0.026	0.0923	0.0099	0.0028
	HI	Children	41.43	15.25	0.144	0.5775	6.5
		Adult	1.77	6.5	0.062	0.2475	2.8
Tilapia fish	ED	Children	0.03477	0.1909	0.1164	0.0574	0.0057
		Adult	0.01490	0.0510	0.0499	0.0246	0.0025
	HI	Children	4.97	47.725	0.776	1.46	5.7
		Adult	2.12	12.75	0.0333	0.67	2.5
African carps	ED	Children	0.0362	0.0711	0.1264	0.0415	0.0035
		Adult	0.0155	0.0304	0.0541	0.0178	0.0015
	HI	Children	5.17	17.775	0.84	1.038	3.5
		Adult	2.21	7.6	0.361	0.445	1.5

*FAO/WHO (Codex Alimentarious Commission, 2013 in Chauhan & Chauhan, 2014)
RfD = Reference Dose; **ED –** Estimated Dose Time (mg/kg); **HI =** Health Index
ED and **HI** are calculated from the expressions; **ED** = Conc. of element of interest x Food consumption rate/Body wt, kg; **HI** = ED/ RfD

Health Index < 1 suggests unlikely adverse health effects. Cr is the only metal that its index less than one throughout the work with copper in some fishes. Health Index > 1 suggests the probability of adverse health effects for children and adults. Health risk estimates for arsenic, copper, lead and cadmium were high for the general public at the 0.08 mg/kg, day ingestion rate (Table 1) and for the same elements, were higher for children at the stated ingestion rate.

Conclusion and Recommendation

The concentrations of essential and trace elements obtained were high in fish and were above the safety guidelines. The order of accumulation of heavy metals in the fish species investigated generally increased in sequence: **Zn > Cu > Ni > Cr > Mn > Pb > Cd > As.** The bioaccumulation factors of metals in *O. niloticus, H. niloticus, C. gariepinus* and *S. batensisda* in this study showed that *C. gariepinus* and *O. niloticus* recorded higher values than the rest of the fish species.

From this work, it could be observed that stomach, gills and bones of fish contained higher concentrations of heavy metals and numerous mineral elements, respectively compared to muscles (flesh). It is therefore, generally advisable not to consume the stomach and bones so as to reduce the risk of heavy metals intake from contaminated fish. This study shows that pelagic fish (African carp and Tilapia fishes) contained the higher concentration of Zn and Cu compared to the values of other heavy metals.

The Health Index calculated for the metals as recorded in Table 1 indicated that only Cr was within the safe region of the metals, Cu had some of the values within the safe regions while others in the toxic region and all other metals above the safety region and consumption of fish from Kiri Dam could pose a health problem for both children and Adults. It therefore recommended that further research be carried to ascertain the levels of the metals in both dry and raining to advice the general public.

Conflict of Interest

Authors declare that there is no conflict of interest related to this study.

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