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ASSESSMENT OF HEAVY METALS BIOMAGNIFICATION IN SELECTED AQUATIC FAUNA FROM NEW GUSAU RESERVOIR, NORTHERN NIGERIA

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Abstract
This study aimed to assessing the concentration of Copper (Cu), Cadmium (Cd), Iron (Fe), Lead (Pb) and Zinc (Zn) in the muscle of the selected aquatic animals: Snail (Gabiella africana), Frog (Rana esculenta), African catfish (Clarias gariepinus) and Tilapia (Tilapia zilli), obtained from New Gusau Reservoir, for eighteen (18) months. The Reservoir, receives effluent from three effluent channels namely; Yar Dole (YDL), Yar Dantse (YDS) and Yar Rumfa (YRF). The selected animals were collected with the help of artisanal fisher men and identified to species level based on standard taxonomic keys. Analysis done included concentrations of Cu, Cd, Fe, Pb, and Zn, in muscles tissue, using Atomic Absorption Spectrophotometer (AAS).The mean concentration of Cu in the tissues was 0.92±.126, 0.90±.124, 0.93±.116, 1.35±.113mg/kg and for Zn were 0.99±.139, 1.09±.154, 2.29±.218, and 2.51±.178 mg/kg for catfish, Tilapia, Frog and Snail, respectively. All selected animals investigated were accepted standard limit set by European Commission (EC), World Health Organization (WHO) and Food and Agriculture Organization (FAO). The mean concentrations of Fe was 7.12±.567, 5.32±.602, 15.96±1.549, 15.55±.894mg/kg and that of Pb were 0.01±.002, 0.09±.014, 0.01±.007, 0.04±.013 mg/kg for catfish, Tilapia, frog and snail, respectively. The concentrations of Fe, in snail and in frog muscles were higher compared to catfish and tilapia. Cd was not detected in all the studied animals. The research suggested that the animals may be safe for human consumption

Keywords: AAS, Catfish, Heavy Metals, Reservoir, Tilapia,

INTRODUCTION

Bio magnification is a process whereby certain substances such as pesticides, fertilizer, insecticides or heavy metals move up the food chain; rivers, reservoir or lakes, taken by aquatic organisms such as fish, birds or humans and become concentrated in the tissue. Metals are defined as elements which conduct electricity, have a metallic luster, are malleable and ductile, form cations, and have basic oxides (Atkins and Jones, 1997). Metals have many diverse applications and play an important role in the industrial-dominated society. Some metals have critical important physiological and biochemical functions in biological systems, and either their deficiency or excess can lead to disturbance of metabolism and various diseases development. Some metals and metalloids are essential for 'biological' life. Metal may play important physiological and biochemical roles in the body as they may be part of biomolecules such as enzymes which catalyze biochemical reactions in the body (Duffus, 2002). Environmental pollution is one of the major challenges in the modern human society (Ali and Khan, 2017). Environmental contamination and pollution by heavy metals is a threat to the aquatic environment and is of serious concern (Ali *et al.*, 2013 and Hashem *et al.*, 2017). Rapid industrialization and urbanization have caused contamination of the environment by heavy metals, and their rates of mobilization and transport in the environment have greatly accelerated since 1940s (Khan *et al.*, 2004). Their natural sources in the environment include weathering of metal-containing rocks and volcanic eruptions, while principal anthropogenic sources include industrial emissions, mining, smelting, and agricultural activities like application of pesticides and phosphate fertilizers (Viard *et al.* 2004). Combustion of fossil fuels also contributes to the release of heavy metals such as cadmium (Cd) to the environment (Spiegel, 2002). Heavy metals are persistent in the environment, contaminate the food chains, and cause different health problems due to their persistence toxicity. Chronic exposure to heavy metals in the environment is a real threat to living organisms (Wieczorek *et al*., 2013). Among these, heavy metals have long been recognized as serious pollutants of the aquatic environment, where they impose serious damage to metabolic, physiological and structural systems of the organisms when present in high concentrations in the environment. Metals such as zinc, iron and copper are essential elements for normal metabolism of aquatic organisms in low concentrations, while mercury, cadmium, lead are nonessential without any recognized role in aquatic systems (Canli and Atli, 2003). They may have direct effects on organisms by accumulating in their body or indirectly through food web to the next trophic level. One of the most serious consequences of this transfer is biological amplification through the food chain (Unlu *et al.,* 1993).

In an aquatic environment, heavy metals are easily taken up in dissolved form by organisms. These metals are then strongly bound with sulfhydryl groups of proteins and accumulate in tissues of the organism (Kargin, 1996) which may result in chronic illness leading to damage to the population (Beiney and Beeko, 1991). Gusau reservoir, regularly receive broad types of effluents discharged from Yar Dantse, Yar Dole and Yar Rumfa effluent channels. The accumulation of heavy metals in aquatic invertebrates exposed to environmental pollution is well documented (Al-Yousuf *et al.,* 2000). Molluscs, in particular, have shown considerable promise as biomonitors of such pollution and an extensive literature has appeared concerning mechanisms of uptake, detoxification and storage of heavy metals. Important advantages of snails for biomonitoring research are their limited mobility and large size in comparison with other freshwater organisms. It is worth noting that bioaccumulation of metals in aquatic gastropods varied strongly according to sampling site, metal and the specific species (Yap and Cheng, 2013). Even within the same species, individual characteristics such as age, growth rate and feeding can have significant effects on responses to heavy metal contamination. In Nigeria, the African giant snail *Archachatina marginata* is widely consumed by various ethnic groups.

On the other hand, rapid industrialization of Zamfara State, with more than seventeen (17) ginnery, within the last two decades has resulted in a heavy pollution. This study evaluated the presence of heavy metals (Cu, Cd, Fe, Zn and Pb) accumulation in some selected aquatic animals; Snail (*Gabiella africana*), Frog *(Rana esculenta*), African catfish (*Clarias gariepinus*) and Tilapia (*Tilapia zilli*) in New Gusau Reservoir. The results were compared to the permissible limits from European Commission (EC), US Food and Drug Administration (USFDA), Food and Agriculture Organization (FAO) and the World Health Organization (WHO) to detect whether the heavy metal contamination levels in animals muscles from this reservoir exceed the safe consumption permissible limit or not.

MATERIALS AND METHODS

Study area

The new Gusau reservoir is located in Gusau Local Government Area of Zamfara State, Nigeria, between latitude 12°17'02.40" N and longitude 6°39'50.83" 6°66'41.20" E, and occupies an area of 3,364km^2 (figure i). Gusau Local Government had a population of 383,162 people (National Population Commission (NPC), 2006). The new Gusau reservoir is gated in the channel of Sokoto River, it is made up of a mass concrete surmounted by five steel gates which is operated by electric motors and bar-link chains with provision for emergency manual operation. Concrete walls are also provided at each end of the reservoir to protect the ends from the erosion (Jabbi *et al.,* 2018).

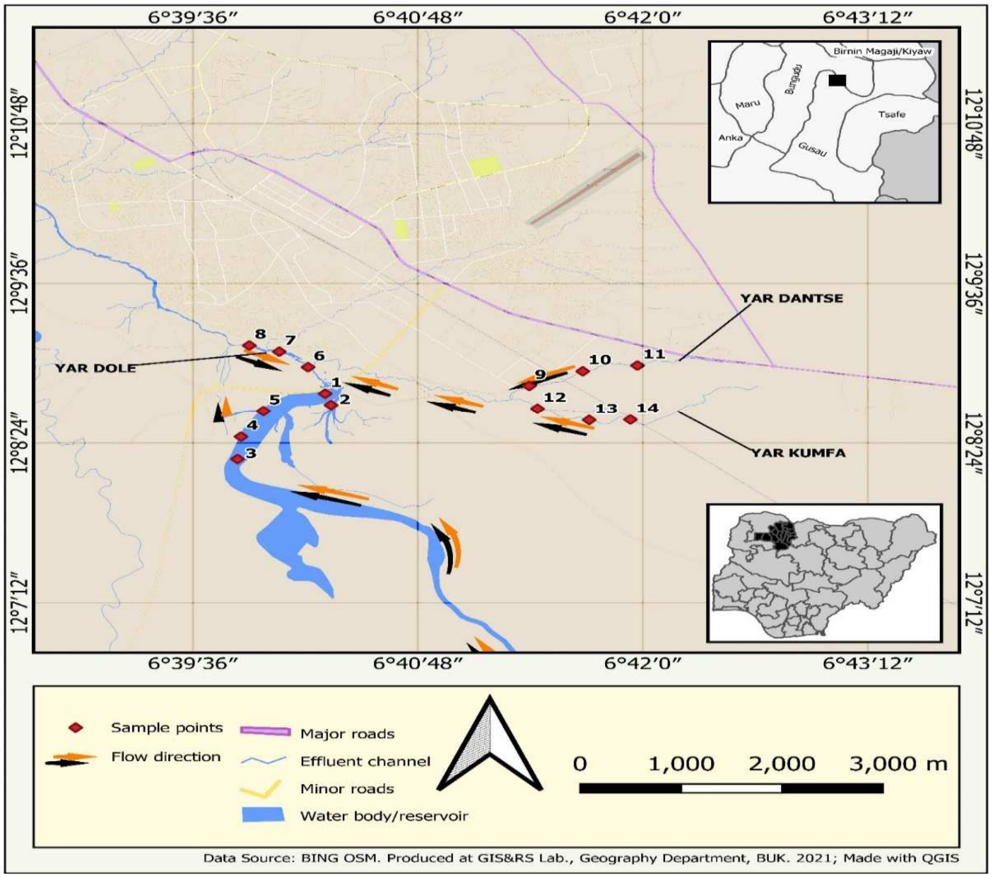

Figure 1: Map of the Study Area with Sampling Sites

Study design

Sampling was done on monthly basis. Five sampling points were selected in the New Gusau reservoir with approximate distance of 500m between them (Figure 1). Four selected animals were caught using nets with the assistance of fishermen from one of the communities surrounding the reservoir.

Sampling of aquatic animals

Sampling was carried out in accordance with the recommendation of UNEP (2000) method for marine pollution studies. The snails were collected from the reservoir by hand picking. The age of the snails was not considered; only fully grown specimens were collected since this is the product consumed by the local population. In the laboratory the snails were washed thoroughly with distilled water. The shell was cracked with a wooden hammer; the body was again washed with distilled water and stored at -18^0C prior to analysis while catfish and *Tilapia* were caught with the help of local fishermen, washed with distill water and transferred into clean plastic bags. Upon arrival at the laboratory the fish was weighed before and after being cut into small pieces and ground thoroughly to achieve homogeneity and stored at –4°C until metal analysis. Frogs were caught with sweep nets and transferred to properly aerated cages made from aluminum wire and brought to the laboratory for heavy metal analysis. Tissue were separated from bones using stainless steel scalpels and forceps and washed in distilled water, and then stored in polyethylene bags and frozen at -4^0C for metal analysis (Mohsin and Ambak, 1991).

Digestion and determination of heavy metals from tissue samples

Fish, Frog and Snail muscles were weighed before and after being cut into small pieces and grounded thoroughly. Digestion was done according to method adapted by Abolude (2007). One (1.0g) of thawed muscles was weighed, dried, homogenized and ground to a powder. Tissue samples were digested by adding 7 mL of nitric acid to 1 g of the weighed sample. One (1ml) of hydrogen peroxide was then added and the samples were heated in a water bath for 2 hrs at 90±5°C.

After cooling, the digested samples were adjusted with deionized water to a final volume of 25 ml. The final suspended mixture was filtered through an 11μm membrane filter with standard quantitative cellulose filter paper after cooling, the solution was filtered and analysis was carried out using Atomic Absorption Spectrophotometer (AAS) in the department of soil Science laboratory, Bayero University, Kano for estimation of Cu, Fe, Cd, Zn and Pb concentrations in the muscles (APHA, 2005).

Data Analysis

The data were statistically analyzed to test the hypothesis; there is no significant difference in heavy metals biomagnification in selected aquatic animals from New Gusau Reservoir. By one way analysis of variance (ANOVA) using Microsoft excel (2012) and IBM SPSS Statistics software version 23.0 and significant differences accepted at $p < 0.05$. Where significant differences were found, the mean values were separated using post-hoc Duncan multiple range test (DMRT).

RESULTS AND DISCUSSION

The result of heavy metal concentration in (mg/kg) in muscles of *Gabiella africana*, *Rana esculenta*, *Clarias gariepinus* and *Tilapia zilli*, from new Gusau reservoir is presented in Table I. The concentration of Cu varied significantly among the animals ($p<0.05$). The Cu concentration in snail was the highest (1.35±.113) compare to that of the surface water (1.13±.063) indicating bioaccumulation, but in Tilapia, catfish and Frog are lower than that of water (Table 1). The Cu concentration in Tilapia, snail, Catfish and Frog did not exceed 3.0mg/kg (WHO, 2004) and 75mg/kg (FAO, 2003) international standard for fish. According to Yilmaz (2009), the uptake of heavy metals by fish occurs from water, food and sediment. Heavy metal concentrations in the tissue of fresh water fish varies due to differences in metal concentrations and chemical characteristics of water from which fish are sampled, their ecological needs; metabolism and feeding habits. In this study, the mean Cu levels recorded at New Gusau reservoir varied with other animals species, in which Snail had higher Cu levels in the muscles followed by Frog, catfish and tilapia (Snail > Frog>Catfish > Tilapia). The variations in Cu levels could be attributed to differences in feeding habits of the animal species. African catfish is omnivorous and preys on small fish of other species that could have led to high Cu levels as compared to Tilapia which feeds on phytoplankton. Snail can eat a vegetarian diet of water plants, but prefers to scavenge the bottom the reservoir for insects, crustaceans including zooplankton and benthic worms (Yousafzai *et al.*, 2012). However, the result obtained in this study is higher than mean Cu values of 0.045 mg/kg recorded in muscles tissues of tilapia fish from Tono irrigation reservoir in Ghana (Anim-Gyampo *et al.,* 2013) and lower than 2.8 – 48.84 mg/kg observed in tilapia (*Oreochromis niloticus*) of Northern -Delta Lakes, Egypt (Saeed and Shaker, 2008).

Table I; Heavy Metal Concentration (mg/kg) in Animal Muscles Tissues Recorded from Feb 2019– July 2020 in New Gusau Reservoir

Parameters / Organism	Catfish	Tilapia	Frog	Snail	Water	P-Value	WHO
Cu	0.92^b±.126	0.90^b±.124	0.93^b±.116	1.35^a±.113	1.13±.063	.020	3.0
Range	ND-2.77	ND-2.78	0.02-2.98	0.01-3.00			
Cd	0.00^b±.000	0.00^b±.000	0.00^b±.001	0.00^a±.001	0.02±.017	.009	0.03
Range	ND-0.002	ND-0.002	ND-0.005	ND-0.006			
Fe	7.12^b±.567	5.32^b±.602	15.96^a±1.549	15.55^a±.894	5.94±.997	.000	20
Range	0.01-16.43	0.04-14.87	2.56-35.09	3.18-25.90			
Pb	0.01^b±.002	0.09^a±.014	0.01^b±.007	0.04^b±.013	0.01±.001	.000	0.4/2.0
Range	ND-0.06	ND-0.28	ND-0.34	ND-0.38			
Zn	0.99^b±.139	1.09^b±.154	2.29^a±.218	2.51^a±.178	1.24±.065	.000	5.0
Range	0.05-4.89	ND-4.23	0.06-5.79	0.22-6.09			

Note: Means in same row with different superscripts are significantly different at $p < 0.05$ levels. ND – Below detectable limit of AA224FS

The value of Cd obtained in this study is far less than those reported in Egypt and Ibadan Oyo state Nigeria by Ayeloja *et al.,* 2014, the amount of Cd in tilapia is 0.073±0.02, catfish 0.123±0.04mg/kg in each samples. However, restriction of Cd in Gusau reservoir water body, should be encouraged so as to prevent its bioaccumulation, because its human accumulation leads to kidney dysfunction, skeletal damage and reproductive dysfunction (Mohammed *et al.*, 2011).

The concentration of Fe indicated that there was significant difference in concentration of Fe among different Organisms at ($p<0.05$).The Fe concentration in water is higher (5.94±.997) than that of Tilapia, while that of Frog, Snail, and catfish, are above that of surface water iron, the range in catfish (0.01-16.43), Tilapia (0.04-14.87), Frog(2.56-35.09) Snail (3.18-25.90), respectively, with concentration in order of decreasing as follows (Frog> Snail> catfish> Tilapia). The Fe concentration in both animals and water are below WHO, FAO and EC guideline of 20mg/kg. However, the result of lead in the different animals species muscles indicate that there was significant different ~~(p = 0.000)~~ The Pb concentration in Tilapia (0.09mg/kg) is greater than that of surface water (0.01±.001mg/l), while other organism are below. The level of lead in all the animal samples were less than those recommended by European commission (EC) 2001, guidelines and FAO, as reported by Sivaperumal *et al.*(2007), the allowable level of Pb in fish and frog, is 0.4 and 0.5mg/kg respectively. The Pb concentration recorded in Catfish muscles at New Gusau Reservoir is lower to the levels obtained in Common Carp muscles (1.24± 0.20 mg kg-1) from Lake Hashenge, Ethiopia (Asgedom *et al.,* 2012). In this study the Pb levels was lower when compared to results observed in African Catfish in Lake Victoria (Tole and Shitsama, 2003) and 5.895 – 14.51 mg kg-1 in River Nile, Egypt (Osman and Kloas, 2010). In Avsar dam Lake in Turkey, higher mean Pb (2.14 ± 2.09 mg/kg) in Common Carp (*Cyprinus carpio*) muscles have been recorded (Oztiirk *et al.,* 2009). Anim *et al.* (2011) recorded much higher mean Pb levels in African Catfish muscles (0.08 ± 0.01 mg/kg) and *Tilapia zilli* (0.34 ± 88 0.02 mg/kg) from Densu River, in Ghana.

Heavy metal contamination in sediments is known to affect water quality and also leads to bioaccumulation of metals in aquatic organisms (Fernandes *et al.,* 2007). In this study, the sediments of new Gusau reservoir showed high Zn concentration levels, hence the high Zn levels in snail and frog muscle tissues unlike the other selected animal species. The result also indicate there is significant different in Zinc among different animals samples (0.000). The Zinc concentration in snail was the highest (2.51±.178) while that of water is the lowest (1.24±.065) the concentration of zinc follow the following decreasing order (Snail> Frog>Tilapia>Catfish). The Zinc concentrations in all selected animals are below (WHO) guideline of 5.0 permissible limits. So also the zinc level are below international standard level of 75mg/kg (FAO, 2003) This agrees with the opinion of Bordajandi *et al.* (2003) that diet has a remarkable role in the bioconcentration process of some metals, mainly Cu and Zinc. Ayeloja *et al.* (2014), also reported that feeding strategy influenced the content of Cu and Zinc in Fish. Mean Zn levels recorded by Kumar *et al.* (2011) in Tilapia (*Oreochromis niloticus*) muscle tissues (51.20 ±3.90 mg kg^{-1}) obtained from aquaculture ponds in Kolkata wetlands, India was higher than levels observed in this study. In Afikpo freshwater ecosystem in Nigeria, lower mean Zn levels in *Tilapia zilli* have been observed (Nwani *et al.,* 2004). Anim-Gyampo *et al.,* (2013) obtained lower mean Zn levels (0.004 mg kg-1) in tilapia caught from Tono irrigation reservoir in Ghana. Studies carried out in Lake Hashenge, Ethiopia revealed comparable Zn levels in Tilapia (24.95 ± 1.80 mg kg-1) and Common carp (46.08 ± 1.93 mg kg-1) muscles (Asgedom *et al.,* 2012)

Bioaccumulation Transfer Factor

The transfer factor (TF) of heavy metals in the animals species from new Gusau reservoir, water and sediments are presented in Table 2. The TF of Cu from water to the four animal's species ranged from 0.79 in (Tilapia) to 1.19 in (snail) while from sediments it ranged from 0.39 in (catfish) to 0.82 in (frog). TF of Fe, Zn and Pb from water to the Snail muscle tissues was more than 2.0 ($1 \geq CF \geq 3$) refers to moderate contamination, so also Fe in Frog. This result disagrees with what Asgedom *et al.* (2012) obtained in Hashenge Lake, Ethiopia. The trends of TF for heavy metals from water and sediment to Snail muscles tissue were in the ranking order Pb>Fe>Zn>Cu>Cd and Cu >Fe>Pb>Zn>Cd, respectively. Canterford *et al.* (1978) reported that it is useful to express results of bioaccumulation in terms of TF when comparing the order of uptake of metals. TF is the ratio of a specific heavy metal in the organism (fish muscle) to the concentration of the metal in the reservoir water or sediment according to Kalfakakour and Akrida-Demertzi (2000) and Rashed (2001).

Table 2: **Transfer Factor (TF) of Heavy Metals in Muscle Tissues of Selected Animal Species from New Gusau Reservoir**

		Parameter				
Animal species	**Ecosystem component**	**Cu**	**Cd**	**Fe**	**Pb**	**Zn**
Catfish	Water	0.81	0.00	1.19	1.00	0.79
	Sediment	0.39	0.00	0.20	0.05	0.07
Tilapia	Water	0.79	0.00	0.89	1.00	0.87
	Sediment	0.38	0.00	0.15	0.50	0.09
Snail	Water	1.19	0.00	2.62	4.0	2.02
	Sediment	0.58	0.00	0.44	0.22	0.19
Frog	Water	0.82	0.00	2.69	1.0	1.84
	Sediment	0.40	0.00	0.45	0.05	0.18

When fish is exposed to high levels of metals in an aquatic environment, they absorb the bio-available metals either through the gills and skin or through the ingestion of contaminated water or food. However, the presence of metals in high levels does not indicate a direct toxic risk to fish or aquatic animal, if there is no significant accumulation of metals by the organism tissues (Kamaruzzaman *et al.* 2010). According to Heath (1991), metals in fish body are regulated (uptake and loss system) to a certain level beyond which bioaccumulation of metals takes place. This study showed that TF from surface water were greater than those from sediments, this was a sign of close correlation between heavy metal concentrations in water and aquatic animals, as such it can be inferred that the major source of heavy metal contamination of animal species in new Gusau reservoir is from water. This agrees with other studies done by Rashed (2001), determined TF for Cr, Cu, Zn and Mn from water and sediment in Tilapia fish from Lake Nasser, Egypt and found only TFs from water were more than 1.00. Also, Abdel-Baki *et al.* (2011) observed similar results when they calculated TFs of heavy metals from water and sediment in Frog. Frog accumulates metals from water by diffusion through skin and oral consumption of water (Oguzie, 2003).

CONCLUSION AND RECOMMENDATIONS

The research confirmed that concentration of heavy metals in all selected aquatic animals (Snail, Frog, Catfish and Tilapia) from New Gusau Reservoir, did not exceed WHO (2008) and FAO (2003) international accepted standard for fish and fish product. Therefore, null hypothesis is rejected and uphold alternate hypothesis.

Based on the findings from this research, the reservoir may be managed by regulating external pollution loading using the following measures: i. It is recommended that government should carried out public enlighten on the dangers of aquatic pollution to the users of natural resources (water and fish) within Gusau reservoir. ii. Soil erosion should be controlled in the New Gusau Reservoir catchment area by trees planting and control of deforestation. iii. Industries within the identified point sources of pollution to New Gusau Reservoir should be monitor and detoxify their west effluent before discharging into the channel effluent iv. The reservoir input (point source of YDS, YDL YRF) should be monitored regularly by Zamfara State Government and the sediment sources be mitigated by dredging with the view to physically remove the introduced sediments which was found to be slightly polluted.

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