RECORDS OF CHEMICAL SCIENCES

Heavy Metal Concentrations in Fish and Water of Ajiwa Dam, Katsina State, Nigeria.

*[1]Uduma, A. U., [1]Okunola, O. J., *[1]Mohammed Sani Mohammed and [3]Awagu E. F.*

https://doi.org/10.33003/frscs_2024_0303/06

Accepted: 15th Oct, 2024
Published: 30th Oct, 2024

1. 1Chemistry Department, Federal University Dutsin-Ma, P.M.B 5001, Katsina State, Nigeria.
2. Nigerian Stored Products Research Institute, Rumueme, Mile Four, Port Harcourt, River State, Nigeria

Corresponding Author:
Uduma A. U.
auduma@fudutsinma.edu.ng

FRsCS Vol.3 No. 3 (2024)
Official Journal of Dept. of Chemistry, Federal University of Dutsin-Ma, Katsina State.
http://rudmafudma.com

ISSN (Online): 2705-2362
ISSN (Print): 2705-2354

Abstract
In this current study determination of the physicochemical parameters of water and the concentration of heavy metals in catfish bone from Ajiwa dam, Katsina State, Nigeria, were conducted. Standard methods were employed in the sampling protocol and the analysis. The physicochemical parameters of the water were recorded as follows; pH ranges from 7.23±0.15 to 6.17±0.06, Turbidity ranges from 196±1.73 to 148.67±2.08 mg/L, Hardness ranges from 47.14±0.01 to 40.41±0.02 mg/L, Nitrate ranges from 0.99±0.006 to 0.002±0.001 mg/L, Phosphate ranges 19.37±0.015 to 1.89±0.002 mg/L, Sulphate ranges from 23.40±0.53 to 15.00±1.00 mg/L, Electrical conductivity ranges from 105.37±0.32 to 89.77±0.06 mg/L and Total Dissolve Solid ranges from 50.03±0.06 to 43.40±0.00 mg/L. The spectrophotometric method was used to evaluate the concentration of Nitrates, Phosphates, Sulphates, pH, Total dissolved solids, and Electrical Conductivity, while the titrimetric method was used for the determination of hardness. The concentration of Zinc (Zn), Lead (Pb), Iron (Fe), Manganese (Mn), Copper (Cu), Cobalt (Co), Nickel (Ni), Cadmium (Cd), and Chromium (Cr) in catfish bone and water from Ajiwa dam were determined using Atomic Absorption Spectrophotometer (AAS). A total of seven samples each of catfish and water were collected and analyzed for heavy metals. Data obtained were subjected to an analysis of variance (ANOVA) test at a 0.05% confidence level, principal component analysis, cluster analysis, and Pearson correlation. The result showed that all the metal concentrations in both catfish bone and water were below the WHO recommended values: Pb (0.05 mg/l), Fe (10.1 mg/l) Zn (5.0 mg/l), Ni (0.02 mg/l), Cd (0.005 mg/l), Cr (0.05 mg/l), Co (0.05 mg/l) Cu (1.0 mg/l) and Mn (0.05 mg/l) for water and Pb (0.4 mg/l), Fe (3.0 mg/l), Cd (0.03 mg/l), Cu (2.0 mg/l), Mn (0.4 mg/l) Zn (3.0 mg/l) Cr (0.05 mg/l) Ni (0.02 mg/l) and Co (0.05 mg/l) for catfish bone. These findings indicate that the fish and water are safe for both aquatic life and human consumption.
Keywords: Heavy Metal, Catfish Bone, Ajiwa Dam and Statistical Analysis

Introduction

The heavy metal contamination of aquatic ecosystems has attracted the attention of researchers all over the world (Dutta and Dalal, 2008) and has increased in the last decades due to the extensive use of agrochemicals in agricultural activities, chemical and industrial processes that are becoming a threat to living organisms. Heavy metals belong to a subset of elements that exhibit metallic properties. Many different definitions have been proposed for heavy metals; some based on density, some on atomic number or atomic weight, and some on chemical properties or toxicity (Duffus, 2002). Heavy metals occur naturally in the ecosystem with large variations in concentration. Some of them are dangerous to health or the environment (e.g. mercury, cadmium, lead, chromium) (Hogan, 2010), some may cause corrosion (e.g. zinc, lead), while some are harmful in other ways (e.g. arsenic, which may pollute catalysts). Some heavy metals are essential to humans in minute amounts (cobalt, zinc, copper, chromium, manganese, nickel) while others are carcinogenic or toxic, affecting, among others, human and animal life (Zevenhoven and Kilpinen, 2001).

However, once the permissible limit is exceeded, the body mechanisms that maintain balance no longer operate. None of the heavy metals is biodegradable, although they can change forms from solid, to liquid, to dust and gas; they never completely disappear. The toxic ones even in minute amounts create instant cellular destruction in any of their forms. They all exist naturally on the earth's crust and the most toxic must be mined by man before they become a threat to plant and animal life.

Heavy metals have been known to be responsible for historic diseases like; the *Minamata* disease resulting from mercury poisoning (Hightower, 2008), and the *itai-itai* disease from cadmium poisoning (ICETT, 1998). Heavy metals are introduced into the environment by a wide spectrum of natural and anthropogenic sources. Natural sources include volcanic activities, erosion and atmospheric condensation as well as natural disasters such as earthquakes, landslides, tornadoes, and cyclones (Nathaniel *et al*., 2000). The commonest forms of anthropogenic sources of heavy metals are industrial and mining activities, industrial waste, petroleum exploration and exploitation, processing and effluent management, domestic and industrial sewage, nuclear reactor accidents, and solid weapons. Heavy metals obtained from all these sources constitute potential dangers to the environment. Industrial discharges, domestic sewage, non-point sources such as urban run-off, and atmospheric precipitation are the main sources of toxic heavy metals that enter aquatic ecosystems (Joyeux *et al*., 2004). Heavy metal toxicity in humans can result in damaged or reduced mental and central nervous function, lower energy levels, and damage to blood composition, lungs, kidneys, liver, and other vital organs. Long-term exposure may result in slowly progressing physical, muscular, and neurological degenerative processes that mimic Alzheimer's disease, Parkinson's disease, muscular dystrophy, and multiple sclerosis. Allergies are not uncommon and repeated long-term contact with some metals or their compounds may even cause cancer (International Occupational Safety and Health Information Centre, 1999).

In water bodies, the obvious sign of elevated heavy metal pollution is dead fish, which is readily apparent while sub-lethal heavy metal pollution might result only in the occurrence of unhealthy fish. However, very low levels of pollution may have no apparent impact on the fish itself, which would show no obvious signs of illness but may decrease the fecundity of fish populations, leading to a long-term decline and eventual extinction of this important natural resource (Krishnani *et al*., 2003 and Burger and Gochfeld, 2011). Structured barriers created to hinder or control the flow of water in rivers and streams are sometimes known as dams (Nicklow, 2003). Dams are built to supplement water supply shortages, particularly during the dry season. Dams are one of the most productive ecosystems, contributing significantly to a region's ecological sustainability and serving as a vital component of human civilization. Katsina State is home to Ajiwa Dam. Local farmers mostly utilize the dams to irrigate rice, watermelon, sugarcane, pepper, onions, tomatoes, and fish. Due to a lack of pipe-borne water, residents in rural areas typically use the most convenient source of water in their area, regardless of quality. Water's physical, chemical, and biological properties have significant implications for all biological structures and functions. A fish is any gill-bearing aquatic vertebrate (or craniate) animal that lacks limbs with digits. Included in this definition are the living hagfish, lampreys, and cartilaginous and bony fish, as well as various extinct related groups. The *Clarkias gariepinus* or African sharp-tooth catfish; a species of catfish of the family Clariidae, the air-breathing catfishes is among the common fish in Ajiwa Dam. It got its binomial name in 1822 by a Scientist named Burchell (Coetzee *et al*., 2002). Contamination of freshwater fish with heavy metals is a recognized environmental problem. The World Health Organization as well as the Food and Drug Organization of the United Nations stated that monitoring eight elements in fish; Hg, Cd, Pb, As, Cu, Zn, Fe, and Sn is obligatory, and monitoring of other heavy metals is suggested (Staniskiene, 2006). Heavy metals after contaminating water, penetrate fish directly through the skin and later gill (Sinha *et al*., 2002). Fish assimilate metals by ingestion of particulate material suspended in water, ingestion of food, and ion exchange of dissolved metals across lipophilic membranes. Excretion of heavy metals occurs via the feces, urine, and respiratory membranes while heavy metals distribution between the different tissues depends on the mode of exposure (Alam *et al*., 2002).

Heavy metal levels in live fish usually follow the ranking: Fe > Zn > Pb > Cu > Cd > Hg. The levels of Zn may be very high, up to over 300 µg/g dry weight (dw); the maximum concentrations of lead and copper are lower and usually do not exceed 10 µg/g (dw) while Cadmium and mercury are accumulated by fish in very low amounts, below 1 µg/g (dw) (Ebrahimi and Taherianfard, 2011).

Heavy metal accumulation in fish depends on pollution and may differ among fish species living in the same water body (Terra *et al*., 2009). Generally, the higher the heavy metal concentration in the environment, the more the amount taken up and accumulated by fish. Heavy metals are dangerous because they tend to be bio-concentrated and biomagnified. Bio-concentration is the intake of chemical contaminants through an organism's epithelial tissues or gills, and the subsequent concentration of that chemical contaminant within the organism‘s tissues to a level that exceeds ambient environmental concentrations (Gobas *et al*., 1999). It is important to determine the concentrations of heavy metals in fish to evaluate the possible risk of consuming such fish (Cid *et al*., 2001). Evaluation and understanding of the sources and impact relationship of the heavy metals in the water bodies and biological species is important for effective water management, and the preservation of the aquatic ecosystem. Thus, it becomes pertinent to carry out a preliminary assessment of the heavy metals pollution status of the dam and their main economic fish: the African catfish (*Clarias gariepinus*) consumed in and around the community.

Materials and Methods

Materials

Study Area

Ajiwa is located in the Batagarawa Local Government Area of the State, its geographical coordinates are 12° 59' 0" North, 7° 45' 0" East. (Parkman and Haskoning, 1996).

Methods

Sample Collection and Analysis

A total number of 14 samples were collected from Ajiwa dam, which includes seven (7) water samples and seven (7) samples of *Clarias gariepinus* (catfish) for the determination of physicochemical parameters and assessment of selected heavy metals. In all, standard methods were employed both for the sampling and analysis (APHA, 2016).

Statistical Analysis

All data obtained from this study were quantitative. They were analyzed using the Statistical Package for Social Science (SPSS) version 15.0. The data was first summarized using descriptive statistics and later subjected to a series of inferential analyses such as independent and paired sample t-tests at a 5% level of significance as well as ANOVA and multivariate analysis. The results of the data analyzed are presented in tables and figures in the results section.

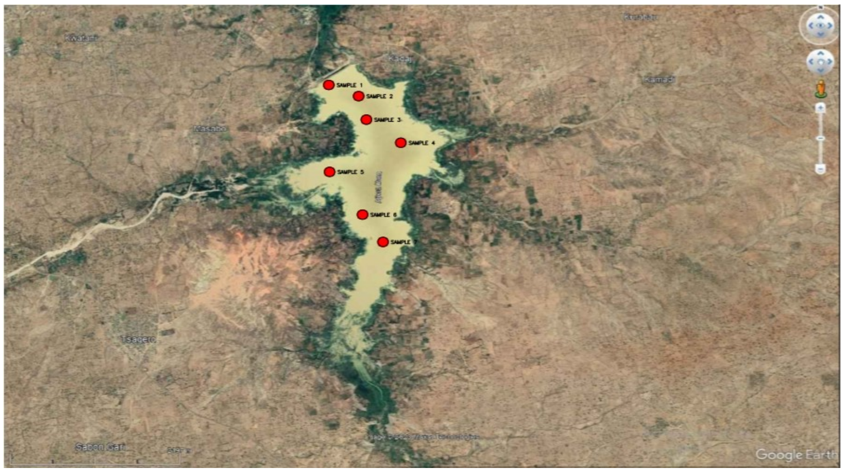

Figure 1: Map of Ajiwa Dam showing sampling locations (Google Map).

Health Risk Assessments

The potential risk from heavy metals in water is calculated based on recommendations proposed by the United States Environmental Protection Agency (USEPA 2001; 2000). The Average daily intake (ADI) (mg/kg-day) of each heavy metal through ingestion and dermal contact pathways was calculated using the following equations:

$$ADI = \frac{C_{metal} \times IR \times ED \times CF}{BW \times AT} \quad \text{------ equ. 3.3}$$

Where, ADI = Average Daily intake, IR=ingestion rate (2.2g/day), ED = Exposure duration (70 years), CF= Conversion factor (0.085), BW (60kg) = Body weight of the exposed individual, AT (days) = Estimated period over which the dosed is estimated.

The potential health risk can be categorized by target hazard quotients (HQ) and hazard index (HI) as proposed by (USEPA 2001; 2000). HQ is a ratio of determined Estimated daily intake (EDI, mg/kg/day to reference dose RFD, (mg/kg/day) of an individual element. All HQs can be added to generate a HI for the estimation of total potential health risks.

$$HI = \sum HQ \quad \text{------ equation 3.4}$$

RESULTS AND DISCUSSION

Table 1: **Physico-Chemical Parameters of Ajiwa Dam Water**

Sample	Turbidity (NTU)	Hardness (mg/L)	Nitrate (mg/L)	Phosphate (mg/L)	Sulphate (mg/L)	pH	EC (µs/cm)	TDS (mg/L)
A	148.67±2.08^{e}	42.76±0.10^{d}	0.99±0.006^{a}	1.89±0.002^{g}	15.00±1.00^{e}	7.10±0.10^{a}	97.47±0.06^{d}	46.03±0.06^{e}
B	162.00±2.00^{d}	43.64±0.46^{c}	0.002±0.001^{d}	14.22±0.015^{c}	16.93±0.06^{d}	6.43±0.06^{cd}	103.00±0.00^{b}	48.70±0.00^{b}
C	150.33±1.53^{e}	47.14±0.01^{a}	0.87±0.002^{b}	1.96±0.001^{f}	16.07±0.12^{de}	6.47±0.12^{c}	93.30±0.10^{e}	44.10±0.00^{f}
D	180.67±0.58^{b}	44.87±0.02^{b}	0.72±0.006^{c}	10.97±0.012^{e}	18.67±0.58^{c}	6.17±0.06^{e}	89.77±0.06^{f}	43.40±0.00^{g}
E	196.00±1.73^{a}	43.56±0.04^{c}	0.004±0.001^{d}	11.98±0.015^{d}	20.21±0.27^{b}	6.70±0.10^{b}	105.37±0.32^{a}	50.03±0.06^{a}
F	180.67±0.58^{b}	44.87±0.02^{b}	0.007±0.001^{d}	19.37±0.015^{a}	17.00±1.00^{d}	7.23±0.15^{a}	97.07±0.23^{d}	46.17±0.06^{d}
G	175.00±2.00^{c}	40.41±0.02^{e}	0.003±0.002^{d}	17.23±0.016^{b}	23.40±0.53^{a}	6.27±0.12^{de}	99.57±0.49^{c}	47.30±0.00^{c}

Table 2: Pearson Correlations Results among Physiochemical Parameters of Ajiwa Dam Water

Correlations								
Parameters	Turbidity	Hardness	Nitrate	Phosphate	Sulphate	pH	EC us	TDS
Turbidity	1							
Hardness	-0.196	1						
Nitrate	-0.645**	0.415	1					
Phosphate	0.678**	-0.390	-0.887**	1				
Sulphate	0.622**	-0.615**	-0.569**	0.570**	1			
pH	-0.080	0.071	0.004	-0.033	-0.502*	1		
EC	0.294	-0.488*	-0.694**	0.328	0.270	0.204	1	
TDS	0.396	-0.510*	-0.737**	0.396	0.340	0.155	0.991***	1

***Correlation is significant at 0.05 level (2-tailed) H**
**** Correlation is significant at 0.01 level (2-tailed)**

Table 3: **Mean Concentration and Standard Deviation of Heavy Metals in Ajiwa Dam Water**

Sample	Zn	Pb	Cd	Fe	Cu	Mn	Ni	Co	Cr
A	0.056±0.001[c]	0.034±0.005[cd]	-0.004±0.006[a]	5.21±0.08[f]	3.37±0.018[b]	0.038±0.004[bc]	0.037±0.003[b]	0.022±0.002[a]	0.177±0.008[b]
B	0.038±0.001[d]	0.024±0.012[de]	-0.012±0.001[b]	5.66±0.03[e]	0.41±0.016[f]	0.043±0.001[b]	0.025±0.003[c]	0.017.±0.001[a]	0.184±0.021[b]
C	0.057±0.000[c]	0.032±0.003[cd]	-0.013±0.002[b]	5.51±0.063	1.70±0.010[e]	0.020±0.002[d]	0.022±0.002[c]	0.16±0.004[a]	0.165±0.038[c]
D	0.068±0.003[a]	0.085±0.005[a]	-0.010±0.001[b]	7.68±0.10[d]	1.75±0.013[d]	0.050±0.001[a]	0.035±0.004[b]	0.019±0.004[a]	0.223±0.058[ab]
E	0.064±0.002[b]	0.016±0.019[e]	-0.013±0.002[b]	8.94±0.14[b]	0.36±0.005[g]	0.049±0.006[a]	0.056±0.003[a]	0.023±0.004[a]	0.241±0.013[a]
F	0.061±0.003[b]	0.046±0.008[bc]	-0.012±0.001[b]	9.94±0.17[a]	1.90±0.015[c]	0.041±0.003[b]	0.051±0.003[a]	0.022±0.006[a]	0.217±0.011[ab]
G	0.056±0.002[c]	0.053±0.006[b]	-0.013±0.001[b]	8.25±0.08[c]	6.12±0.004[a]	0.034±0.001[c]	0.039±0.002[b]	0.022±0.004[a]	0.203±0.016[ab]

Table 4: Correlations for heavy metals in Ajiwa Dam Water

					Correlations				
Metals	Zn	Pb	Cd	Fe	Cu	Mn	Ni	Co	Cr
Zn	1								
Pb	0.434*	1							
Cd	0.320	0.060	1						
Fe	0.522*	0.207	-0.398	1					
Cu	0.097	0.334	0.155	0.050	1				
Mn	0.206	0.187	0.111	0.428	-0.349	1			
Ni	0.524*	-0.098	-0.077	0.811**	-0.008	0.540*	1		
Co	0.157	-0.076	0.250	0.413	0.201	0.260	0.516*	1	
Cr	0.455*	0.127	-0.272	0.625**	-0.132	0.573**	0.635**	0.160	1

***Correlation is significant at 0.05 level (2-tailed)**
****Correlation is significant at 0.01 level (2-tailed)**

Table 5: Mean Concentration and Standard Deviation of Heavy Metals in fish

Sample	Zn	Pb	Cd	Fe	Cu	Mn	Ni	Co	Cr
A	0.80±0.001^{d}	0.16±0.013^{bc}	-0.0013±0.001^{a}	1.32±0.015^{f}	0.21±0.048^{e}	0.30±0.002^{e}	0.085±0.007^{b}	0.055±0.001^{b}	0.22±0.012^{b}
B	0.93±0.001^{a}	0.20±0.012^{a}	0.0003±0.002^{a}	4.51±0.006^{a}	0.38±0.001^{c}	0.67±0.006^{a}	0.100±0.004^{a}	0.065.±0.002^{a}	0.34±0.008^{a}
C	0.78±0.006^{e}	0.16±0.005^{bc}	-0.0073±0.001^{b}	1.49±0.031^{d}	0.29±0.002^{d}	0.25±0.003^{f}	0.077±0.006^{bc}	0.046±0.005^{c}	0.24±0.023^{b}
D	0.74±0.002^{f}	0.18±0.015^{ab}	-0.0073±0.001^{b}	1.16±0.085^{g}	1.44±0.003^{a}	0.44±0.002^{b}	0.069±0.007^{c}	0.054±0.001^{b}	0.20±0.022^{bc}
E	0.60±0.002^{g}	0.14±0.013^{c}	-0.016±0.002^{d}	2.37±0.002^{b}	0.69±0.002^{b}	0.25±0.005^{f}	0.051±0.006^{d}	0.036±0.003^{d}	0.16±0.015^{c}
F	0.87±0.003^{b}	0.19±0.020^{ab}	-0.012±0.002^{c}	2.20±0.017^{c}	0.30±0.002^{d}	0.37±0.002^{d}	0.047±0.011^{d}	0.045±0.006^{c}	0.23±0.035^{b}
G	0.82±0.001^{c}	0.18±0.009^{ab}	-0.011±0.001^{c}	1.37±0.016^{e}	0.20±0.004^{e}	0.43±0.005^{c}	0.051±0.002^{d}	0.037±0.003^{d}	0.20±0.049^{bc}

Table 6: Correlations Among Heavy Metals In Fish Bone

Correlations									
Metals	Zn	Pb	Cd	Fe	Cu	Mn	Ni	Co	Cr
Zn	1								
Pb	0.7	1							
Cd	0.61*	0.406	1						
Fe	0.43*	0.371	0.335	1					
Cu	0.46*	-0.031	-0.142	-0.180	1				
Mn	0.67*	0.753**	0.535*	0.683**	0.100	1			
Ni	0.419	0.342	0.900**	0.440*	-0.065	0.461*	1		
Co	0.56*	0.527*	0.872**	0.472*	0.117	0.635**	0.822*	1	
Cr	0.7	0.551*	0.676**	0.683*	-0.282	0.680*	0.658*	0.722**	1

***Correlation is significant at 0.05 level (2-tailed)**
****Correlation is significant at 0.01 level (2-tailed)**

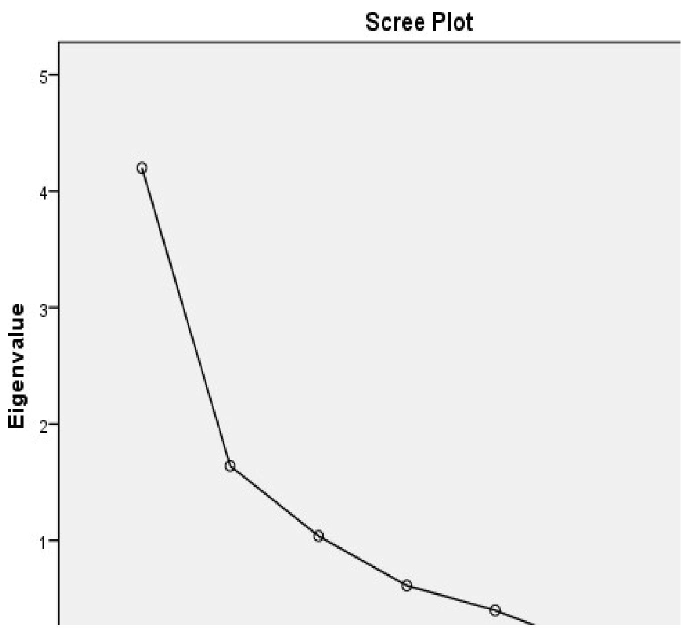

Fig 2: Scree Plot of Physicochemical Parameters of the Study Area

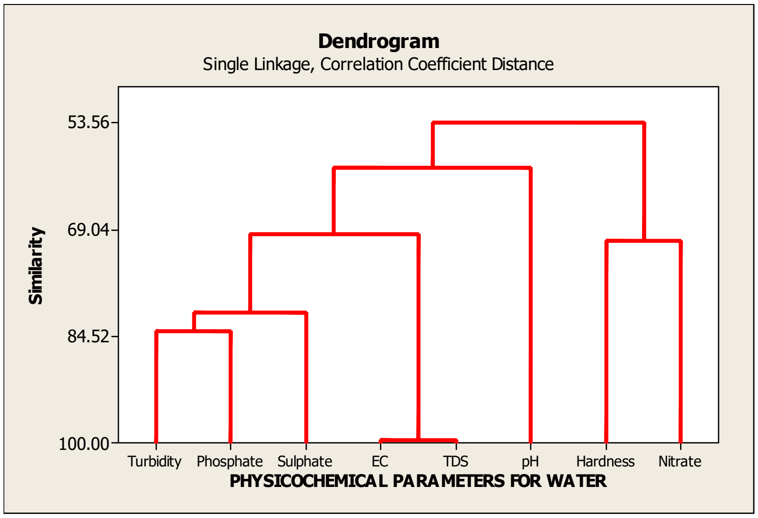

Fig 3: Cluster Analysis of Physicochemical Parameters of the Dam Water

Discussion on Cluster Analysis of Physicochemical Parameters of Ajiwa Dam Water

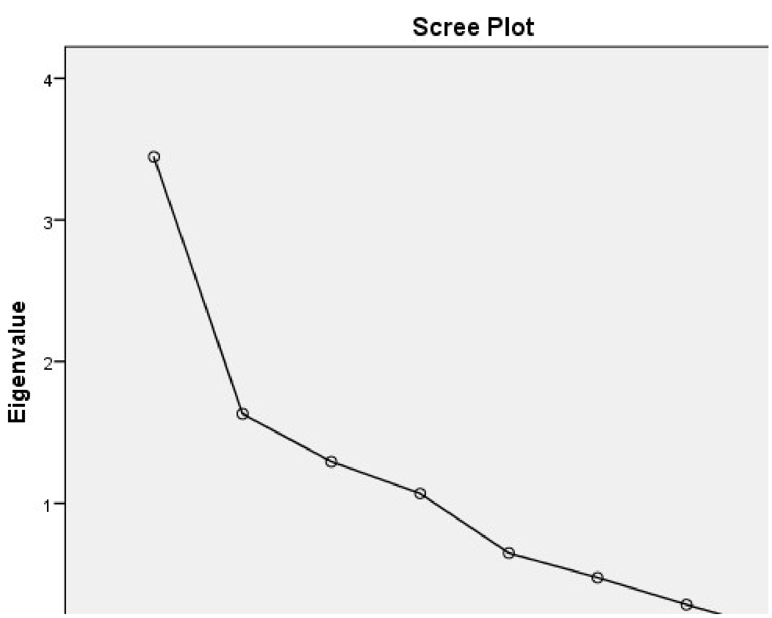

Fig 4: Scree Plot of Principal Component Analysis of Heavy Metals in Ajiwa Dam

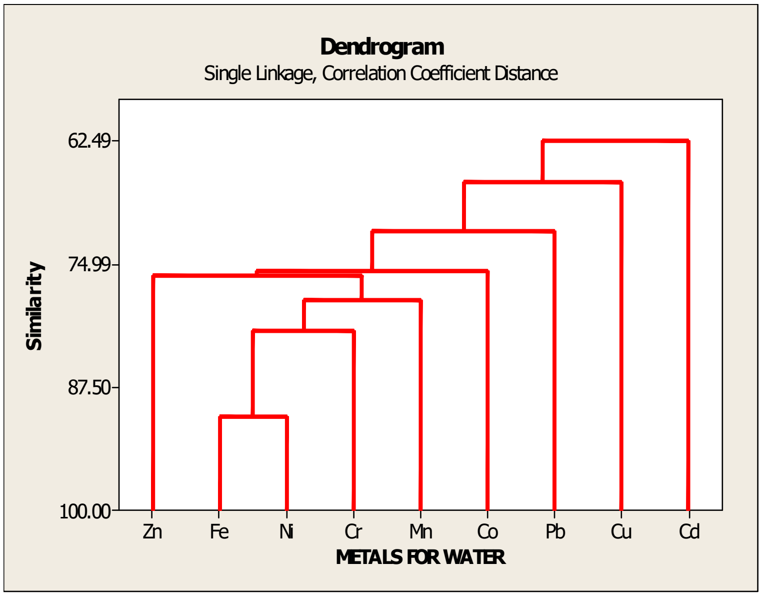

Fig. 5: Cluster Analysis of Heavy Metals from Ajiwa Dam Water

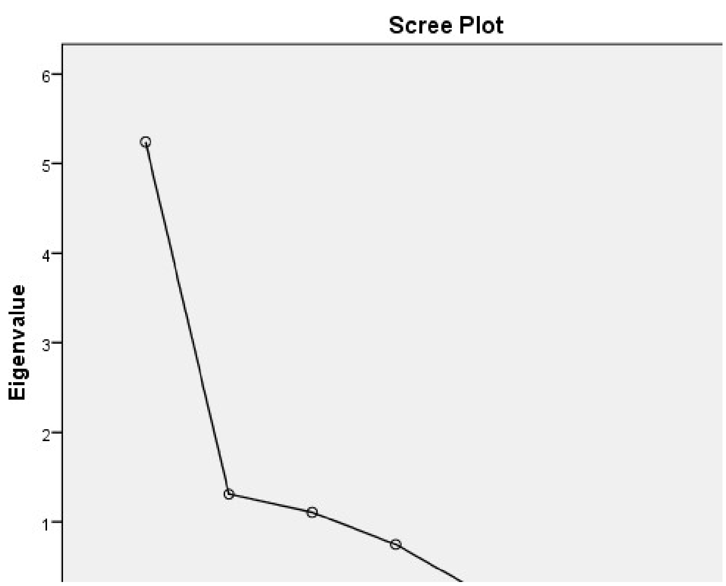

Fig 6: Scree Plot of Principal Component Analysis of Metals in Fish Bone

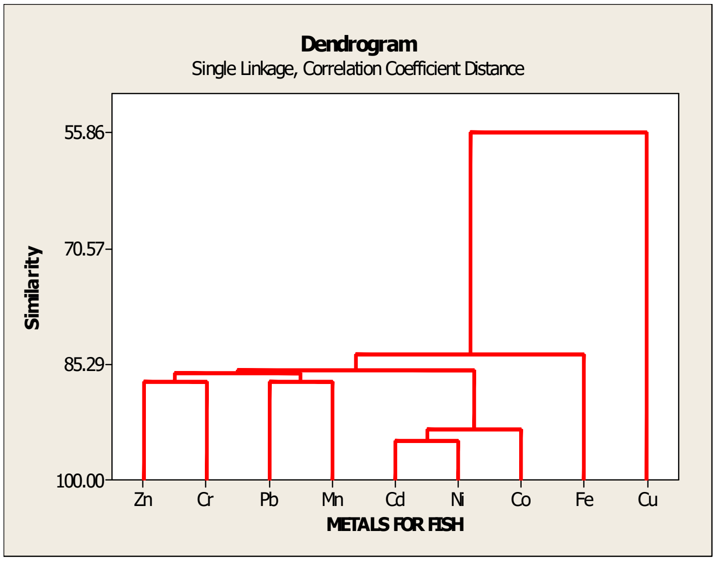

Fig. 7: Cluster Analysis of Metals in Fish Bone

Table 7: Estimated Human Health Risks of Heavy Metals in Water

HM	ADI	HQ
Zn	0.0000005	0.000001
Pb	0.0000004	0.0001
Fe	0.00007	0.0001
Cu	0.00002	0.0005
Mn	0.0000003	0.000002
Ni	0.0000003	0.000015
Co	0.0000001	0.000003
Cr	0.000002	0.00067
H I = 0.001		

HM = Heavy metals, ADI = Average daily intake, HQ = Hazard quotient, HI= Hazard index

Table 8: Estimated Human Health Risks of Heavy Metals in Fish

HM	ADI	HQ
Zn	0.00001	0.00003
Pb	0.000002	0.0005
Fe	0.00002	0.00002
Cu	0.000004	0.0001
Mn	0.000003	0.000002
Ni	0.0000006	0.00003
Co	0.0000004	0.00001
Cr	0.000002	0.00067
H I = 0.0014		

HM = Heavy metals, ADI = Average daily intake, HQ = Hazard quotient, HI= Hazard index

DISCUSSION

The results of physicochemical analyses of water samples collected from Ajiwa dam are presented first. Physicochemical properties are the intrinsic physical and chemical characteristics of a substance. The physicochemical parameters are very important to test for the water quality before it is used for drinking, domestic, agricultural, or industrial purposes. Water must be tested for different physicochemical parameters such as pH, turbidity, electrical conductivity, total dissolved solids, hardness, nitrates, phosphates, and sulfates levels. The results of the physicochemical parameters of collected water samples were analyzed using standard procedures and the summary of the results is presented in Table 1. The turbidity of water depends on the quantity of solid matter present in the suspended state. The mean turbidity values obtained ranged between 148.67±2.08NTU, 150.33±1.53NTU, 162.00±2.00NTU, 175.00±2.00NTU, 180.67±0.58NTU, 180.67±0.58NTU and 196.00±1.73NTU in Ajiwa dam respectively. These mean values were found to be outside the permissible limits of 5 NTU for drinking water (WHO, 2006) and (EPA, 1999). This may be due to the presence of clay, silt, finely divided organic and inorganic matter, plankton, and other microscopic organisms. In Table 1, the mean values of hardness ranged between 40.41±0.02 mg/L, 42.7±0.10 mg/L, 43.56±0.04 mg/L, 43.64±0.46 mg/L, 44.87±0.02 mg/L, 44.87±0.02 mg/L, and 47.14±0.01 mg/L respectively. The mean and standard deviation values of hardness are within the 100 mg/L (WHO, 2006) specification limits for drinking water, but they are high enough to cause hardness of water. Therefore, this explains further the presence of carbonates/bicarbonates which may cause poor lather formation and scales on boilers (Durrance, 1986). The mean of nitrates, phosphates and sulphates values in Table 1, ranged between 0.002±0.001 mg/L, 0.003±0.002 mg/L, 0.004±0.001 mg/L, 0.007±0.001 mg/L, 0.72±0.006 mg/L, 0.87±0.002 mg/L, 0.99±0.006 mg/L for nitrate, 1.89±0.002 mg/L, 1.96±0.001 mg/L, 10.97±0.012 mg/L, 11.98±0.015 mg/L, 14.22±0.015 mg/L, 17.23±0.016 mg/L, 19.37±0.015 mg/L for phosphates and 15.00±1.00 mg/L, 16.07±0.12 mg/L, 16.93±0.06 mg/L, 17.00±1.00 mg/L, 18.67±0.58 mg/L, 20.21±0.27 mg/L, 23.40±0.53 mg/L for sulphates respectively. These values were found to be within the permissible limit except for five (5) samples in phosphates which are higher than the WHO permissible limits of 5.0 mg/L, 6.5 mg/L, and 400 mg/L for nitrates, phosphates, and sulphates levels in drinking water respectively (WHO, 2006). The test for the pH of the water was carried out to determine whether it is acidic, neutral, or alkaline in nature. The mean values obtained 6.17±0.06, 6.27±0.12, 6.43±0.06, 6.47±0.12, 6.70±0.10, 7.10±0.10 and 7.23±0.15 are within the range of 6.5-8.9, recommended by WHO (1996) for drinking water. The electrical conductivity mean and standard deviation values obtained are 89.77± 0.06 µs/cm, 93.30±0.10 µs/cm, 97.07±0.23 µs/cm, 97.47±0.06 µs/cm, 99.57±0.49 µs/cm, 103.00±0.00 µs/cm, and 105.37±0.32 µs/cm respectively. All the values are within the WHO's maximum permissible limits (8-10,000 µs/cm) for drinking water (WHO, 2006). The mean and standard deviations of total dissolved solids for Ajiwa dam were 43.40±0.00 mg/L, 44.10±0.00 mg/L, 46.03±0.06 mg/L, 46.17±0.06 mg/L, 47.30±0.00 mg/L, 48.70±0.00 mg/L, and 50.03±0.06 mg/L in (Table 4.1) are lower than the recommended value of 500 mg/L by the National Guideline and Standards for water quality in Nigeria and the WHO specification limits (1000 mg/L) for drinking water (Edimeh et al., 2011). For the statistical result, **Table 2,** shows the correlation among physicochemical parameters for water and it indicates that turbidity has a significant negative correlation with nitrate for water. This means the higher the concentration of turbidity the lower the concentration of nitrate for water and vice versa. It also indicates that turbidity has a significant positive correlation with phosphate and sulphate which means the higher concentration of turbidity results in higher concentrations of phosphate and sulphate for water and vice versa.

Figure 2 is the cumulative proportion of the physicochemical parameters of the total variance explained by each principal component (PC) and can also be displayed as a scree plot. A scree plot displays how much variation each principal component captures from the data. The principal component analysis is used for data set reduction. Any component whose eigenvalue is less than one is rejected and considered a distractors. From Fig 2, the first three principal components may be retained as they capture the most variability in the data and as the PCs with an eigenvalue greater than one. This means that the original 8 physicochemical parameters for water can adequately be represented by the first three PCs. The first three PCs explained 85.959**%** variability in the data sets.

A dendrogram for physicochemical parameters of the dam Fig. 3 is a diagram that shows the hierarchical relationship between objects. It is most commonly created as output from hierarchical clustering. This dendrogram was created using a final portion of 5 clusters, which occurs at different similarity levels. The first cluster is composed of two physicochemical parameters for water namely turbidity and phosphate. The second cluster is composed of one physicochemical parameter for water namely sulphate. The third cluster is composed of two physicochemical parameters for water namely EC and TDS. The fourth cluster is composed of one physicochemical parameter for water namely pH. The fifth cluster is composed of two physicochemical parameters for water namely Hardness and Nitrate. Physicochemical parameters for water within a cluster are very similar and variables outside a cluster are very dissimilar. The total metal content in water samples was analysed using Atomic Absorption Spectrophotometer and is summarized in Table 3. Table 3, presents the mean and standard deviations of heavy metals in water obtained from the Ajiwa Dam. The mean concentration of zinc obtained from sample A to sample G was found in the range of 0.038 to 0.068 mg/L, lead from 0.016 to 0.085 mg/L, cadmium ranges from 0.004 to -0.013 mg/L, iron from 5.21 to 9.94 mg/L, copper from 0.36 to 6.12 mg/L, manganese ranges from 0.020 to 0.050 mg/L, nickel from 0.022 to 0.056 mg/L, cobalt ranges from 0.019 to 0.023 mg/L and chromium from 0.165 to 0.241 mg/L from the dam water respectively. This result highlighted some heavy metal concentrations are higher in some points while some are at lower concentrations in dam water, this implies that water samples collected at the extreme of the dam are of higher concentration due to the water used by the irrigation farmers that flows back to the dam. The average concentrations of the heavy metals were within the permissible limits recommended by WHO.

Table 4, reported the correlation for heavy metals in Ajiwa Dam water. Analysis of variance revealed that the concentration of Zn for water is statistically different among the samples at a 5% level of significance. Furthermore, samples with the same superscripts namely samples E and F have statistically the same concentration of Zn for water at a 5% level of significance while samples with different superscripts have statistically different concentrations of Zn for water. Analysis of variance revealed that the concentration of Pb for water is statistically different among the samples at a 5% level of significance. Furthermore, samples with the same superscripts namely samples A and C have statistically the same concentration of Pb for water at a 5% level of significance while samples with different superscripts have statistically different concentrations of Pb for water for example sample A and B as shown by Duncan multiple comparison test. Furthermore, samples with the same superscripts namely samples B and C have statistically the same concentration of Fe for water at a 5% level of significance while samples with different superscripts have statistically different concentrations of Fe for water for example samples A and B as shown by Duncan multiple comparison test. Analysis of variance revealed that the concentration of Cu for water is statistically different among the samples at a 5% level of significance. Furthermore, samples with the same superscripts have statistically the same concentration of Cu for water at a 5% level of significance while samples with different superscripts have statistically different concentrations of Cu for water. This therefore indicated that all the samples have different concentrations of Cu for water as shown by Duncan's multiple comparison test.

Analysis of variance revealed that the concentration of Mn for water is statistically different among the samples at a 5% level of significance. Furthermore, samples with the same superscripts for example samples D and E have statistically the same concentration of Mn for water at a 5% level of significance while samples with different superscripts have statistically different concentrations of Mn for water for example samples A and B as shown by Duncan multiple comparison test. Analysis of variance revealed that the concentration of Ni for water is statistically different among the samples at a 5% level of significance. Furthermore, samples with the same superscripts for example samples B and C have statistically the same concentration of Ni for water at a 5% level of significance while samples with different superscripts have statistically different concentrations of Ni for water for example sample A and B as shown by Duncan multiple comparison test. Analysis of variance revealed that the concentration of Co for water is statistically the same for all the samples at a 5% level of significance. Duncan's multiple comparison tests further revealed that all the samples have the same superscripts. Analysis of variance revealed that the concentration of Cr for water is statistically different among the samples at a 5% level of significance. Furthermore, samples with the same superscripts for example samples A and B have statistically the same concentration of Cr for water at a 5% level of significance while samples with different superscripts have statistically different concentrations of Cr for water for example sample B and C as shown by Duncan multiple comparison test.

Figure 4, is a scree plot of the metal content of the dam. A scree plot displays how much variation each principal component captures from the data PC1 captures the most variation, PC2 — the second most, and so on. From Fig 4, the first four principal components may be retained as they capture the most variability in the data set and as the PCs with an eigenvalue greater than one. This means that the original 9 metals for water can be adequately represented by the first four PCs. The first four PCs explained 82.684% variability in the data sets.

Figure 5, explains the cluster analysis of the metal content of the dam. A dendrogram is a diagram that shows the hierarchical relationship between objects. It is most commonly created as output from hierarchical clustering. This dendrogram was created using a final portion of 8 clusters, which occurs at different similarity levels. The first cluster is composed of one metal for water namely Zn. The second cluster is composed of two metals for water namely Fe and Ni. The third cluster is composed of one metal for water namely Cr. The fourth cluster is composed of one metal for water namely Mn. The fifth cluster is composed of one metal for water namely Co. The sixth cluster is composed of one metal for water namely Pb. The seventh cluster is composed of one metal for water namely Cu and the eighth cluster is composed of one metal for water Cd. Metals for water within a cluster are very similar and variables outside a cluster are very dissimilar.

Table 5, presents the mean and standard deviation of heavy metals in fish bone of *Clarias gariepinus* (catfish) obtained from the Ajiwa Dam. The mean and standard deviation of zinc obtained from sample A to sample G was found in the range of 0.60 to 0.93 mg/kg from the dam water. The mean and standard deviation of lead obtained from sample A to sample G were found in the range of 0.14 to 0.20 mg/kg from the dam water. The mean and standard deviation of cadmium obtained from sample A to sample G was found in the range of -0.0003 to -0.016 mg/kg from the dam water. The mean and standard deviation of iron obtained from sample A to sample G was found in the range of 1.32 to 4.51 mg/kg from the dam water. The mean and standard deviation of copper obtained from sample A to sample G was found in the range of 0.20 to 1.44 mg/kg from the dam water. The mean and standard deviation of manganese obtained from sample A to sample G was found in the range of 0.25 to 0.67 mg/kg from the dam water. The mean and standard deviation of nickel obtained from sample A to sample G was found in the range of 0.047 to 0.100 mg/kg from the dam water. The mean and standard deviation of cobalt obtained from sample A to sample G was found in the range of 0.036 to 0.065 mg/kg from the dam water. The mean and standard deviation of chromium obtained from sample A to sample G were found in the range of 0.16 to 0.34 mg/kg from the dam water respectively.

Based on the recorded concentrations, the findings did not suggest immediate hazard since concentrations did not exceed the permissible limit set by WHO. Table 6, indicates that Zn has a significant positive correlation with Pb, Cd, Fe, Mn, Ni, Co, and Cr for fish. This means the higher the concentration of Zn, the higher the concentration of Pb, Cd, Fe, Mn, Ni, Co, and Cr for fish and vice versa. It also indicates that Zn does have a significant negative correlation with Cu for fish. Therefore it indicates that the higher the value of Zn the lower the value of Cu for fish and vice-versa. It also indicates that Pb does have a significant positive correlation with Mn, Co, and Cr for fish. This means the higher the concentration of Pb the higher the concentration of Mn, Co, and Cr for fish and vice versa. It also indicates that Pb does not have a significant correlation with Cd, Fe, Cu, and Ni for fish. Therefore it indicates that there is no relationship between Pb with Cd, Fe, Cu, and Ni for fish and vice versa. It also indicates that Cd does have a significant positive correlation with Mn, Ni, Co, and Cr for fish. This means the higher the concentration of Cd the higher the concentration of Mn, Ni, Co, and Cr for fish and vice versa. Figure 6, is a scree plot of the metal content in catfish bone. A scree plot displays how much variation each principal component captures from the data PC1 captures the most variation, PC2 — the second most, and so on. Each of them contributes some information to the data, and in a PCA, there are as many principal components as there are characteristics. From the above figure, the first three principal components may be retained as the capture most variability in the data and as the PCs with an eigenvalue greater than one. This means that the original 9 metals for fish can be adequately represented by the first three PCs. The first three PCs explained 85.114**%** variability in the data sets.

Figure 7, is a dendrogram of heavy metals in catfish bone, which shows the hierarchical relationship between the metals.. It is most commonly created as output from hierarchical clustering. This dendrogram was created using a final portion of 6 clusters, which occurs at different similarity levels. The first cluster is composed of two metals for fish namely Zn and Cr. The second cluster is composed of two metals for fish Pb and Mn. The third cluster is composed of two metals for fish namely Cd and Ni. The fourth cluster is composed of one metal namely Co. The fifth cluster is composed of one metal for fish namely Fe. The sixth cluster is composed of one metal for fish Cu. Within a cluster are very similar and variables outside a cluster are very dissimilar.

Hazard Quotient (HQ)

Non-carcinogenic risks for individual heavy metals were evaluated by computing the target hazard quotient (THQ) using THQ = CDI/RfD (Micheal *et al*., 2015). CDI is the chronic daily heavy metal intake (mg/kg/day) and RfD is the oral reference dose (mg/kg/day) which is an estimation of the maximum permissible risk on the human population through daily exposure, taking into consideration a sensitive group during a lifetime ((Li & Zhang, 2010). EPA-recommended RfD values of Zn, Pb, Fe, Cu, Mn, Ni, Co, and Cr were used in the above equation (Liu et al., 2013; USEPA, 2005). The result for the health quotients of metals for the exposed population is presented in Table 7 and Table 8.

Hazard index (HI)

To evaluate the potential risk to human health through more than one heavy metal, the chronic hazard index (HI) is obtained as the sum of all hazard quotients (THQ) calculated for individual heavy metals for a particular exposure pathway (NFPCSP Nutrition Fact Sheet, 2011). It is calculated as follows: HI = THQ1 + THQ2 + ⋯ + THQn ……………………………………......equation 4.1

It is assumed that the magnitude of the effect is proportional to the sum of the multiple metal exposures and that a similar working mechanism linearly affects the target organ (RAIS, 2007). The calculated HI is compared to standard levels: the population is assumed to be safe when HI < 1 and in a level of concern when 1 < HI < 5 (Guerra *et al.,* 2012).

Conclusion

The results of the physicochemical parameters revealed that the water samples were enriched with organic substances, which include Nitrates (NO_3^-), Sulphates (SO_4^-), and phosphates (PO_4^{2-}). Their contents were higher than the WHO permissible limits. The pH was found to be acidic in five samples while the other two samples were alkaline in nature, Turbidity also was found to be outside the permissible limit and has high electrical conductivity. Total dissolved solids and hardness were also within the permissible limit. The result of our study revealed that the levels of Zn, Pb, Fe, Cu, Mn, Ni, Co, and Cr in fish and water samples were within the WHO permissible limits. Cadmium (Cd) was not detected in this study. Therefore, it is concluded that the investigated heavy metals occurred at various concentration levels in fish and water, and were within the acceptable limit set by WHO. The human health risk assessment in this study classifies the Fish-bone and water as safe with regards to dermal exposure to heavy metals in which each of the Hazard quotient (HQ) and Hazard index (HI) was <1; indicating that there is no health risk associated with the heavy metals in the dam water. However, despite the low levels of the metals in this work compared to the pieces of literature in the world, they could still lead to serious health hazards over time, considering their cumulative effects on the environment.

Recommendation

Based on the study outcome there is a need for relevant authorities to put in place strict measures for a proper waste management approach to checkmate indiscriminate refuse dumping of waste into the dam and irrigation farming. There is also a need for regular monitoring of the water quality of the Ajiwa Dam to prevent fish contamination. Excessive application of agrochemicals in agricultural activities should be controlled by legislation.

References

Agatha, A.N. (2010) Levels of Some Heavy Metals in Tissues of Bonga Fish, *Ethmallosa fimbriata* from Forcados River. Journal of Applied Environmental and Biological Sciences,1:44-47.

Akoto, O., Bismark Eshun, F., Darko, G., & Adei, E.(2014). Concentrations And Health Risk

Assessments Of Heavy Metals In Fish From The Fosu Lagoon.Int. J. Environ. Res. 8(2):403-410.

Alaa, G.M., Osman, W.K. (2010) Water Quality and heavy metal monitoring in water, sediments and tissues of the African catfish Clariasgariepinus (Burchell, 1822) from the River Nile, Egypt. Journal of Environmental Protection, 1:389-400.

Alam, M.G.M., Tanaka A., Allison G., Laurenson, L.J.B., Stagnitti, F. And Snow, E. (2002). A Comparison Of Trace Element Concentrations in Cultured and Wild Carp (*Cyprinus carpio)* of Lake Kasumigaura, Japan. Ecotoxicology And Environmental Safety 53:348 354.

Alfridi, H. I., Kazi, T. G., Kazi, N., Kandhro, G. A., Baig, J. A., Jamali, M. K., Shah, A. Q. (2011). Interactions Between Cadmium and Zinc in the Biological Samples of Pakistani Smokers and Nonsmokers Cardiovascular Disease Patients. Biol Trace Elem Res. 139:257-268. doi :10.1007/s12011-009-8607-3.

Anderson, J. and Fitzgerald, C. (2010). Iron: An Essential Nutrient Review. Online. From:http://www.ext.colostate.edu/pubs/foodnut/09356.html. [Accessed on November 2014].

Arnot, J. And Gobas, F (2006). A Review Of Bio-Concentration Factor (BCF) And Bioaccumulation Factor (BAF) Assessments For Organic Chemicals In Aquatic Organisms. Environment Review 14:257-297.

APHA (American Public Health Association) (1999). Standard Methods for Examination of Water and Waste Water. American Public Health Association, New York, U. S.A. 1-8pp.

Aremu, M. O. Olaofe, O. Ikokoh, P. P & Yakubu, M. M. (2011) Physicochemical characteristics of Stream, well and borehole water sources in Eggon, Nasarawa State, Nigeria. Journal Chemical Society Nigeria, 36 (1), 131-136.

ATSDR (Toxicological Profile for Lead). (2001). US Department of Health and Human Services, Public Health Service 205-93- 0606.

Barceloux, D. G. (1999). Nickel. Clin. Toxicol. 37:239.

Berberi E, Shumka S. (2013) Clinical Indicator Priory to Diagnosis Of Spring Viiemia Of Carp (Suc) in Albania. Journal of International Environmental Application and Science 8 (1): 42-46.

Camusso, M., Vigano, L. And Balestrini, R. (1995). Bioaccumulation of Trace Metals in Rainbow Trout: A Field Study. Eco-Toxicology and Environmental Safety 31:133-141.

Chasapis, C. T., Loutsidou, A., Spilliopoulou, C. A., & Stepanidou, M. E. (2012). Zinc and Human Health: An Update. Arch Toxicol. 86: 521-534. Doi: 101007/s00204-011-0775-1.

Chove BE, Ballegu WR, Chove LM (2006). Copper and Lead levels in two popular leafy vegetables grown around Morogoro Municipality, Tanzania. Tanzania Health Research Bulletin 8(1) 37-40.

Cid, B.P., Boia, C., Pombo, L. And Rebelo, E. (2001). Determination of Trace Metals in Fish Species of Ria De Aveiro (Portugal) By Electrothermal Atomic Absorption Spectrometry. Food Chemistry 75.93:100.

Coetzee, L., Du Preez, H.H., and Van Vuren J.H.J. (2002). Metal Concentrations in Clarias.

Detectronic, (2019) Measuring total dissolved solids (TDS) in water detectronic 7th december, 2021 https://detectronic.org/measuring-total-dissolved-solids-tds-in water/

Duffus, J. H. (2002). ""Heavy Metals" A Meaningless Term? (IUPAC Technical Report)" Pure and Applied Chemistry 74:793-807. Doi: 101351/Pac200274050793.

Dogan Altinbilek, (2002). The Role of Dams in Development, International Journal of Water Resources Development, 18:1, 9-24, DOI: 10.1080/07900620220121620.

Dupler, D. (2001). Heavy Metal Poisoning. Gale Encyclopedia of Alternative Medicine. Farmington Hills, MI: Gale Group.

Durance, J. L. (1986). United States Geological Survey (USGS) water Science for School. Retrieved 4, April, (2009) Pp 1-8. http://ga.water.usgsgov/edu/earthgw-qulity.htm

Dutta H.M. and Dalal R (2008). The Effect of Endosulfan on the Ovary Of Blue Gill Sun Fish: A Hispathologica Study (Leponis Macrochirussp). Int. J. Environ. Res2008; 2: 215-224.

Ebrahimi, M. And Taherianfard, M. (2011). The Effects Of Heavy Metals Exposure On Reproductive Systems of Cyprinid Fish from Kor River. Iranian Journal of Fisheries Sciences 10:13-24.

Edimeh, P. O., Eneji, I. S., Oketunde, O. F. & Sha'ato, R. (2011). Physico-chemical parameters and some Heavy metals content of Rivers Inachalo and Niger in Idah, Kogi State. Journal Chemical Society Nigeria 36 (1): 95-101.

Ekpo, K.E., Asia, I. O., Amayo, K. O. and Jegede, D. A. (2008). Determination of lead, cadmium, and mercury in surrounding water and organs of some species of fish from Ikoba river in Benin City, Nigeria. International journal of physical sciences 3.11:289 292.

Eman M. A. And Gordon A. F. Heavy Metal Poisoning and Cardiovascular Disease, Journal of Toxicology Volume (2011), Article ID 870125, 21 Pages Doi:10.1155/2011/870125.

Eneji IS, Sha'Alto R, Annune PA. (2011). Bioaccumulation of Heavy Metals In Fish (*Tilapia Zilli* and *Clarias gariepinus*) Organs from River Benue North Central Nigeria. Pakistan Journal of Analytical/Environmental Chemistry (2011); 12(122)25-31.

Environmental Protection Agency, EPA Guidance Manual, Turbidity Provisions, USA, (1999). 14. Standards Organization of Nigeria (SON): Nigerian Industrial Standards, NIS 554 Nigerian Standard for Drinking Water Quality, pp. 15-17.

Erdman Jr, J. W., Macdonald, I. A., & Zeisel, S. H. (Eds.). (2012). Present Knowledge in Nutrition. 10th Edition. A John Wiley & Sons, Ltd., Publication.

FAO, (2003) Committee for Inland Fisheries of Africa.Report of the third session of the Working Party on Pollution and Fisheries. Accra, Ghana, Food and Agricultural Organization, Fisheries Report, 471:25-29.

Food and Agriculture Organisation of the United Nations/ World Health Organization (FAO/WHO), (2011) Joint FAO/WHO Food Standards Program, CODEX Committee on contaminants in Foods. CODEX Alimmentarius Commission. Pp 1-88.

Farombi, E.O., Adelowo, O.A. and Ajimoko, Y.R. (2007). Biomarkers of oxidative stress and heavy metal levels as indicators of environmental pollution in African catfish (*Clarias gariepinus*) from Nigerian Ogun river. International Journal of Environmental Research of Public Health 4.2:158-165.

Ferner, D.J. (2001). Toxicity, Heavy Metals. Emeds. Journal 2.5:1.

FishBase. (2005). "Phycodurus eques". F. Rainer and D. Pauly Eds. Retrieved 24 May 2011.

Forti, E., Salovaara, S., Cetin, Y., Bulgheroni, A., Tessadri, R., Jennings, P., Prieto, P. (2011). *In vitro* Evaluation of the Toxicity Induced by Nickel Soluble and Particulate Forms in Human Airway Epithelial Cells. Toxicology *in vitro*. 25 (2): 454-461.doi:10.1016/j.tiv.2010.11.013.

Garcia-Leston, J., Mendez, J., Pasaro, E., & Laffon, B. (2010). Author's Copy Genotoxic Effects of Lead: An Updated Review. Environment International. 36: 623-636. Doi:10.1016/J.Envint.2010.04.011.

Glanze, W.D. (1996). Mosby Medical Encyclopedia. Revised Ed. St. Louis, MO: C.V. Mosby.

Gobas, F.A.P.C., Wilcockson, J.B., Russell, R.W. and Haffner, G.D. (1999). Mechanisms Of Biomagnification in Fish under Laboratory and Field Conditions. Environmental Science and Technology 33.1:133-141.

Golhaber, S. B. (2003). Trace Element Risk Assessment: Essentially Vs Toxicity. Regulatory Toxicity and Pharmacology. 38: 232-242. Doi: 101016/S0273-2300(02)00020-X

Gu, Y., Kodama, H., Sato, E., Mochizuki, D., Yanagawa, Y., Takayanagi, M., Lee, C. (2002). Prenatal Diagnosis of Menkes Disease by Genetic Analysis and Copper Measurement. Brain & Development. 24:715-718.

Guerra, F., Trevizam, A. R., Muraoka, T., Marcante, N. C., & Canniatti-Brazaca, S. G. (2012). Heavy metals in vegetables and potential risk for human health. Scientia Agricola, 69, 54–60

Güven A.;Aydemir (2020),A.Dams.In risk assessment of dams*; Springer:*

Berlin/Heidelberg, Germany, 2020; Pp.1–14.

Hanna, (2017) The complete guide to measuring turbidity in water Hanna instrument, 07th December, 2021. https://www.google.com/amp/s/blog.hannainst.com/turbidityguide%3fhs_amp=true Data assessed.

Hanfi, M.Y.; Mostafa, M.Y.A.; and Zhukovsky, M.V (2019). Heavy metal contamination in urban surface sediments: Sources, distribution, contamination control and remediation. Environ. Monit. Assess. 2019, 192, 32.

Hightower, J. (2008). Diagnosis Mercury: Money, Politics and Poison. Island Press. 77

Hogan, M. (2010). Heavy Metal. Encyclopedia of Earth. National Council for Science And The Environment. E. Monosson and C. Cleveland. Eds. Washington DC: CRC Press. 1350pp.International Centre for Environmental Technology Transfer (ICETT). 1998.

Ibrahim A. Y, Alhassan AJ, Nasir A,Matazu KI, Muhammad I, Idi A Muhammad IU and Aliyu SM. Evaluation of Heavy Metals in Fish of Some Selected Dam from Katsina Nigeria International Journal of Scientific and Technical Research in Engineering (IJSTRE) www.ijstre.com Volume 3 Issue 2 ǁ March 2018.

International Occupational Safety and Health Information Centre. (1999). Metals: In Basics of Chemical Safety. Metals. Geneva: International Labour Organization.

International Centre for Environmental Technology Transfer (ICETT). (1998). Itai-itai disease. www.icett.or.jp/lpca_jp.nsf/a21a0d8b947 40fbd492567ca000d5879/b30e2e489 f4b4ff1492567ca0011ff90? OpenDocument Data assessed.

Jackson, H.M. and Morris, G. P. (1989). Environmental Health Reference Book. Bodmin: Hartnolls Ltd. 215pp.

Jarup I. (2003) Hazards of Heavy Metal Contamination. British Medical Bulletin 2003; 68:167-182.

Joyeux, J.C., Filho, E.A.C. And De Jesus, H.C. (2004). Trace Metal Contamination in Estuarine Fishes from Vitoria Bay, ES, Brazil. Brazilian Archives of Biotechnology 47.5:765774.

Kakulu, S.E., Osibanjo, O. and Ajayi S.O. 1987. Trace metal content of fish and shell-fishes of the Niger Delta area of Nigeria. Environmental International 13:247-251.

Karadede, H. and Unlo, E. (2000). Concentrations of some heavy metals in water, sediment and fish species from the Ataturk Dam Lake (Euphrates), Turkey. Chemosphere 41.9:1371-1376.

Kumar Raju, Dharmendra, V.; Roy, P.; Taylor, C.; Kar, P.; A.; and Krishnaiah, A. (2013) Determination of Precious Metals in Rocks and Ores by Microwave Plasma-Atomic Emission Spectrometry (MP-AES) for geochemical prospecting. Curr. Sci, 104, 1207–1215. (Google Scholar)

Kunz, M. J., Wüest, A., Wehrli, B., Landert, J., And Senn, D. B (2011) Impact Of A Large Tropical Reservoir On Riverine Transport Of Sediment, Carbon, And Nutrients To Downstream Wetlands, Water Resource. Res., 47, 1–16, Https://Doi.Org/10.1029/WR010996, 2011.

Kupeli, T., Altundag, H. And Imamuglu M. (2011). Assessment of Trace Element Levels in Muscle Tissues of Fish Species Collected From a River, Stream, Lake And Sea In Sakarya, Turkey. The Sci World Journal.

Koyashiki, G. A. K., Paoliello, M. M. B., & Tchounwou, P. B. (2010). Lead levels in Human Milk and Children's Health risk: A Systematic Review. Rev Environ Health 25(3):243-253.

Krishnani, K. K., Azad, I. S., Kailasam, M., Thirunavukkarasu, A. R., Gupta, B. P., Joseph, K. O., Muralidhar, M. (2003). Acute Toxicity of Some Heavy Metals to Lates Calcarifer Fry with a Note on Its Histopathological Manifestations. Journal of Environmental Science and Health 38.4: 645-655.

Lupton, G., Kao, G. and Johnson, F. 1985. Cutaneous mercury granuloma: A clinic pathologic study and review of the literature. Journal of American academy of dermatology 12:296-303.

Liu X, Song Q, Tang Y, Li W, Xu J, et al. (2013) Human health risk assessment of heavy metals in Fish–water system: A multi-medium analysis Sci Total Environ 464: 530-540.

Mahfuza, S. S., Jolly, Y. N., Yeasmin, S., Satter, S., Islam, A., & Tareq, S. M. (2014). Heavy metals in fishes and their impact on humans: Prospects and challenges (Chapter-12, pp. 331–366).London: *Elsevier*

Micheal, B., Patrick, O., & Vivian, T. (2015). Cancer and noncancer risks associated with heavy metal exposures from street foods: Evaluation of roasted meats in an urban setting. *Journal of Environment Pollution and Human Health*, 3, 24–30.

Mishra, A.K. (2010), A River About To Die: Yamuna, *Journal Of Water Resource and Protection*, 2, 489-500.

Musa, M. S., Dagari, M. S., Umar, A and .Shafiu, I. M., (2020) Determination of Some Heavy Metals in Selected fishes Grown in Ajiwa and Jibia Dams of Katsina State, Nigeria Dutse Journal of Pure and Applied Sciences (DUJOPAS) 6 (3): 23-29.

Nathaniel, I. T., Salami, A. T. And Olajuyigbe, A. C. (2000). Environmental Features of Nigerian Economic Exclusive Zone (EEZ): Ibino and Bonny As Case Study. African Journal of Environmental Studies 1.1: 9-17.

NFPCSP Nutrition Fact Sheet. (2011). Joint report of Food Planning and Nutrition Unit (FMPU) of the Ministry of Food of Government of Bangladesh and Food and Agricultural Organization of the United Nation (FAO), September 14, 1–2. National Food Policy Plan of Action and Country Investment Plan, Government of the People's Republic of Bangladesh

Oguzie, F.A. and Izevbigie, E.E. (2009) Heavy metals concentration in the organs of the silver Catfish, *Chrysichthys nigrodigitatus* (Lacèpéde) caught upstream of the Ikpoba River and the reservoir in Benin City. Bioscience Research Communications, 21:189-197

Oronsaye, J.A.O., Wangboje, O.M. and Oguzie, F.A. (2010) Trace metals in some benthic fishes of the Ikpobariver dam, Benin City, Nigeria;African Journal of Biotechnology,9: 8860-8864.

Olatunji OS, Osibanjo O. (2012). Determination of Selected Heavy Metals in Inland Fresh Water of Lower River Niger Drainage in North Central Nigeria. Afr. J. Environ 2016 Columbia Encyclopedia. 2007. Columbia Electronic Encyclopedia, 6th Ed. Columbia University Press.

Ozcan MM, Dursun N, Juhaimi FY. (2013) Heavy Metals Intake by Cultured Mushrooms Growing In Model System. Environ. Monit. Assess. 2013; 185 (10): 8393-7

Parkman, B. and Haskoning, M. (1996). Reconstruction of Ajiwa Reservoir Katsina, Katsina state. Nigeria. P 1-23. Pielou.

Proti, S. 1989. Metals in Fish and Sediments from the River Kolbacksan. Water System 7: 26 27.

Rahman, M., & Islam. (2010). Adsorption Of Cd (Ii) Ions From Synthetic Waste Water Using Maple Sawdust Adsorption Of Cd (Ii) Ions From Synthetic Waste Water Using Maple Sawdust, Energy Sources, Part A. n32: 222-231-Dal: 10.1080/15567030802459297

RAIS. (2007). The Risk Information System. Retrieved from http://rais.oml.govt/tox/rap_toxp.shtml.

Roberts, J.R. (1999). Meat Toxicity in Children. Training Manual Pediatric Environmental Health: Putting It Into Practice. Emeryville, CA: Children's Environmental Health Network.

Roberts, R.J. (1978). Fish pathology: The Aquatic Environment. London: Bailliere Tindall Cassell Ltd. ISBN 07020 06742.

Saha, N, & Zaman, M.R. (2013). Evaluation of Possible Health Risks Of Heavy Metals By Consumption of Foodstuffs Available In the Central Market of Rajshahi City, Dal: 10.1007/S10661-012-2835-2.

Alnikow, K., & Kasprzak, K. S. (2005) Ascorbate Depletion: A Critical Step in Nickel Carcinogenesis. Environmental Health Perspectives. 113 (5): 577-584. doi:10.1289/ehp.7605.

Sarkar, B. (1999). Treatment of Wilson and Menkes Diseases. Chem. Rev. 99: 2535-2544

Sawyer, C.N., Mccarty, P.L. and Parkin, G.F. (1994). Chemistry for environmental engineering and science. 4th ed. New York: McGrawhill.

Sinha, A.K., Dasgupta, P., Chakrabarty, S., Bhattacharyya, G. And Bhattacharjee, S. (2002). Bioaccumulation of Heavy Metals in Different Organs of Some of the Common Edible Fishes of Kharkai River, Jamshed. Indian Journal of Environmental Health 46:102.

Sivaperumal, P., Sankar, T. V, & Nair, P. G. V. (2007). Food Chemistry Heavy Metal Concentrations in Fish, Shellfish and Fish Products from Internal Markets of India Vis-à- vis International Standards. Food Chemistry. 102: 612 - 620.

Standards Organization of Nigeria (SON): Nigerian Industrial Standards, NIS 554 Nigerian Standard for Drinking Water Quality, pp. 15-17 (2007)

Sun, B., Zhao, F.J., Lombi, E. and McGrath, S.P. (2001). Leaching of Heavy metals from contaminated soils using EDTA. Environmental pollution 113.2:111-120.

Scerri, E. (2007). The Periodic Table: Its Story and Its Significance. Oxford: Oxford University Press. 299pp ISBN 0-19-530573-6.

Smith, J.C., Allen, P.V.and Turner, M.D. (1997). The kinetics of intravenously administered methylmercury in man. Toxicology of Applied Pharmacology 128:251-256.

Staniskiene, B., Matusevicius, P., Budreckiene, K.A. and Skibniewska, K.A. (2006). Distribution of Heavy Metals in Tissues of Freshwater Fish in Lithuania. Polish Journal of Environmental Studies 15.4:585-591.

Stipanuk, M. H. and Caudill, M. A. (2012). Biochemical, Physiological, and Molecular Aspects of Human Nutrition. 3rd Edition. Elsevier Saundre Publishing, Philadelphia.

Sujeet k. Shrivastava and Dipak K.Banerjee,(2003) ”Speciation of heavy metals in sewage Sludge and Sludge-amended Soils” School of Environmental Sciences, Jawaharland Nehru University New Delhi, India ”Water, Air and soil pollution”152; 219 232,2004

Terra, N.R., Feiden, I.R., Fachel, J., Lemos, C.T. And Nunes, E.A (2009). Ecotoxocological Evaluation of Sediment and Water Samples from Sinos River, Rio Grande Do Sul, Brazil, Using Daphnia Magna and V79 Cells. Acta Limnologica Brasiliensia, 20: 65 74.

The British Dam Society 2021, Institution of Civil Engineers, accessed 30th November, (2021), https://britishDams.org/about-Dams/Dam-information/types-of-Dam

Tulasi, G., & Rao, K. J. (2014). Essentiality of Chromium for Human Health and Dietary Nutrition. *Journal of Entomology and Zoology Studies*. 2(1): 107-108.

Umar A. Umar R. Ahmad Ms. (2001). Hydrogeological and Hydrochemical Frame Works of Regional Aquter System in Kali-Ganga Sub-Basin. India. Envir. Geol. 40_4-5): 602611.

USEPA (2005) Best Management Practices for Pb at Outdoor Shooting Ranges. EPA-902-B-01e001. Revised June 2005. Region 2.

Van Den Broek, J.L., Gledhill, K.S. And Morgan, D.G. (2002). Heavy Metal Concentration In The Mosquito Gambusia Holbrooki, In the Manly Lagoon Catchment. In: UTS Freshwater Ecology Report. Department of Environmental Sciences, University Of Technology, Sydney.

WHO (2003). Guidelines for drinking water quality, Health Criteria and Other Supporting Information 2nd Ed, Vol 2.

WHO (2006). Guideline for Drinking Water Quality (Electronic Resource). Incorporating first Addendum 1, Recommendations 3rd Retrieved June 4, 2008 from http://www.whglibdoc.who .int/publications/2006/9241546964.eng.pd

WHO. The World Health Report (2002): reducing risks, promoting healthy life. World Health Organization; 2002. Available:https://apps. who.int/iris/handle/10665/4251035

Zevenhoven, R. And Kilpinen, P. (2001). Flue Gases and Fuel Gases. In: Control of Pollutants In Flue Gases and Fuel Gases. Picaset Oy, Espoo. 298. ISBN 951-22-5527-8

Zhang X, Baptiste L, Vivian H, Edward P, Guilleume E, Marie-Odile S. (2016) Increasing Purity of Ammonium Nickel Sulfate Hexahydrate and Production Sustainability in A Nickel Phytomining

Process. Chemical Engineering Research and Design 2016; 106: 26-32.