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Research Paper

BIOACCUMULATION OF SOME HEAVY METALS OF SIX FRESH WATER FISHES CAUGHT FROM LAKE CHAD IN DORON BUHARI, MAIDUGURI, BORNO STATE, NIGERIA

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Abstract: Six species of fishes (*Tilapia zilli, Clarias anguillaris, Protoptenus, Oreochromis niloticus, Eutropius niloticus* and *Synodentis budgetti)* were caught from Lake Chad in Doron Buhari between the periods of February to September 2008. The bone, liver, stomach, gills and Kidney from the six species were carefully dissected for the determination of heavy metals. Levels of heavy metals were determined using Perkin-Elmer Analyst 300 Atomic Absorption Spectrophotometry (AAS). The maximum concentration of heavy metals studied was observed in the liver tissues, while bone tissues had the least concentration. The highest level of copper was observed in *O. niloticus*, while *E. niloticus* shows the least. For Co concentrations, the maximum was obtained in *E. niloticus* and the minimum in *C. anguillaris*. High levels of Pb, Fe and Cd were found in the liver tissues of *T. zilli*, while *S. budgetti* had the least concentrations. Variations in the parameters determined were found to be statistically significant ($p<0.05$). Based on the result obtained, the levels of the elements under study in the six species were within tolerance limits that are safe for human consumption.

Keywords: Bioaccumulation, heavy metals, fishes, Lake Chad, Maiduguri, Borno State

INTRODUCTION

Available information suggests that the concentrations of toxic metals in many ecosystems are reaching unprecedented levels. Due to the steady load of contaminated dust in overcrowded cities, the ambient concentrations of toxic metals are now among the highest ever being reported. Metals are elements that generally do not break down further into less harmful constituent; they accumulate where they are released [1]. The problem of pollution is attracting the attention of people around the world. With increased urbanization and industrialization, there has been a rapid increase in the municipal waste water (sewage water and industrial effluents), which in turn has intensified the environmental pollution. The disposal of industrial effluents and municipal wastes is therefore a major problem for big cities. The major sources of contamination in surface water can be traced to industrial discharges, domestic waste disposal and application of agrochemicals on farmlands [1]. The pollutants like heavy metals after entering into aquatic environment accumulate in tissues and organs of aquatic organisms. The amount of absorption and assembling depends on ecological, physical, chemical and biological condition and the kind of element and physiology of organisms [2]. Also sexuality, weight, age, feeding habits and tissues trace can be effective [3, 4]. These metals after accumulation by the body of aquatic organisms enter into food chain and extremely consumed by human [5]. Reactions of these element depends on the concentration, physiochemical properties, chemical bonds and their solution on the absorption, accumulation, distribution in body and physiological effects on metals [5, 6]. Human mediation activities have locally and episodically introduced numerous potentially hazardous metals to the environment since the onset of industrial revolution [7-10]. Aquatic ecosystems are very vulnerable to water pollution. Concern over the environmental, aquatic and human health impacts associated with heavy metals distributions and concentrations in aquatic environments have a long history [10]. Notably aquatic ecosystems are often polluted with anomalously high levels of toxicants (organic and inorganic substances), which find their way into the aquatic systems with wastewater and effluents generated from industrial enterprises [9]. Heavy metal accumulation in aquatic ecosystem shows that they are accumulated either in aquatic organisms [11-13] or in the sediment.

In recent years, there has been an increasing interest in the utilization of fishes as bioindicators of the integrity of aquatic environmental systems [14-17]. Several studies have indicated enhanced levels of both non-essential and essential heavy metal load in muscle and liver tissues of fishes [18-20]. The frequent presence of Pb and Cr, Zn and Cd in industrial wastes and its high toxicity along with considerable bioaccumulation in freshwater fishes make it a toxicant that should be given due consideration in aquatic toxicology. Fish accumulate xenobiotic chemicals, especially those with poor water solubility occurs because of the very intimate contact with the medium that carries the chemicals in solution or suspension and also because fish have to extract oxygen from the medium by passing enormous volumes of water over the gills. Fish kill or injury due to metal contamination is considered the primary cause of reducing fish populations and other animals including humans through the food chain. [21]. Behavioural avoidance of contaminants may be an additional cause of reduced fish populations [22]. For fish, the gills, skin and digestive tract are potential sites of absorption of water- borne chemicals. The chemicals once absorbed are transported by the blood to either a storage point such as the bone, or to the liver for transportation. If transported by the liver, it may be stored there, excreted in the bile, or passed back into the blood for possible excretion by the kidney or gills or stored in extra hepatic tissues such as fat [22]. The concentration of heavy metal were found generally higher in the liver and gills than in the gonad and muscle tissues in three species Dicentrachus ibrax D. sparus arata D and Mugli cphalus L; the levels of all metals in a given tissue were generally higher in Mugil Cephalus [23]. The muller fish, Liza klunzinger, commercially important and widely relished by Kumaiti residents and the stressed ecosystem in Kuwait Bay instigated us to conduct toxicity and bioaccumulation tests on heavy metals (Pb, Ni, V, Cu, and Fe). Among five metals, Pb had the lowest observed effect concentration at tissues-gills, kidneys, liver, skin and muscle of Clarias batrachus exposed to sub lethal concentration (7 ppm) of cadmium chloride was investigated and the mean rate of accumulation of exposure was in the order gills>kidneys>liver>skin>muscle [24]. Bhattacharya *et al.*[25] observed that chromium and cadmium in the muscles tissue and gill of six commercially edible fishes is higher than gonads and skin in upper course of gangetic West Bengal, India.

Lake Chad received a wide variety of waste from agricultural activity. This waste generated contaminates the Lake with a variety of heavy metals acting as point sources. The lake is one of the main fish supply sources for Borno State and other parts of Nigeria. A lot of fishing activities take place in the lake and fish from the lake supplements the protein requirements of the inhabitants within the area, thus the contamination of fish and the aquatic environment by heavy metals is viewed with serious concern. This study therefore aims at determining the levels of some heavy metals (Cu, Co, Pb, Cr, Mn, Fe, Ni, Cd, Zn, As, and Mg) in bone, liver, stomach, gills and Kidney tissues of six commercially important species of fishes (*Tilapia zilli, Clarias anguillaris, Proptoptenus, Schilbedae intermediu* and *Synodentis budgetti)* caught within Lake Chad, Maiduguri, Borno State, Nigeria.

MATERIALS AND METHODS

The study was carried out at Doron Buhari region situated along Lake Chad in Maiduguri, Borno State, Nigeria during the period of February to September 2008. Fish samples, specimen of uniform size were collected in order to avoid the possible error due to size differences. The different organs (bone, liver, stomach, gills and Kidney) were carefully dissected after rinsing with double distilled water and oven dried at 110 ^{O}C. The heavy metal concentrations in the dried samples were estimated after acid digestion following standard methods as laid down in [26], using Atomic Absorption spectrophotometer. The results were expressed in µg g^{-1} metal per dry weight.

RESULTS AND DISCUSSION

The concentrations of heavy metals in different organs (bone, liver, stomach, gills and kidney) of *T. zilli, C. anguillaris, Protoptenus, O. niloticus, E. niloticus* and *S. budgetti* are as presented in Table 1 to 5. The distribution of heavy metals in all the fish organs studied are in the order of liver> gills> stomach> kidney> bone. The levels of copper in the different organs of the six species of fish range between 0.01±0.01 and 0.65±0.11 µg g^{-1} Table 1 to 5. The higheset concentration of copper (0.65±0.11 µg g-1) was detected in the liver tissue of *O. niloticus* Table 4, while the lowest detected limit (0.01±0.01µg g^{-1}) was found in the bone tissue of *E. niloticus* Table 5. Liver concentrates higher levels of copper in all the six species of fishes than the other organs Table 1 to 5, This high level of copper in the liver tissues for all the fishes is due to the fact that, the liver is a target organ for the accumulation of this element. For the gills samples, it may be due to the fact that freshwater fishes gills might be expected to be the primary route for the uptake of water borne pollutants [27]. WHO [28] reported that copper toxicity in fish is taken up directly from the water via gills and stored in the liver, the present study showed the similar accumulation of copper in the gills and livers. Effects of high concentrations of copper in fish are not well established; however, there is evidence that high concentrations in fish can lead to toxicity [29]. Copper can combine with other contaminants such as ammonia, mercury, and zinc to produce an additive toxic effect on fish [30, 31]. However, the concentrations of copper levels in bone, liver, stomach, gills and Kidney tissues of *T. zilli, C. anguillaris, Protoptenus, O. niloticus, E. niloticus* and *S. budgetti* from Lake Chad were below the maximum level of 1.0µg g^{-1} reported by [32]. The concentration of copper was highest in the liver of *O. niloticus,* while the bone of *E. niloticus* shows the least concentration.

Table 1: Concentration of heavy metals in different organs of *Tilapia zilli* caught from Lake Chad

Organs	Concentrations (µg g^{-1})										
	Cu	Co	Pb	Cr	Mn	Fe	Ni	Cd	Zn	As	Mg
Bone	0.02 ± 0.01	0.12 ± 0.02	0.01 ± 0.01	0.02 ± 0.01	0.22 ± 0.06	0.21 ± 0.01	0.01 ± 0.01	0.11 ± 0.03	0.13 ± 0.02	0.01 ± 0.01	0.21 ± 0.01
Liver	0.52 ± 0.10	0.32 ± 0.03	0.32 ± 0.12	0.18 ± 0.04	0.32 ± 0.03	0.34 ± 0.02	0.03 ± 0.01	0.22 ± 0.04	0.54 ± 0.06	0.04 ± 0.02	0.41 ± 0.03
Stomach	0.34 ± 0.05	0.21 ± 0.02	0.02 ± 0.01	0.11 ± 0.03	0.20 ± 0.02	0.15 ± 0.05	0.02 ± 0.01	0.02 ± 0.01	0.20 ± 0.02	0.02 ± 0.01	0.31 ± 0.12
Gills	0.45 ± 0.01	0.22 ± 0.06	0.03 ± 0.01	0.21 ± 0.02	0.29 ± 0.07	0.28 ± 0.04	0.04 ± 0.01	0.01 ± 0.01	0.33 ± 0.10	0.03 ± 0.01	0.37 ± 0.07
Kidney	0.31 ± 0.03	0.16 ± 0.01	0.01 ± 0.01	0.12 ± 0.06	0.13 ± 0.01	0.15 ± 0.02	0.02 ± 0.01	0.10 ± 0.02	0.12 ± 0.08	0.01 ± 0.01	0.24 ± 0.12

Table 2: Concentration of heavy metals in different organs of *Clarias anguillaris* caught from Lake Chad

Organs	Concentrations (µg g^{-1})										
	Cu	Co	Pb	Cr	Mn	Fe	Ni	Cd	Zn	As	Mg
Bone	0.04 ± 0.02	0.11 ± 0.07	0.01 ± 0.01	0.03 ± 0.01	0.14 ± 0.02	0.11 ± 0.02	0.02 ± 0.01	0.01 ± 0.01	0.11 ± 0.04	0.02 ± 0.01	0.13 ± 0.02
Liver	0.32 ± 0.01	0.43 ± 0.10	0.15 ± 0.05	0.23 ± 0.02	0.29 ± 0.01	0.26 ± 0.09	0.01 ± 0.01	0.03 ± 0.01	0.31 ± 0.11	0.02 ± 0.01	0.42 ± 0.12
Stomach	0.27 ± 0.04	0.13 ± 0.02	0.01 ± 0.01	0.15 ± 0.01	0.13 ± 0.04	0.18 ± 0.03	0.01 ± 0.01	0.01 ± 0.01	0.15 ± 0.01	0.01 ± 0.01	0.21 ± 0.01
Gills	0.32 ± 0.14	0.42 ± 0.03	0.10 ± 0.02	0.17 ± 0.04	0.22 ± 0.05	0.24 ± 0.01	0.03 ± 0.02	0.02 ± 0.01	0.28 ± 0.06	0.03 ± 0.02	0.32 ± 0.03
Kidney	0.21 ± 0.05	0.14 ± 0.01	0.02 ± 0.01	0.13 ± 0.02	0.11 ± 0.02	0.12 ± 0.03	0.01 ± 0.01	0.01 ± 0.01	0.13 ± 0.03	0.01 ± 0.01	0.21 ± 0.04

Table 3: Concentration of heavy metals in different organs of *Protoptenus* caught from Lake Chad

Organs	Concentrations (µg g^{-1})										
	Cu	Co	Pb	Cr	Mn	Fe	Ni	Cd	Zn	As	Mg
Bone	0.11 ± 0.05	0.21 ± 0.05	0.02 ± 0.01	0.21 ± 0.07	0.12 ± 0.03	0.23 ± 0.04	0.01 ± 0.01	0.10 ± 0.02	0.12 ± 0.01	0.01 ± 0.01	0.16 ± 0.04
Liver	0.34 ± 0.02	0.42 ± 0.05	0.11 ± 0.04	0.23 ± 0.02	0.32 ± 0.13	0.33 ± 0.06	0.12 ± 0.03	0.14 ± 0.02	0.50 ± 0.03	0.11 ± 0.04	0.43 ± 0.14
Stomach	0.22 ± 0.03	0.12 ± 0.01	0.02 ± 0.01	0.21 ± 0.06	0.13 ± 0.01	0.12 ± 0.02	0.11 ± 0.02	0.01 ± 0.01	0.18 ± 0.02	0.01 ± 0.01	0.27 ± 0.11
Gills	0.41 ± 0.08	0.32 ± 0.05	0.21 ± 0.04	0.25 ± 0.11	0.22 ± 0.04	0.26 ± 0.05	0.02 ± 0.01	0.02 ± 0.01	0.30 ± 0.03	0.03 ± 0.01	0.41 ± 0.15
Kidney	0.10 ± 0.01	0.21 ± 0.04	0.02 ± 0.01	0.22 ± 0.03	0.13 ± 0.03	0.14 ± 0.02	0.01 ± 0.01	0.01 ± 0.01	0.13 ± 0.02	0.01 ± 0.01	0.31 ± 0.06

Table 4: Concentration of heavy metals in different organs of *Oreochromis niloticus* caught from Lake Chad

Organs	Concentrations (µg g^{-1})										
	Cu	Co	Pb	Cr	Mn	Fe	Ni	Cd	Zn	As	Mg
Bone	0.02 ± 0.01	0.12 ± 0.01	0.21 ± 0.01	0.21 ± 0.04	0.12 ± 0.02	0.12 ± 0.02	0.01 ± 0.01	0.01 ± 0.01	0.12 ± 0.05	0.01 ± 0.01	0.16 ± 0.03
Liver	0.65 ± 0.11	0.24 ± 0.06	0.16 ± 0.06	0.35 ± 0.12	0.45 ± 0.18	0.22 ± 0.01	0.11 ± 0.04	0.18 ± 0.02	0.62 ± 0.21	0.12 ± 0.01	0.55 ± 0.17
Stomach	0.22 ± 0.02	0.21 ± 0.10	0.02 ± 0.01	0.26 ± 0.02	0.15 ± 0.06	0.15 ± 0.04	0.10 ± 0.05	0.05 ± 0.02	0.16 ± 0.03	0.01 ± 0.01	0.32 ± 0.04
Gills	0.43 ± 0.16	0.45 ± 0.12	0.14 ± 0.03	0.31 ± 0.05	0.30 ± 011	0.17 ± 0.03	0.04 ± 0.01	0.10 ± 0.04	0.45 ± 0.21	0.05 ± 0.02	0.44 ± 0.12
Kidney	0.10 ± 0.02	0.13 ± 0.02	0.21 ± 0.01	0.24 ± 0.10	0.13 ± 0.05	0.14 ± 0.01	0.02 ± 0.01	0.03 ± 0.01	0.13 ± 0.01	0.02 ± 0.01	0.21 ± 0.02

Table 5: Concentration of heavy metals in different organs of *Schilbedae (Eutropius niloticus)* and *Synodentis budgetti* caught from Lake Chad

Organs	Concentrations (μg g^{-1})										
	Cu	Co	Pb	Cr	Mn	Fe	Ni	Cd	Zn	As	Mg
E. niloticus											
Bone	0.01 ± 0.01	0.32 ± 0.14	0.02 ± 0.01	0.03 ± 0.01	0.22 ± 0.10	0.21 ± 0.01	0.01 ± 0.01	0.11 ± 0.05	0.13 ± 0.06	0.01 ± 0.01	0.24 ± 0.11
Liver	0.43 ± 0.08	0.50 ± 0.17	0.21 ± 0.11	0.18 ± 0.07	0.35 ± 0.14	0.27 ± 0.02	0.05 ± 0.02	0.12 ± 0.02	0.33 ± 0.02	0.02 ± 0.01	0.35 ± 0.18
Stomach	0.34 ± 0.07	0.13 ± 0.05	0.02 ± 0.01	0.11 ± 0.02	0.20 ± 0.02	0.15 ± 0.01	0.02 ± 0.01	0.02 ± 0.01	0.20 ± 0.03	0.02 ± 0.01	0.31 ± 0.05
Gills	0.32 ± 0.03	0.21 ± 0.02	0.03 ± 0.01	0.21 ± 0.05	0.32 ± 0.03	0.28 ± 0.12	0.03 ± 0.01	0.01 ± 0.01	0.44 ± 0.11	0.02 ± 0.01	0.37 ± 0.14
Kidney	0.31 ± 0.01	0.12 ± 0.05	0.02 ± 0.01	0.12 ± 0.02	0.13 ± 0.01	0.15 ± 0.01	0.02 ± 0.01	0.10 ± 0.03	0.13 ± 0.04	0.03 ± 0.02	0.21 ± 0.12
S. budgetti											
Bone	0.02 ± 0.01	0.13 ± 0.04	0.01 ± 0.01	0.03 ± 0.01	0.14 ± 0.02	0.10 ± 0.03	0.02 ± 0.01	0.01 ± 0.01	0.13 ± 0.07	0.04 ± 0.02	0.15 ± 0.03
Liver	0.32 ± 0.11	0.45 ± 0.10	0.15 ± 0.02	0.40 ± 0.13	0.22 ± 0.04	0.26 ± 0.05	0.01 ± 0.01	0.03 ± 0.01	0.31 ± 0.03	0.02 ± 0.01	0.32 ± 0.13
Stomach	0.27 ± 0.07	0.32 ± 0.01	0.02 ± 0.01	0.15 ± 0.04	0.13 ± 0.11	0.18 ± 0.05	0.01 ± 0.01	0.01 ± 0.01	0.15 ± 0.01	0.01 ± 0.01	0.21 ± 0.02
Gills	0.32 ± 0.05	0.42 ± 0.12	0.10 ± 0.11	0.17 ± 0.02	0.29 ± 0.11	0.24 ± 0.12	0.03 ± 0.02	0.02 ± 0.01	0.28 ± 0.10	0.02 ± 0.01	0.32 ± 0.11
Kidney	0.21 ± 0.01	0.11 ± 0.03	0.02 ± 0.01	0.13 ± 0.02	0.12 ± 0.02	0.12 ± 0.03	0.01 ± 0.01	0.01 ± 0.01	0.13 ± 0.03	0.01 ± 0.01	0.21 ± 0.06

The concentrations of cobalt in the different organs of all the six species of fishes are as presented in Table 1 to 5. The maximum concentrations of cobalt (0.50±0.17 μg g^{-1}) was detected in the liver tissue of *E. niloticus* Table 5, while the lowest detection limit of 0.11±0.07μg g^{-1} was observed in the bone tissue of *C. anguillaris* Table 2. Cobalt has not been considered in compliance policies or MCL and NCBP guideline. In *T. zilli, C. anguillaris, Protoptenus, O. niloticus, E. niloticus* and *S. budgetti* liver were the target organs of cobalt, while the bone showed the lowest concentration. The result is in line with the work of [33] who indicated that in fish, the liver is the major storage organ for cobalt. Accumulation in the liver can be the result of detoxicating mechanisms and may originate from metal in the food [34, 35]. However, the liver is the preferred organ for metal accumulation as could be deduced from the present study.

Lead accumulates significantly in the bone, liver, stomach, gills and kidney tissue of *T. zilli, C. anguillaris, Protoptenus, O. niloticus, E. niloticus* and *S. budgetti* Table 1 to 5. The highest levels of lead (0.32±0.12µg g^{-1}) was observed in the liver tissue of *T. zilli* Table 1, while the lowest limit (0.01±0.0.01µg g^{-1}) was detected in the bones of *C. anguillaris* and *S. budgetti* Table 2 and 5. The concentrations of lead were higher in the following order liver>gills>stomach>kidney>bone. Similar findings were reported by [36] that highest concentrations were in gills, kidney and spleen in rainbow trout. [37] noticed in *O. niloticus*, the gills consistently accumulated higher amount of lead as lead nitrate. Lead is highly toxic to aquatic organisms, especially fish [31]. The biological effects of sublethal concentrations of lead include delayed embryonic development, suppressed reproduction, and inhibition of growth, increased mucous formation, neurological problems, enzyme inhalation and kidney dysfunction [31, 38]. The levels of lead in liver, gills, stomach, kidney and bone tissue of *T. zilli, C. anguillaris, Protoptenus, O. niloticus, E. niloticus* and *S. budgetti* were below the 0.5µg g^{-1} limits [39].

The concentrations of chromium in the different organs of the six species of fishes varied from 0.02±0.01µg g^{-1} to 0.40±0.13 µg g^{-1} Table 1 to 5. It was found that the concentrations of chromium in the different organs of six the fish species from Lake Chad varied from one organ to another. The maximium concentration of chromium (0.40±0.13 µg g^{-1}) was detected in the liver tissue of *S. budgetti* Table 5, while the minimium was observed in the bone of *T. zilli* Table 1. Their lowest detection concentrations were found in the bone tissues. On the other hand, the highest concentrations of Cr were found in liver for the six species studied. Chromium is an essential trace element in humans and some laboratory animals [40], but in excess, it could have lethal and sublethal effects on fish and wildlife [41]. No guideline documents are available for chromium in the edible part of fish; neither was it assessed by NCBP or FEPA. In view of other sanctions, the present chromium concentrations in the liver of *T. zilli, C. anguillaris, Protoptenus, O. niloticus, E. niloticus* and *S. budgetti* which was the highest are well below the levels validated by USEPA (53.8 ppm) for fish tissue [42]. However, surveys of contaminants in edible shellfish conducted by FDA and National Marine Fisheries Service reported chromium levels from 0.1 up to 0.9µg g^{-1} [43], which is in line with the above threshold. The present chromium tissues concentrations for this study are below 4.0 µg/g levels suggested by [44] as indicative of Cr contamination.

Mn tends to reside in the liver in all the fish samples studied, while the bone is the least accumulated organ. Hence, Mn concentrations in the entire species of fish were below quid line limit of 0.7 µg g^{-1} set by [45] and do not constitute any threat upon the consumption of these species of fish.

In contrast to earlier reports showing Iron (Fe) to be normally highest in gills [46], and in the liver [45], the present study showed liver as the highest Fe concentrations. The concentrations of Iron in the six species of fishes varied from 0.35±0.02 µg g^{-1} to 0.10±0.03 µg g^{-1}. The highest concentrations of 0.26 to 0.33 µg g^{-1} for Fe in all the six species were below the high residue concentrations of Fe (34-107 ppm) in fish samples on MNW Refuge [45]. The highest level of iron was observed in the liver of *T. zilli* Table 1, while the bone of *S. budgetti* shows the least concentration Table 5.

The maximum concentrations of nickel (0.01±0.01 to 0.12±0.03 µg g-1) were detected in the liver of *T. zilli, C. anguillaris, Protoptenus, O. niloticus, E. niloticus* and *S. budgetti* Table 1 to 5, while the minimum levels were detected in the bone. From the result of this analysis, the concentrations of nickel in the fish organs are in the order of liver> gill>stomach>kidney>bone. Nickel level of 0.7µg g^{-1} is considered potentially lethal to fish and aquatic birds that consume them [47]. Nickel concentrations of 2.3µg g^{-1} or greater, may cause reproductive impairment and lack of recruitment in fishes [48]. None of the samples in this study approached these levels of concern. Hence, nickel concentrations in the entire species of fish do not constitute any threat upon its consumption.

The highest concentrations of Cadmium (0.03±0.01 to 0.22±0.04 µg g^{-1}) were observed in liver tissues of *T. zilli, C. anguillaris, Protoptenus, O. niloticus, E. niloticus* and *S. budgetti*, while the lowest concentrations of (0.01±0.01 to 0.11±0.05 µg g^{-1}) were detected in bone Table 1 to 5. Cadmium is a nonessential trace metal that is potentially toxic to most fish and wildlife, particularly freshwater organisms [41]. The highest concentrations of (0.03±0.01 to 0.22±0.01 µg g^{-1}) in liver tissues of the above species were below the 0.5 µg g^{-1} threshold considered harmful to fish and predators [39].

Zinc was detected in all the fish samples, and the highest concentration was observed in the liver tissues followed by the gills, stomach and kidney, while the bone shows the least concentrations Table 1 to 5. The concentrations of Zn in *T. zilli, C. anguillaris, Protoptenus, O. niloticus, E. niloticus* and *S. budgetti* were below the NCBP 34.2 µg g^{-1}. Fish can accumulate zinc from both the surrounding water and from their diet [49]. Although zinc is an essential element, at high concentrations, it can be toxic to fish, cause mortality, growth retardation, and reproductive impairment [50]. Zinc is capable of interacting with other elements and producing antagonistic, additive, or synergistic effects [49]. Zinc does not appear to present a contaminant hazard to fish within this portion of Lake Chad.

Arsenic was detected in all the fish organs sampled, with concentrations ranging from 0.01±0.01 to 0.12±0.04 µg g^{-1} dry weight. The highest concentration of arsenic was observed in liver tissues followed by the gills, stomach and kidney, while the bone shows the least concentrations. Arsenic in all the organs of *T. zilli, C. anguillaris, Protoptenus, O. niloticus, E. niloticus* and *S. budgetti* were below NCBP 0.27 µg g^{-1} dry weights [32]. [39] considered arsenic concentrations >0.5 µg g^{-1} dry weight a level that could harm fish. Based on the above levels, the Lake Chad region of Nigeria contained fish with arsenic concentrations below this potentially harmful threshold.

Magnesium occurs naturally in sediment; it is one of the most common ions in freshwater and a major contributor to water hardness [51]. In *T. zilli, C. anguillaris, Protoptenus, O. niloticus, E. niloticus* and *S. budgetti,* magnesium tends to reside in the liver, while the bone shows the least concentrations (Table 1 to 5). The concentrations of magnesium in the liver tissues varied from 0.32±0.11 and 0.55±0.17 µg g^{-1} in the six species of fish to 0.13±0.03 to 0.24±0.11 µg g^{-1} in the bone. The maximium level of Magnesium (0.55±0.17 µg g-1) was observed in the liver tissue of *O. niloticus* Table 4, while minimium concentration of 0.13±0.03 µg g^{-1} was detected in the bone of *C. anguillaris* Table 2. In a survey of composite sample of predator fish as spotted gar and white crappie was 1455- 10819 ppm dry weight, while in benthic feeding fish, it was 1304 - 9804 ppm dry weight in Small mouth buffalo and carp [52]. Taking into account that Mg is not potentially harmful to fish and wildlife [53] and that little is known concerning whether or not elevated levels of Mg in fish tissue are harmful to the organism itself and to human and other wildlife species which consume the organism [54], the present Mg levels might not be a major concern.

CONCLUSION

Fish absorb metals through ingestion of water or contaminated food. Heavy metals have been shown to undergo bioaccumulation in the tissue of aquatic organisms. On consumption of fish and other aquatic organisms these metals become transferred to man. However, it is not yet known whether the fishes in the Lake Chad have been severely affected by heavy metals based on the results obtained from this study. Although the results do not explicitly indicate a manifestation of toxic effects, the possibility that deleterious effects could manifest after a long period of consumption of fish caught in Lake Chad with trace metal contamination cannot be ruled out.

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