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Heavy Metals Health Risk Index (HRI) in Human Consumption of Whole Fish and Water from Some Selected Dams in Katsina State Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Author AIY designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors AIY, AJA and AN managed the analyses of the study. Authors AUK, AI, IUM and AMK managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

This study was conducted in the year 2016 to determine the heavy metal concentrations in whole fish (*Clarias gariepinus*) samples and water obtained from some selected Dams (Ajiwa, Zobe and Dannakola) in Katsina state Nigeria. The objectives were mainly to detect the presence of heavy metals in whole fish and water from some selected Dams in the study area, compare the concentration of heavy metals in samples from the selected Dams concerning the permissible limits specified by WHO/FAO and USEPA Standards. Eight (8) water samples were collected at 8 random points within approximately 1000 meters on each extremity and median parts of the

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selected dams. Fish (*Clarias gariepinus*) was sampled using standard methods (AOAC, 1990). The fish and water samples were collected from Ajiwa, Zobe and Dannakola Dams of Katsina state Nigeria. Nine adult fish samples, three each from Ajiwa Dam, and Dannakola were procured from fishermen. Analysis of the concentration of these heavy metals; Cr, Cd, Fe, Ni, Mn, Pb and Zn was conducted by the use of AAS (by Atomic Absorption Spectrophotometry) method. The results showed wide mean concentrations of the heavy metals in the selected dams water; iron recorded the highest level (range 0.4596 µg / g - 2.9510 µg / g) and lead (range 0.0031 µg / g -0.0323 µg / g) recorded the lowest level, for the fish samples the mean concentrations of the same heavy metals showed iron recording the highest level (range 1.8847 µg / g -10.0474 µg / g) and cadmium (0.0130 µg / g -0.0138 µg / g) recording the lowest level. Results from this study indicate that with the exception of the heavy metals Cd, Fe and Pb (from Zobe dam sample) values of Mn, Pb (Ajiwa and Dannakola dams samples) and Zn in the water samples were generally lower than the USEPA, WHO/FAO maximum permissive limits while Ni was below the detection level (BDL) in all the samples. the results of this study showed that apart from Mn (PI range = 0.02-0.09), Zn (PI range = 0.01-0.03) and Pb for sampled water from Dannakola dam (PI= 0.77) which have no effect on the water quality, all the other heavy metals have pollution indices which suggest slightly, to moderate and strong effect on the selected dams water quality consideration for human and aquatic health. The metal indices also showed that all the heavy metals are at the threshold level (MI > 1) except for the heavy metals Mn and Zn in sampled waters from all the selected dams, Pb for water samples from Ajiwa and Dannakola dams and Cr for Zobe dam water sample. With the exception of the heavy metals Pb, Ni and Cr that were BDL in the fish samples the levels of the heavy metals all fall below the USEPA, WHO/FAO permissible limit for fish. The results from the present study suggests that the selected dams water quality is threatened by heavy metals pollution and may have adverse implication for drinking and aquatic health, in the fish samples the concentration levels of the heavy metals all fall below the USEPA, WHO/FAO permissible limit for fish. However, the fish's bio-accumulation factors of the metals suggest that they have high potentials to bio-accumulate some of the heavy metals to high levels and this may have adverse implication for human consumption.

Keywords: Beans; heavy metals; Katsina; dams; water; fish.

1. INTRODUCTION

The heavy metal contamination of aquatic system has attracted the attention of researchers all over the world [1] and has increased in the last decades due to extensive use of them in agricultural, chemical, and industrial processes that are becoming a threat to living organisms. Heavy metals are commonly defined as those having a specific density of more than 5 g/cm3 such as lead, mercury, aluminium, arsenic, cadmium, nickel. Exposure to others [2] often accompanies exposure to one heavy metal contaminant, hence the proposed investigation of seven heavy metals (Mn, Zn, Pb, Cd, Ni, Fe, Cr) in the present study. Fish are more frequently exposed to these pollutants because it is believed that regardless of where the pollution occurs, it will eventually end up in the aquatic environment [3]. Potential of heavy metal to accumulate in fish living in waters polluted with heavy metals is rather high [4]. Fish has been recognised as an essential food source for the human body. Fish provides essential fatty acids like Omega 3, proteins, vitamins, and minerals [5]. However, despite its nutritional value, consumption of fish contaminated with heavy metals brings many times a potential hazard concern for the human consumers. It has been reported that prolonged consumption of unsafe concentrations of heavy metals which especially accumulate in organs of fish, such as internal organs, kidneys, and spleen, may lead to the chronic accumulations of the metals in the kidney and liver of humans causing disruption of numerous biochemical processes, leading to cardiovascular, nervous, kidney and bone diseases [6;7;8;4]. Exposure to heavy metals has adverse effects on children health including lower birth weight, lower anogenital distance, lower Apgar scores, lower current weight, lower lung function, lower hepatitis-B surface antibody levels, higher prevalence of attention deficit/ hyperactivity disorder and higher DNA and chromosome damage [9]. Most studies on evaluation of heavy metals in fish target specific organs [4,7]. The typical Hausa/Fulani of northwestern Nigeria consume fish whole as such the need to evaluate heavy metals concentration in whole fish as opposed to selected organs. The selected dams for the study are high economic resources which serve diverse human needs such as domestic utilization, fishing, and subsistence farm irrigation in the host communities.

Evaluation and understanding the sources and impact relationship of the effects of heavy metals in water bodies and biological species is essential for effective water management, and the preservation of the aquatic ecosystem [10]. Thus, it becomes pertinent to carry out a preliminary assessment of heavy metals pollution status of the selected dams and their main economic fish: the African catfish (*Clarias gariepinus*) consumed in and around the selected communities. The aim of the present study was to assess the composition of some selected heavy metals in whole fish (*Clarias gariepinus)* and water samples from some selected dams in Katsina state, and to compare the concentration of heavy metals in the samples in relation to the permissible limits specified by WHO/FAO, FEPA and E.U Standards.

2. MATERIALS AND METHODS

2.1 Sampling Area

Katsina State, Nigeria located between latitude 11˚ to 13˚25'N and longitude 6˚45' to 9˚E is a state of North West Zone of Nigeria, with an area of 24,192km2 (9,341 sq meters) of which 67% (about 1.6 million hectares) is devoted to cultivation [11] Katsina State is divided into 36 Local Government Areas (LGAs) with a total population of about 6 million people [12]. The state is an agrarian state and Agriculture in the form crop, and livestock production is the primary employer of labour. There are several irrigation sites distributed all over the state. For sampling, a comprehensive list of all the major irrigation sites in Katsina state with characteristic 100 and above hectares size of an area of cultivation was obtained from the State Ministry of Agriculture and natural resources. With the use of table of random numbers three sites were selected

(a) Zobe Dam located in Dutsin Ma local government area of the state with a water reservoir capacity of 177.0ccu and 5000 hectares size of area of cultivation
(b) Sabke/Dannakola Dam located in Daura local government area of the state with a water reservoir capacity of 62.0ccu and 1000 hectares size of area of cultivation
(c) Ajiwa Dam located in Batagarawa local government area of the state with a reservoir capacity of 50.0ccu 300 hectares size of area under cultivation and also provides portable drinking water to 3 local government areas namely Katsina, Batagarawa and Rimi.

2.2 Fish Sampling

Fish (*Clarias gariepinus*) was sampled using standard methods [13]. The fish (collected from commercial fishermen) and water samples were collected from Ajiwa, Zobe and Dannakola Dams of Katsina state Nigeria. Nine adult fish samples, three each from Ajiwa Dam (mean weight: 314.2 ± 2.74g and mean length: 33.0 ± 1.15 cm), Zobe (mean weight: 463.8 ± 3.76 g and mean length: 36.7 ± 0.88 cm) and Dannakola (mean weight: 805.0 ± 47.68 g and mean length: 39.3 ± 1.45 cm). The fish samples were put in sterile polythene bags and taken in the icebox to the laboratory where they were washed with running tap water to remove dirt. All the fish samples were then separately stored in the deep freezer and were allowed to thaw; transferred into sterile sample bottles, labeled and kept for digestion and analysis of heavy metals.

2.3 Water Sampling

Prior to water samples collection, all the containers (high density polythene bottles) used were washed thoroughly with solution of detergent and deionised water. Then, they were soaked in 10% "Analar" nitric acid overnight followed by rinsing with deionised water to remove trace elements contamination [14]. The samples were randomly collected in August 2016 within a 1000 meters stretch of the selected dams. A total of 8 samples were collected at 8 random points on each extremity and median parts of the selected dams by immersing the pre acid-washed high-density polythene bottles to approximately 30cm below the water surface and allowed to overflow. For preservation, the water samples were acidified with nitric acid to a pH of 2 [15] and analysed within two weeks.

2.4 Fish Analysis

Whole fish was dried at 800C for 2 hours in a Gallenkamp hotbox oven (CHF097XX2.5) and then blended in an electric blender. 0.5 g of each sample was weighed and ashed at 5500C for 24 hours in an electric muffle furnace (Thermolyne FB131DM Fisher Scientific). The ash was diluted with 4.5 ml concentrated hydrochloric acid (HCl) and concentrated nitric acid ($HN0_3$) mixed at ratio

3:1 the diluent is left for some minutes for proper digestion in a beaker. 50 ml of distilled water was added to the diluents to make up to 100 ml in a volumetric flask. The levels of heavy metals were determined using AA210RAP BUCK Atomic Absorption Spectrometer flame emission spectrometer filter GLA-4B Graphite furnace (East Norwalk USA), according to standard methods [16] and the results were given in part per million (µg / g).

2.5 Water Analysis

The raw, unfiltered water samples were mixed very thoroughly, and then four subsamples (each 100 ml) were taken and subjected to wet digestion. Each 100 ml of the unfiltered water was measured into a 250 ml beaker followed by addition of 20 ml "Analar" nitric acid solution plus 10 ml of 50% hydrochloric acid solution. The acidified water was then evaporated on a hot plate to almost dryness and 5ml of 50% hydrochloric acid was again added and heated for 15 minutes. The beaker was removed and cooled to room temperature before transferring the contents into a 100 ml volumetric flask, and the volume made up to the mark with deionised water [14]. Then, the digested water was filtered and analysed for the levels of Pb, Ni, Cr, Cd, Zn, Mn and Fe using AA210RAP BUCK Atomic Absorption Spectrometer flame emission spectrometer filter GLA-4B Graphite furnace (East Norwalk USA).

2.6 The Dams Water Quality Assessment

2.6.1 Metal Quality Index (MQI)

The following two quality indices were employed to determine the heavy metals' pollution status of the selected dams in Katsina state northwestern part of Nigeria.

Pollution index (PI): The pollution index (PI) is based on individual metal calculations according to the following equation [15].

$$PI = \frac{\sqrt{\left(\frac{Ci}{Si}\right) max^2 + \left(\frac{Ci}{Si}\right) min^2}}{2}$$

Where Ci = the concentration of each element; Si = metal level according to national water quality criteria. The water quality criteria used in this study were the USEPA's permissible limits of lead, arsenic, chromium, copper, and zinc, and WHO allowable limits of cadmium, zinc, iron, as reported by Mohod and Dhote [16]. The calculated metals' pollution indices were interpreted based on the standard classification outlined by Goher et al. [17].

2.6.2 Metal Index (MI)

Metal Index (MI) is a method of rating that shows the composite influence of individual parameter on the overall quality of water [18]. It is based on a total trend evaluation of the present status. The metal index rated between zero and one and reflects the relative importance of individual metal quality considerations. Metal index value >1 is a threshold of warning [19]. Metal index of pollution has wide application and is used as the indicator of the quality of sea [20] and river water [21,22], as well as drinking water [23,24].

According to Tamasi and Cini [18], the MI is calculated by using the following formula:

$$\sum_{i=1}^{n} \frac{Ci}{(MAC)i}$$

Where Ci is the concentration of each element and MAC is the maximum allowable concentration of the element.

2.7 Daily Intake of Metals (DIM)

The daily intake of metals was calculated using the following equation:

$$\mathrm{DIM} = \frac{C_{\mathrm{metal}} * C_{\mathrm{factor}} * D_{\mathrm{intak}}}{B_{\mathrm{weight}}}$$

Where, C metal, C factor, D intake and B weight represent the heavy metal concentrations in the whole fish samples, the conversion factor, the daily intake of the fish and the average body weight, respectively. The conversion factor (CF) of 0.085 was used for the conversion of the fish samples to dry weights. The per capita consumption of fish and shellfish in Nigeria for human food is averaged 9.0 Kg [25], which is equivalent to 24.7 g per day was used for the estimation of daily intake, and the average body weight for the adult population was 60 kg; these values were used for the calculation of HRI as well.

2.8 Health Risk Index (HRI)

The HRI referred to the ratio of the daily intake of metals in the food to the oral reference dose

(RfD) and was calculated using the following equation:

$$HRI = \frac{DIM}{RfD}$$

An HRI > 1 for any metal in food indicates that the consumer population faces a health risk.

3. RESULTS AND DISCUSSION

Heavy metals are non-biodegradable and their bio-accumulation increases in nutrition deprived state, therefore, developing countries with higher prevalence of under-nutrition are at a greater risk of heavy metal toxicity. Table 1 presents the mean concentrations (ppm) of triplicate analyses of Manganese (Mn),Zinc (Zn), Lead (Pb), Cadmium (Cd), Nickel (Ni), Iron (Fe) and Chromium (Cr) determined in sampled water from the selected dams in Katsina state northwestern part of Nigeria. The result of sampled water from Ajiwa dam showed wide concentrations of the heavy metals with iron recording the highest level of 2.9510 µg / g and lead (0.0031 µg / g) recorded the lowest level. The other results showed that Zn recorded a mean concentration of 0.0912 µg / g, Mn, 0.0557 µg / g, Cd and Cr recorded 0.0101 µg / g and 0.2739 µg / g respectively while the heavy metal Ni was not detected. The sampled water from Zobe dam also has the heavy metal Fe recording the highest level of 0.4596 µg / g and Cd (0.0114 µg / g) recording the lowest. The other results for heavy metals analysed showed that Zn recorded a mean concentration of 0.0469 µg / g, Pb 0.0323 µg / g, Cr 0.0242, Mn 0.0132 µg / g while Ni was not detected. Water sample from Dannakola has Fe as the heavy metal with the highest mean concentration (0.5297 µg / g) and Cd (0.0119 µg / g) with the lowest mean concentration. The other results showed Cr as having mean concentration of 0.2615 µg / g, Zn 0.0860 µg / g, Mn 0.051 µg / g, Pb 0.0031 µg / g while Ni was not detected. Apart from Zn, Mn and Pb (Ajiwa and Dannakola) in which the present concentrations are lower than their guideline regulatory limits (Zn 5 µg / g (26); Mn 0.4 µg / g [27]; Pb 0.015 [28], the concentrations of the other heavy metals exceeded their WHO and USEPA's maximum guideline values, Cd 0.005 µg / g [16], Cr 0.1 µg / g [26]. Fe is involved in the haemoglobin synthesis in the red blood corpuscles of the blood. Fe also helps with red blood cell production. It is a necessary element in the human diet and plays a significant role in metabolic processes. In this study, the observed mean value of Fe in the water far exceeded the WHO/FEPA recommended limits of 0.300(µg / g) in water [16]. Though an essential heavy metal, Fe tends to become toxic to living organisms, even when exposure is low. The concentration values of Fe for sampled water in this study is lower than that reported for studies conducted in Bayelsa state, Nigeria [29] and Egypt [30] but similar to that of a study conducted in Kaduna state Nigeria [31]. Likewise, the concentration of Pb in the sampled waters is lower than that reported for studies conducted in Ibadan, Oyo state Nigeria [32], Koko creek Bayelsa state, Nigeria [29], lake Baringo Kenya [33] and river Kaduna, Kaduna state Nigeria [31]. Zinc is an essential trace metal for both plants and animals. Its deficiency may be responsible for retarded growth, loss of taste and hypogonadism, leading to decreased fertility [34]. The concentration values for Zn in the sampled water from the selected dams is similar to that reported for Cirato dam west Java, Indonesia [35], Eleyele reservoir Ibadan Oyo state Nigeria [32] but lower than that reported for Koko creek Bayelsa state [29] and El-Rahawy drain Egypt [30]. The concentration values for the heavy metals Mn, Cr and Cd falls within the reported range in studies conducted in Eleyele reservoir Ibadan Oyo state Nigeria [32], but lower than that reported for El-Rahawy drain Egypt [30].

Table 1. Heavy metal concentration (µg / g) in water of some selected dams in Katsina State

Dam	*Mn*	*Zn*	*Pb*	*Cd*	*Ni*	*Fe*	*Cr*
Ajiwa	0.0557 ± 0.0014	0.0912 ± 0.0019	0.0031 ± 0.0027	0.0101 ± 0.0005	BDL	2.9510 ± 0.0041	0.2739 ± 0.0537
Zobe	0.0553 ± 0.0011	0.0469 ± 0.0574	0.0323 ± 0.0033	0.0114 ± 0.0003	BDL	0.4596 ± 0.0037	0.0242 ± 0.0669
Dannakola	0.0510 ± 0.0009	0.0860 ± 0.0039	0.0031 ± 0.0013	0.0119 ± 0.0012	BDL	0.5297 ± 0.0018	0.2615 ± 0.0739

Values are expressed as Mean ± SD

Tables 2 show the mean concentrations (ppm) of the heavy metals in whole catfish (*Clarias gariepinus*) from the selected dams. In *C. gariepinus* sample from Ajiwa dam, Iron recorded the highest mean concentration of 1.8847 µg / g while Cd recorded the lowest level (0.0130ppm). Cr, Zn, Pb and Mn showed respective mean concentration in µg / g of; 0.1321, 0.0866, 0.0292 and 0.0137 while Ni was at BDL. From the table the *C. gariepinus* sample from Zobe dam showed Iron (Fe) as recording the highest mean level of 10.0474 µg / g while Pb (0.0125 µg / g) was the lowest. The levels of the other heavy metals were Cr = 0.0863 µg / g, Zn = 0.0841 µg / g, Cd = 0.0138 µg / g while Ni was BDL. The result of sampled *C. gariepinus* from Dannakola also showed Fe concentration (2.188 µg / g) as the highest with Cd (0.0131 µg / g) being the lowest. The levels of other heavy metals were; Zn = 0.2205 µg / g, Mn= 0.0709 µg / g) while the heavy metals Pb, Ni and Cr were at BDL. In the present study, the mean Lead content in all the *C. gariepinus* samples was below the WHO/FAO maximum permissible limit of 1.5 µg / g [36], Which is lower than the values reported for *C. gariepinus* from El-Rahawy dam Egypt [30], Ayeloja et al. [32] for *C. gariepinus* from Eleyele reservoir in Ibadan Oyo state Nigeria, that reported for Koko creek, Bayelsa state Nigeria [29], Imo river Nigeria [37], *C. gariepinus* from lake Baringo Kenya [33] and that from Cirato dam west Java, Indonesia [35]. Lead (Pb) level recorded in this study in sampled water from Ajiwa and Zobe Dams may be probably due to contamination of the river by the activities of car wash operators and automobiles repair workshop located in the area that have tributary rivers that empty into such Dams.

Cadmium (Cd) like any other substance could be absorbed via the gills and has been known to cause damage to fish. In man, Cd poisoning could lead to anemia, renal damage, bone disorders and cancer of the lungs [38]. The mean Cadmium concentration range for the *C. gariepinus* samples from the selected dams was 0.0130-0.0138 µg / g which is lower than that reported for *C. gariepinus* fish from Koko creek, Bayelsa state Nigeria, lake Baringo Kenya and *C. gariepinus* from Cirato dam west Java Indonesia [29,33,35] but similar to result reported for *C. gariepinus* analysed from river Kaduna [31], the levels were also low in comparison to the 0.58-1.26mg/100g recorded in fishes of Olomoro water body, [Idodo-Umeh, 2002 University of Ibadan unpublished PhD thesis). Okoronkwo (University of Ibadan unpublished MSc thesis, 1992] also recorded 0.270mg/100g for fishes of the River Niger. In the present study, the mean Fe concentration in both *C. gariepinus* samples was lower than that reported in a study in eastern Nigeria [30] and much lower than that recorded by Nyingi et al (33) who analysed different fish species (tilapia, cat fish and lung fish) from Kenya and reported a higher Fe concentration and Seham et al. [30] in *C. gariepinus* from El-Rahamy drain Egypt. The range of Zn level in the whole *C. gariepinus* samples in this study is low when compared to the zinc level reported by Obasohan [39] in Parachanna obscura from Ogba River, Benin City, Nigeria. The possible explanation for this could be difference in fish species, sizes, ages sampling sides and sampling periods. Adeyeye [40] reported that differences in metal concentrations in fish were a function of species, while Idodo-Umeh [University of Ibadan, unpublished PhD thesis] reported that bigger fishes tend to accumulate higher concentrations of metals than smaller ones, consequently, consumption of fish from the selected Dams in this study could not pose any Zn-induced health hazards.

The result for Mn concentrations in *C. gariepinus* in the present study differs from results of a study on heavy metals in *C. gariepinus* in Egypt that reported a higher concentration range [30] but is similar to that of a study conducted in Ibadan Oyo state Nigeria [32]. The results indicate a concentration range of 0.0863-0.1321 µg / g) for the heavy metal Cr in the whole *C. gariepinus* samples, values that are similar to that reported by Ayeloja et al. [32] but lower than that reported by Udiba et al. [41] in their study conducted in Zaria, Kaduna state Nigeria. The two tailed comparism of the heavy metals in whole *Clarias gariepinus* and water sampled has revealed that with the exception of the heavy metals Zn for Ajiwa *(P* value = 0.0733), Zobe *(P* value = 0.2721), Cr for Zobe (*P* value = 0.2317) and Cd for Dannakola (*P* value = 0.2381) the statistical difference between heavy metals in sampled *Clarias gariepinus* and water is quite significant.

Tables 3 and 4 presents the pollution and metal indices of the heavy metals determined in this study. Based on the classification of metal pollution index for water [17], the results of this study showed that apart from Mn (PI range = 0.02-0.09), Zn (PI range = 0.01-0.03) and Pb for sampled water from Dannakola dam (PI= 0.77) which have no effect on the water quality, all the other heavy metals have pollution indices which suggest slightly, to moderate and strong effect on the selected dams water quality consideration for human and aquatic health. The metal indices also showed that all the heavy metals are at the threshold level (MI > 1) except for the heavy metals Mn and Zn in sampled waters from all the selected dams, Pb for water samples from Ajiwa and Dannakola dams and Cr for Zobe dam water sample, this suggests that the selected dams water quality is threatened by heavy metals pollution and may have adverse implication for drinking and aquatic health. Considering the complexity of factors associated with surface run-off which could elevate heavy metals levels in surface water during rainy season, this finding indicates the need to carry out a more detail study spanning at least, two years to determine the levels of the heavy metals during the dry seasons where surface run-off of effluents are very minimal in the study area. According to Ibrahim and Omar [42], the amount of fluctuations of agricultural drainage water, sewage effluents and industrial wastes discharged into water ways are the main reasons for temporal difference of heavy metals content of water. Water quality can also be affected when the rate of atmospheric deposition, storm water run offs, domestic or industrial waste water discharges, surpasses the carriage capacity of water [43].

Table 5 shows the metal transfer factors values for *C. gariepinus* samples collected from the selected dams. It was found that, transfer factors values of the heavy metals Mn and Zn in *C. gariepinus* collected from Dannakola dam were higher than those in *C. gariepinus* collected from Ajiwa and Zobe dams. It could be seen from the results that while Pb and Cd accumulated the highest concentrations in *C. gariepinus* from Ajiwa dam, Fe and Cr were accumulated at the highest levels in *C. gariepinus* from Zobe dam.

Health risks associated with aquatic food consumption often depends on the quantity that was consumed and an individual's weight. Reports from this study revealed that *C. gariepinus* muscles from the selected dams has health risk index for the detected heavy metals to be less than unity (Table 6), which suggests no potential health effects on the local population.

Table 2. Heavy metal concentration (µg / g) in whole cat fish (*Clarias gariepinus*) of some selected dams in Katsina State

Dam	Mn	Zn	Pb	Cd	Ni	Fe	Cr
Ajiwa	0.0137 ± 0.0023	0.0866 ± 0.0027	0.0292 ± 0.0028	0.0130 ± 0.0006	BDL	1.8847 ± 0.0026	0.1321 ± 0.0231
Zobe	0.0132 ± 0.0018	0.0841 ± 0.0020	0.0125 ± 0.0019	0.0138 ± 0.0010	BDL	10.0474 ± 0.0050	0.0863 ± 0.0368
Dannakola	0.0709 ± 0.0008	0.2205 ± 0.0063	ND	0.0131 ± 0.0009	BDL	2.1188 ± 0.0017	ND

Values are expressed as Mean ± SD

Table 3. Pollution index of heavy metals in water from the selected dams

Heavy metal	Pollution index			[x]Category of water pollution index (PI)	
	Ajiwa	Zobe	Dannakola	Pollution Index[x]	Effect on water quality
Mn	0.09	0.02	0.09	< 1	No Effect
Zn	0.01	0.03	0.01	1-2	Slightly Affected
Pb	1.32	2.03	0.77	2-3	Moderately Affected
Cd	1.40	1.59	1.70	3-5	Strongly Affected
Ni	BDL	BDL	BDL	> 5	Seriously Affected
Fe	6.84	1.09	1.26		
Cr	2.31	3.66	3.17		

[x] *Source: Goher et al., (2014)*

Table 4. Metal index of the heavy metals in water from the selected dams

Heavy metal	Metal index		
	Ajiwa	**Zobe**	**Dannakola**
Mn	0.14	0.13	0.12
Zn	0.02	0.01	0.02
Pb	0.20	2.15	0.20
Cd	2.02	2.28	2.38
Ni	BDL	BDL	BDL
Fe	9.80	1.50	1.77
Cr	2.49	0.22	2.37

Key= Metal Index < 1 Represent no threat to human health and aquatic life; Metal Index > 1 Represent threshold level of threat to human health and aquatic life

Table 5. Metal transfer factor for catfish (*Clarias gariepinus*) from the selected dams

Heavy metal	Ajiwa	Zobe	Dannakola
Mn	0.2460	0.2387	1.3902
Zn	0.9496	1.7931	2.5639
Pb	9.4194	0.3869	BDL
Cd	1.2871	1.2105	1.1008
Fe	0.6387	21.8611	4.0000
Cr	0.4823	3.5661	BDL

Table 6. Daily metal intake and health risk index from consumption of catfish (*Clarias gariepinus*) from the selected dams

Heavy metal	Daily intake of metal			Health risk index		
	Ajiwa	**Zobe**	**Dannakola**	**Ajiwa**	**Zobe**	**Dannakola**
Mn	0.0005	0.0005	0.0250	0.0034	0.0033	0.1786
Zn	0.0030	0.0029	0.0077	0.0100	0.0097	0.0257
Pb	0.0010	0.0004	BDL	0.0017	0.0007	BDL
Cd	0.0005	0.0005	0.0005	0.0010	0.0010	0.0010
Ni	BDL	BDL	BDL	BDL	BDL	BDL
Fe	0.0660	0.3516	0.0741	0.0825	0.4396	0.0926
Cr	0.0046	0.0030	BDL	0.0153	0.0100	BDL

4. CONCLUSION

The results obtained in this study showed extensive mean concentrations of the heavy metals in the selected dam's water with iron (Fe) and lead (Pb) recording the highest and lowest levels respectively. Heavy metal concentration in the sampled fish has the heavy metals Fe and Cd recording the highest and lowest levels respectively. Results from this study indicate that with the exception of the heavy metals Cd, Fe and Pb (from Zobe dam sample), Mn and Pb (Ajiwa and Dannakola dams samples) and Zn the concentration values of the metals in the water samples were generally lower than the USEPA, WHO/FAO maximum permissive guideline values for the protection of human and aquatic health, while Ni was not detected in all the samples. Except the heavy metals Pb, Ni and Cr that were not detected in the fish samples the concentration levels of the heavy metals all fall below the USEPA, WHO/FAO permissible limit for fish. Based on the classification of metal pollution index for water, the results of this study showed that apart from Mn, Zn and Pb for sampled water from Dannakola dam which have no effect on the water quality, all the other heavy metals have pollution indices which suggest slightly, to moderate and strong effect on the selected dams water quality consideration for human and aquatic health. The metal indices also showed that all the heavy metals are at the threshold level (MI > 1) except for the heavy metals Mn and Zn in sampled waters from all the selected dams, Pb for water samples from Ajiwa and Dannakola dams and Cr for Zobe dam water sample. The Results of t-test analysis between mean concentrations of the heavy metals in the sampled waters and fish were statistically significant ($p < 0.01$) except Cr levels. This may be due to differences in the physiological and biochemical functions, including metals storage and elimination from the body by the individual fish. The present levels of the fish's heavy metals were below their regulatory limits for the protection of human health. However, the results of bio-accumulation factors of the metals by the fish suggest that they have high potentials to bio-accumulate some of the heavy metals to high levels and as exposure to heavy metals may occur through various routes such as through occupational exposure, environmental contamination, and accumulation in food [2] this may have an added adverse implication for human consumption. Because heavy metals are non-biodegradable and are bio-accumulative which, therefore, make their presence in human foods even at very minute levels potential toxins, it is essential to monitor their accumulations in the dams water and fish and precautionary advice measures to limit excessive human exposures to the heavy metals content. At the moment, there is no known reported case of metal poisoning arising from direct consumption of fish and water from these dams but, the increase in the levels of these toxicants could pose potential health hazard for the inhabitants of Ajiwa, Zobe and Dannakola considering the fact that fish is the cheapest available source of protein in this environment.

ETHICAL APPROVAL

As per international standard or university standard written ethical approval has been collected and preserved by the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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