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Assessment of Heavy Metal Concentrations as Indicator of Pollution in *Clarias gariepinus* (African Catfish) of Warwade Reservoir, Dutse, Jigawa State-Nigeria

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Abstract
Pollution status of Warwade reservoir was assessed using heavy metals bioaccumulation in water, gills and liver samples of C. gariepinus between July and December, 2019. Heavy metals analyses were carried out using microwave plasma atomic spectroscopy (MP-AES). Water and fish were sampled fortnightly from the three sites coded as upstream (A), midstream (B) and downstream (C) between 7:00 – 7:30am for period of six months. The results revealed that heavy metal concentrations in water followed the order: Cr (2.15mg/L)>Cu (1.40mg/L) > Pb (0.89mg/L)> Cd (0.68mg/L). Bioaccumulation Factor (BAF) of heavy metal concentration in water decreased in the order of Cr > Pb > Cu >Cd. In the fish organs, gills had the highest value of Cr, followed by Pb, Cu and Cd recorded the lowest. The BAF in liver tissues decreased in the order of Cu > Pb > Cr >Cd. BAF for Cu was highest in liver tissue (2.90) while the lowest was obtained in the gills (1.04). Lead (Pb) had its highest value in liver (2.16) and the lowest value (1.33) was obtained in the gill. BAF in Cr had its highest value of 2.15 in water and the lowest was obtained in the gills. Heavy metals bioaccumulation differed significantly (p<0.05) between the sampling sites and seasons with the exception of cadmium which did not differed significantly (p>0.05). It can be deduced that heavy metals bioaccumulation in the fish tissue is attributed to the influx of chemicals into the reservoir as a result of agrochemicals input among other anthropogenic activities. It is recommended that indiscriminate release of the xenobiotic compounds should be minimized in order to avert degradation of the reservoir in the long run. Intervention by appropriate authorities to curtail the effects of heavy metals on fish species among other important biota is recommended.

Keywords: Bioaccumulation, *Clarias gariepinus,* Contaminants, Toxicity, Xenobiotics

INTRODUCTION
Heavy metal toxicity is regarded as the accumulation of metals in the tissues/cells capable of causing detrimental effects by short term or prolong exposure (Abdullahi *et al*., 2021). Harmful heavy metals to humans and other biota have been reported due to exposure to industrial,

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municipal and urban runoff waste water (Ibrahim and Said, 2010; Imam *et al*., 2012). Increase in heavy metal concentration in surface water supplies have been a major source of concern in Jigawa State (Oladeji, 2020). Due to their toxicity, persistence, bioaccumulative and non-biodegradable properties in aquatic ecosystem, heavy metals constitute a core group of aquatic pollutants (Mohammed and Olowolafe, 2020).

Heavy metal contamination in aquatic environment have been reported to cause harmful effects on the ecological balance of the environment due to their bioaccumulative nature along food chain (Butu *et al*., 2019). Many reservoirs in Nigeria were reported to habour high concentrations of heavy metals such as Cu, Cr, Pb, Ni and Cd from domestic, and industrial discharge among other anthropogenic sources (Imam, 2012; Samson, 2015, Ahmad *et al*., 2018; Abdullahi *et al*., 2021). Therefore, aquatic pollution by heavy metals on aquatic biota recorded increasing attention in the last few decades in many developing and developed countries (Ahmad *et al*., 2018). Its harmful effect on fish species and other non-target organisms often depends on the compound's solubility, exposure duration and permeability in cellular compartment, mobility and concentrations which ultimately manifest on its physiological functions (Akinwande *et al*., 2019).

Heavy metals among other xenobiotics were reported to accumulate in fish cells/tissues leading to catalytic reactions that generate reactive oxygen species which produce oxidative stress in the exposed organisms (Nafiu and Ibrahim, 2019). Many authors have reported increased concentrations of toxic heavy metals in fish caught from the same ecological zone. Imam (2012) and Ahmad *et al*. (2018) reported high concentrations of metals (Fe, Cr, Cu, Zn and Pb and Cr, Cd, Cu and Pb) above the WHO (2010) standard in Wasai and Kafinchiri Reservoirs respectively. Heavy metals in aquatic environment alter water quality, adsorbed on to sediments, biomagnify in aquatic biota leading to of morpho-physiological alteration and DNA damage (Habu *et al*., 2021). There was paucity of data on the heavy assessment in fish tissues. In view of the foregoing, this study tends to assess ~~the~~ heavy metal concentration as pollution indicators in *C. gariepinus* sampled from Warwade reservoir, Duste, Jigawa State, Nigeria.

MATERIALS AND METHODS

Study Area

This study was conducted at Warwade reservoir located 15 km south of Dutse, the capital of Jigawa State (Figure 1). The reservoir was impounded in 1976 by the administration of Military Governor of old Kano State Colonel Sani Bello (Dogara *et al*., 2019). It receives water from three major tributaries of Dutse,Tsangaya (Jigawa State) and Albasu (Kano State). The area contains mainly sedimentary formation of the Chad basin where it covers coordinates of 11° 45′ 0″ North and 9° 13′ 0″ East. Two distinct seasons of wet and dry with long summer and short winter with annual mean temperature of 31°C were usually experienced in the region. The wetland surrounding the reservoir serves as roosting and foraging area for many resident and migratory bird species. The area has an estimated average rainfall ~~as~~ of 412 mm during months of July and August. The reservoir has a crest height 10m, crest length 2780m and its spill way type is box culvert. The water in the reservoir contains muddy substratum and gently flowing, highly turbid with rich algal growth and macrophytes. Sandy- loam and clay – loam was reported as the soil types of the study area which are rich in nutrients and other minerals (Abdulhamid, 2014). The reservoir serves the surrounding populace of Sayasaya, Jidawa, Zowon -Hawa and Gatari, Warwade and Sabon -Garin Alhaji. The communities around the reservoir, largely farmers and fishermen depend basically on the water body as source of livelihood by over-exploiting its resources. (Dogara *et al*., 2019).

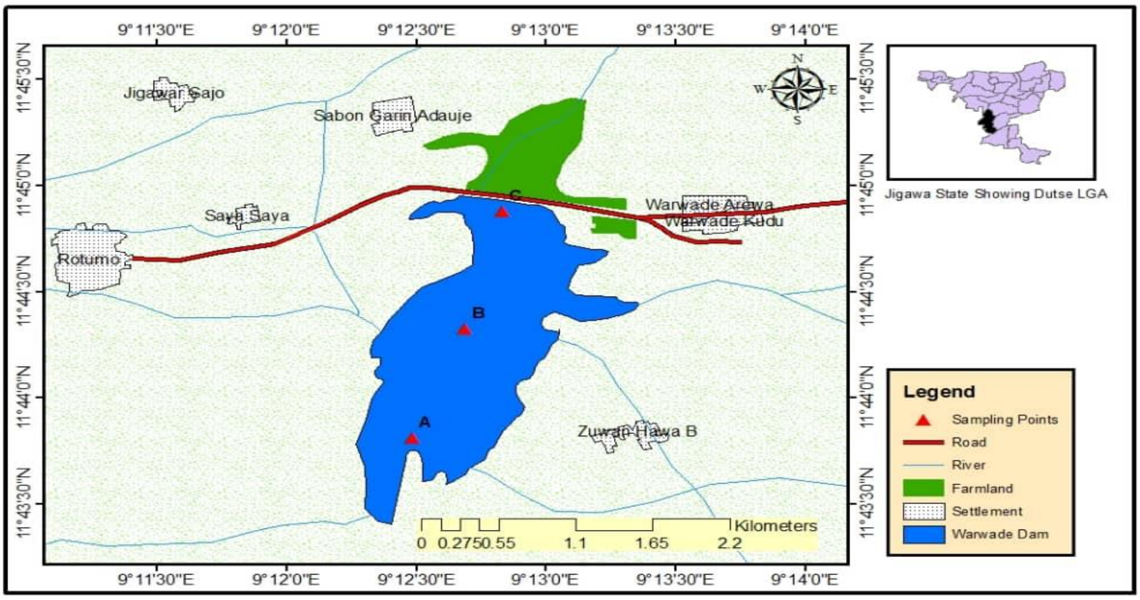

Fig 1: Map of Warwade Reservoir Showing Sampling Sites (Cartography Laboratory Geography Department Bayero University Kano, 2020).

Sample Collection and Analysis

Water and fish sampling were conducted fortnightly for a period of six months in triplicate from 07:00am to 07:30am for each of the sampling sites: upstream (A), midstream (B) and downstream(C). Fish samples were collected using gill nets with the help of the fishers as adopted by Ahmad *et al*. (2018). Sample fishes were immediately, counted, chilled and labeled in ice blocks at the point of collection before being transported to the aquarium at Biological Sciences Department, Bayero University Kano. Sampled fish were weighted to the nearest 0.01g using weighing balance (Ming Heng Digital scale Model MH-777). The total lengths were obtained to the nearest 0.1cm on a modified measuring board and fish species identification was carried out according to the guide of Olaosebikan and Raji (2004).

Collection and Analysis of Heavy metals in Water

Water samples were collected from the three sampling sites in 80ml dark plastic container. The water sample collected was transferred into 250ml beaker and 10ml of HNO_3, was added and heated at 100°C. the samples were allowed to evaporate to about 50ml, later 5ml HNO_3, was further added with continuous heating to a final volume of 15ml. The digested samples were filtered and diluted with distilled water to a final volume of 20ml. Cadmium, Chromium, Copper and Lead concentrations were analyzed in water using Micro Plasma Atomic Emission Spectrometry (MP-AES model) at Centre for Dry land Agriculture Laboratory, Bayero University Kano according to the procedure adopted by Nsofor *et al*. (2014).

Analysis of Heavy metals in fish organs (gills and liver)

Fish samples were examined for presence heavy metals in the liver and gills using the procedure adopted by Nsofor *et al*. (2014). The fish samples were carefully cut and the gills and liver were removed and dried in an oven of about 105°C for 24 hours. After drying, the tissues were grounded and milled using a blender. The powdered form was sieved and put in a plastic container and stored in desiccators until digestion. About 0.2g of each sample was weighed and transferred into 250ml beaker of the digestion rotors. Seven (7ml) of HNO_3, 2ml of H_2O_2 and 1ml of $HCLO_4$ were added to the sample, the rotor for the digestion was placed into microwave digestion system and set under animal tissue programming setting. After complete digestion, the digest were filtered through whatman filter paper and diluted to a volume of 20ml. Ten (10ml) of the samples were taken to microwave plasma atomic spectroscopy (MP-AES) to determine the concentrations of Cu, Cd, Cr and Pb at center for dry land Agriculture (CDA), Bayero University, Kano.

Bio-Accumulation Factor (BAF)

Bioaccumulation factor (BAF) was determined using the protocol described by (Vaseem and Banerjee, 2013):

$$BAF = \frac{M\ tissue}{M\ water}$$

Where; M tissue is the metal concentration in fish tissue mg/kg and M water, metal concentration in water mg/L.

Statistical Analysis

Data was analyzed using descriptive statistics. The data was also subjected to one way analysis of variance (ANOVA) to determine differences between sites, and where differences existed, they were separated with Duncan multiple range test (DMRT) at 0.05%. Seasonal variations were analyzed using student's independent T-test. All analyses were carried out using SPSS version 20.0 software

RESULTS

Figure 2 revealed the mean spatial Cr, Cd, Cu and Pb concentrations in surface water of Warwade Reservoir, Jigawa State. The Cu spatial variation had the highest value of 1.40mg/L at site C while the lowest value of 0.21mg/L was recorded at sampling site A. Cu concentrations differed between sites ($p<0.05$). Cr had the highest mean value of 2.15mg/L at site C while lowest concentration of 1.34mg/L was recorded at sampling site A. Spatially, significant difference ($p<0.05$) in Cr was recorded between the sites. Cadmium concentrations ranged from 0.02 mg/L to 0.68mg/L at sampling sites A and C respectively. The Cd value did not differ significantly between the sites ($p>0.05$). Mean Pb concentrations spatially ranged between 0.40mg/L to 0.89mg/L at site A and C respectively. Mean Pb values revealed significant difference between the sampling sites ($p< 0.05$).

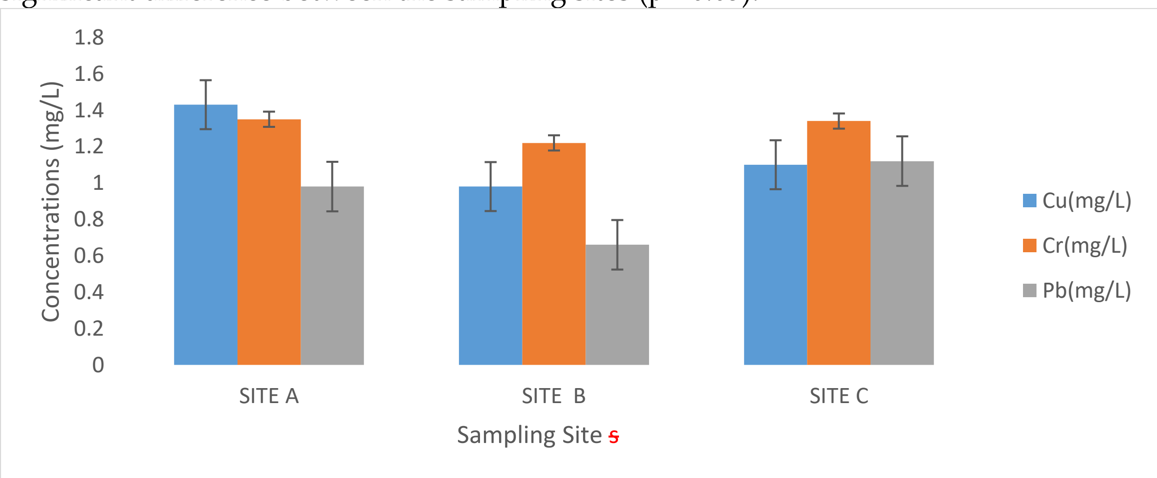

Fig. 2: Spatial Variation of Heavy Metal concentrations (mg/L) in Water obtained from Warwade Reservoir, Jigawa State

The mean monthly range of Pb values were from 1.80±0.11mg/L to 0.21±0.01 in September and November respectively (Table 1). Monthly variation in Pb concentrations indicated significant difference ($p<0.05$). Significant difference ($p<0.05$) was recorded in Cu mean monthly variation in August with highest concentration of 1.82±0.67mg/L while the lowest value was recorded in December of 0.56±0.04mg/L (Table 1). Mean monthly values of Cr ranged between 2.50±0.67mg/L in July to 0.97±1.21mg/L in November. Mean monthly Cd values recorded the highest value of 0.67±0.01mg/L in August while 0.01±0.02mg/L was obtained in November. Monthly values of Cd did not differ significantly ($p>0.05$) (Table 1).

Table 1: Mean Monthly Values of Heavy metals (mg/L) in Water obtained from Warwade Reservoir, Jigawa State

Concentrations	Pb	Cu	Cr	Cd
July	1.50±0.01 ^{d}	1.29 ± 0.02^{a}	2.50 ±0.67^{a}	0.01 ± 1.04^{a}
August	1.39 ±0.10^{a}	1.82 ± 0.67^{a}	1.60 ± 0.01^{a}	0.67 ± 0.01^{a}
September	1.80 ± 0.11^{b}	1.20 ± 0.01^{a}	1.39± 1.86^{a}	0.30 ± 0.01^{a}
October	1.41 ± 1.01^{a}	1.10 ± 0.10^{b}	1.23 ± 0.02^{a}	0.02 ± 0.10^{b}
November	0.21 ± 0.01^{d}	1.19±0.12 ^{a}	0.97± 0.21^{a}	0.01 ± 0.02^{a}
December	0.25 ± 1.01^{a}	0.56 ± 0.04^{b}	1.46 ± 1.14^{a}	0.41 ± 0.00^{a}

Values are means and S.D, values with the same letters in a column did not differ significantly ($p>0.05$). F crit. Value= 4.27

Seasonal variation of heavy metals in Warwade reservoir is presented in Table 2. The mean concentration of Cu during dry season (October- December) was 1.92±0.03mg/L while 1.71±0.91mg/L was recorded in wet season (Table 2). Cu concentration differed between seasons indicated no significant difference ($p>0.05$). Seasonally, the highest mean Cr concentration of 0.25±0.15mg/L was obtained during wet season while was recorded 0.97±0.41mg/L in dry season. Seasonal variation of Cr differed significantly between seasons ($p<0.05$). The seasonal variations in the mean Cd concentrations indicated that dry season had 0.01±0.01mg/L while wet season recorded 0.02±0.10mg/L. Statistically there was significant difference in Cd concentration between the seasons ($p<0.05$). The mean seasonal variation of Pb showed that wet season had 1.69±0.56 while 1.07±0.11mg/L was recorded during dry season. Statistically, Pb revealed significant difference between the two seasons ($p< 0.05$).

Table 2: Seasonal Variation of Heavy metal Concentrations Across the Study Sites from Warwade Reservoir, Jigawa State

Water Parameters	**Dry season**	**Wet season**	**FAO/WHO (2013)**
Cu (mg/L)	1.92±0.03^{a}	1.71±0.91^{b}	0.2*
Cr(mg/L)	0.97±0.14^{a}	0.25±0.15^{b}	0.1*
Cd (mg/L)	0.01±0.01^{b}	0.02±0.10^{a}	0.01*
Pb (mg/L)	1.97±0.11^{a}	1.69±0.56^{d}	0.05*

Astrick * indicates permissible limit in surface water
Values are mean± standard deviation. Superscript with same letters in a row revealed no significant differences ($p>0.05$), F. crit value = 3.41

Table 3 indicates the spatial variation of Cr, Cd, Cu and Pb concentrations in liver and gills of C. *C. gariepinus* sampled from Warwade Reservoir, Jigawa State. The Pb had the highest concentration in gills at site B and C compared with liver at sampling site A. Lead concentrations differed significantly between sites ($p<0.05$). Copper had the highest mean value in gills at sampling site C, followed by site B (in gills) and lowest concentration recorded in liver at sampling site A. Spatially, significant difference in Cu was recorded between the sites(P<0.05). Chromium concentrations had the gills at sampling sites C compared to site B and A respectively. The Cr concentrations did not differ significantly between the sites (p>0.05). Mean Cd concentration spatially was highest in gills at site C than in the liver from site B and A respectively. Mean Cd concentration revealed significant difference between the sampling sites (p< 0.05).

Table 3: Spatial Variation of Heavy metals (mg/kg) in Fish Tissues obtained from Warwade Reservoir, Jigawa State

Sites		Pb	Cu	Cr	Cd
A	Liver	0.19±0.11[a]	1.17 ± 0.10[a]	0.50± 0.01[a]	0.25 ± 0.04[a]
	gills	0.61 ±0.02[a]	0.61 ± 0.01[a]	0.82 ± 0.10[a]	0.42 ± 0.11[a]
B	Liver	0.41 ± 0.07[a]	0.45 ± 0.10[a]	0.43± 0.01[a]	0.11 ± 0.01[a]
	gills	0.91 ± 0.11[c]	0.77 ± 0.10[b]	0.65 ± 0.01[a]	0.35 ± 0.10[b]
C	Liver	0.76 ± 0.10[a]	0.78± 0.10[d]	0.31± 0.30[a]	0.08 ± 0.11[a]
	gills	0.91 ± 0.06[a]	0.91 ± 0.29[a]	0.73 ±1.05[a]	0.37 ± 0.02[a]

Values are means and S.D, values with the different superscript in a column differed significantly (p<0.05)

Monthly variation of heavy metals concentrations in fish tissues recorded from Warwade Reservoir is presented in Table 4. The mean monthly values of Pb had the highest concentrations of 1.25 ± 1.01mg/kg in September from gills tissue while the lowest value of 0.28 ± 0.11mg/kg was obtained December from liver tissues. Lead (Pb) concentrations revealed significant difference on monthly basis (p<0.05). However, Pb was not detected liver and gills tissues in August and September respectively. Monthly variation revealed significant difference (p<0.05) for Cu in gill tissues during the study period (July – December) while liver tissue showed no significant difference (p>0.05). Mean monthly values for Cr in gills ranged between 0.34 ± 0.04mg/kg in December to 1.73 ± 0.02mg/kg in August. The Cr concentration in liver ranged between 0.21± 0.21mg/kg to 0.88 ±0.01mg/kg in December and October respectively. Mean monthly concentrations of Cr differed significantly (p>0.05) as shown in Table 4.

Table 4: Mean Monthly Values (mg/kg) of Heavy in Fish Tissue obtained from Warwade Reservoir, Jigawa State

Concentration		Pb	Cu	Cr	Cd
July	Liver	0.80± 0.11[a]	0.85 ± 0.12[a]	0.61 ±0.10[c]	0.23 ± 0.01[a]
	gills	0.89 ±0.10[b]	1.32 ± 0.67[a]	0.90 ± 0.10[a]	0.02 ± 0.001[d]
August	Liver	0.60 ± 0.11[b]	1.10 ± 0.01[a]	0.29± 1.01[d]	0.01 ± 0.01[d]
	gills	ND	1.70 ± 0.10[b]	1.73 ± 0.02[a]	0.30 ± 0.12[b]
September	Liver	ND	1.19± 0.10[a]	0.27± 0.21[a]	0.11 ± 0.01[a]
	gills	1.25 ± 1.01[a]	0.86 ± 0.04[b]	0.61 ± 0.10[a]	0.30 ± 0.01[a]
October	Liver	0.50± 0.01[a]	1.69 ± 0.02[a]	0.88 ±0.01[a]	ND
	gills	0.89 ±0.01[a]	1.39 ± 0.67[a]	0.23± 0.14[a]	ND
November	Liver	0.60 ± 0.01[a]	1.03 ± 0.01[a]	0.28± 0.01[a]	ND
	gills	0.81 ± 0.00[d]	1.70 ± 0.10[b]	0.30 ± 0.02[a]	ND
December	Liver	0.28 ± 0.11[a]	0.19±0.12 [a]	0.21± 0.21[a]	ND
	gills	0.65 ± 0.01[d]	1.42 ± 0.10[b]	0.34 ± 0.04[a]	ND

ND: not detected
Values are means and S.D, values with the different superscript in a column differed significantly (P<0.05) F crit. Value= 5.23

Mean concentration of Cu during wet season had its highest in the gills of 0.99mg/kg compared with dry season of 0.43mg/kg (Table 5). Copper concentration did not differed significantly between seasons (p>0.05). Seasonally, the highest mean Cr concentration in gills was obtained during wet season while lowest value was recorded in dry season. Seasonal variation of Cr didn't differ significantly between seasons (P>0.05) in all the fish organs. The seasonal variations in the mean Cd concentrations indicated that dry season had 0.018mg/kg while wet season recorded highest value of 0.394mg/kg in gills. Statistically there was no significant difference in Cd concentration between the seasons (p>0.05). The mean seasonal variation of Pb showed that wet season had 0.705mg/kg in gills while 0.320mg/kg was recorded during dry season, and 0.031mg/kg in wet season and 0.011 in dry season in the liver. Statistically, Pb revealed no significant difference between the two seasons (p> 0.05).

Table 5: Seasonal Variation of Mean Heavy Metal Concentration in Fish Tissue Obtained from Warwade Reservoir, Jigawa State

Parts	Season	Heavy metals			
		Cr (mg/kg)	Cd (mg/kg)	Cu (mg/kg)	Pb (mg/kg)
Liver	Dry	0.850^{a}	0.010^{a}	0.43^{a}	0.011^{a}
	Wet	0.780^{b}	0.021^{a}	0.64^{a}	0.031^{a}
Gills	Dry	0.224^{a}	0.018^{a}	0.834^{a}	0.320^{a}
	Wet	0.574^{a}	0.394^{a}	0.990^{a}	0.705^{a}

Note: mean followed by superscript with different letters across the column are significant at P<0.05 using T. test

Bioaccumulation Factor (BAF) of heavy metal concentrations in water decreased in the order of Cr > Pb > Cu >Cd (Table 6). BAF for Cu was highest in liver tissue of 2.90 while the lowest was obtained in the gills of 1.04. Lead (Pb) had its highest in liver with 2.16 and the lowest value of 1.33 was obtained in the gill. Bioaccumulation Factor (BAF) in Cr had its highest value of 2.15 in water and the lowest was obtained in the gills. BAF in gills revealed higher concentrations of Cr, followed Pb, Cu and Cd recorded the least. BAF in liver tissues decreased in the order of Cu > Pb > Cr >Cd (Table 6).

Table 6: Bioaccumulation Factor of Heavy Metals in Fish and Water Obtained from Warwade Reservoir, Jigawa State

Metal concentration (mg/L)	Water	Gills	Liver	BAF	FAO/WHO (2018)
Cu	1.67	1.04	2.90	1.01	NA
Pb	1.81	1.33	2.16	2.52	0.5
Cr	2.15	1.50	1.64	2.26	0.5
Cd	0.94	0.89	1.74	2.68	0.01

BAF = Bioaccumulation Factor, NA= Not available

DISCUSSION

Heavy Metal Concentration in Water and Fish Tissues

Sampling sites variation revealed that chromium in water had the highest mean concentrations of 2.15mg/L while Cd had the least of 0.02mg/L. The higher concentration for Cr could be due to the deposition of domestic waste containing coloured polythene bags, discarded plastic materials and empty paint containers which are known to contain chromium sulfate among other derivatives. This is consistent with findings of Shawai *et al.* (2018) in Tatsawarki reservoir from Tarauni Local Government, Kano. It could also be attributed to geological distribution of minerals that vary from one site to the other as reported by Sa'eed and Mahmoud (2014). Spatial variation indicated that Cr concentration recorded at site C was above the permissible limit of fresh water set by FAO/WHO (2018) of 1.0mg/L. The heavy metal concentration in the water samples decreased in the order of Cr> Pb> Cu> Cd which is in harmony with the findings of Ahmad *et al*. (2018) and Butu *et al*. (2018) from Kafinchiri reservoir and Thomas reservoir, Kano State. They reported significantly high chromium concentration in water of 1.4mg/L and 1.51mg/L respectively above the limit set by WHO (2011) of 1.0mg/L. Seasonal variation indicated higher mean Cr values in wet season (July – September) than in the dry season (October-December). Higher mean Cr values in wet season high nutrient from run off and agrochemical input from nearby farmland as reported by Putshaka *et al***.** (2015). It could also be due to the geological distribution of minerals (organic and inorganic) within the ecological zone.

Lead had the highest concentration in gills at sampling sites B and C compared with liver. High concentrations of Pb in the gills might be due to its proximity with external environment which enhances its diffusion into the gill tissues, thereby increasing its permeability and ultimately high potential to accumulate within tissues. Similar observation was reported by Friday *et al*. (2013) from Owubu Creek, Nigeria. Introduction of agrichemicals, leaded gasoline by vehicles, paints and cosmetics particles into the reservoir might also facilitate high Pb concentration in fish tissues examined. Similar high concentrations of Pb in fish tissues was reported by Imam *et al*. (2012) and Abalaka (2015) from Wasai and Tiga reservoirs respectively. The highest Pb value obtained of 0.91mg/kg in gill tissues is higher than 0.57mg/kg reported by Ibrahim and Said (2010) in Jakara dam Kano. The concentrations of Pb recorded in the fish tissues (gills and liver) above the permissible limit of 0.01mg/kg set by FAO/WHO (2018) but lower than what was reported by Sobhan *et al*. (2011) in gill tissues of five fish species (*Otolithes ruber, Pampus argenteus, Parastromateus niger, Scomberomorus commerson, Onchorynchus mykiss*) ranged from 0.007-0.09 μg g^{-1}; 0.005-0.10μg $g^{-1}$and 0.031-0.11μg g^{-1} respectively.

Copper had the highest mean concentrations in gills at sampling site C, followed by site B and least was recorded in liver tissues at sampling site A. High concentrations of Cu recorded in the gills could be attributed to the physiological roles of the organ, its regulatory ability and feeding habit which play a significant role in bioaccumulation potentialities (Adewunmi *et al*., 2017; Butu *et al*., 2018). The ionic nature of Cu and pH also tends to be another factor in the accumulation process (Samson, 2020). The Cu concentrations in all the tissues examined were below the permissible limit of Cu 2.0 μg/g set by FAO/W H O (2018). The values recorded were higher than 0.04 μg/g and 1.12 μg/g in gills and liver recorded by Ahmad *et al*. (2018) from Kafinchiri Reservoir, Kano.

Chromium in trace amount act as regulator of cholesterol metabolism but in higher concentration chromium is proof to be toxic to aquatic biota (Adamu *et al*., 2018). The present study revealed high concentrations of Cr in the gill tissue. The high concentrations recorded could be due to its proximity to metal polluted medium or due to the presence of metal binding proteins in the tissues (Abdullahi *et al*., 2021). Heavy metal concentration in gills have been reported with the elements complexing with the mucus, which makes it difficult to be detached completely between the lamellae thus, high concentration of various metals can be recovered (Butu *et al*., 2018 and Samson *et al*., 2020). The Cr concentrations recorded in this study is lower than 28.1 – 32.2mg/Kg in *C. gariepinus*'s gills recorded by Ishaq *et al*. (2011) from Benue water body; but lower than 0.42±0.02-0.49±0.14 μg/g recorded in gill tissues by Dimari *et al*. (2008) from Alao Dam, Borno State. Chromium recovered from the reservoir might have come from dying and tanning activities by the locals along the reservoir tributaries as reported by Shawai *et al*. (2018). The concentrations of Cr in gills and liver tissues in *Clarias gariepinus* could also be due to the predatory feeding habit of the fish, suggesting metal enrichment at higher trophic levels (Nsofor *et al*., 2014).

Cadmium in gills of C. *gariepinus* was not detected in the month of October-December with the exception of August in which the highest concentration in the gills of 0.03mg/Kg was obtained. This concentration is higher than the permissible limit of 0.01 mg/Kg set by FAO/WHO (2018). Low concentration of Cd recorded in the fish tissues might have come from geological pattern in the study area and runoff from agricultural activities around the reservoir. Similar observation was reported by Putshaka *et al*. (2015) and Butu *et al*. (2018) from Challawa and Thomas reservoir, in Kano respectively. Cd concentrations recovered might be due to contamination of fish by waste water containing phosphate pesticides and other domestic sewage which are regarded as prominent sources of Cd pollution in the water. Fabio *et al*. (2016) reported that waste water contaminated with Cd can result in anemia, vertebral fractures, and osmoregulatory problems. The Cd concentration reported from this study is lower than the concentrations obtained by Farombi *et al*. (2007) and Ishaq *et al*. (2011) who reported concentration of 0.69ppm and 0.927ppm in the gills of C. *gariepinus* from Ogun and Benue water body respectively. Water contaminated with Cd has been reported to cause loss of membrane bound enzyme activity in fish tissue resulting in cellular death (Hosnia *et al*., 2015).

Bioaccumulation Factor in Fish Tissue

Heavy metals are believed to be potent toxic substances due to their slow degradation rate and long half-life period (ElMoselhy *et al*., 2014). Bioaccumulation Factor (BAF) of heavy metal concentrations in water decreased in the order of Cr > Pb > Cu >Cd. BAF recorded were above the standard set by FAO/WHO (2018). Variations in BAF depends on many factors, such as age of the fish, physiology of the fish, migratory ability of fish, differential exposure and health conditions (Ekweozor *et al*., 2017). The BAF recorded is lower than 5.76 reported by Ahmad *et al*. (2018) in Kafinchiri reservoir, Kano State. However, the BAF obtained in the present findings were within the range of 0.41-2.63 recorded by Imam and Balarabe (2012b) among three cichlid fish species from Wasai Reservoir, Kano, Nigeria.

CONCLUSION AND RECOMMENDATIONS

The study revealed that C. *gariepinus* used as indicator of pollution in Warwade Reservoir accumulates heavy metals in the tissues examine which could pose health risk to consumers. It is therefore recommended that continuous monitoring of these metals in the reservoir by the appropriate authority to ascertain their concentration. Public health awareness on the risk associated with fish consumption contaminated with heavy metals among the communities within reservoir vicinity can be employed in order to minimize potential impact.

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