

Ecological and Human Health Risk Assessment of Toxic Metals in Water, Sediment and Fish from Lower Usuma Dam, Abuja, Nigeria

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Abstract

The study assessed the levels of some toxic metals (As, Cd, Cr, Cu, Hg, Ni, Pb and Zn) with their potential ecological and human health risks in water, African Catfish (*Clarias gariepinus*), Tilapia (*Oreochromis spilurus niger*) and sediment samples from the Lower Usuma dam FCT, Nigeria during two major seasons in a year (rainy and dry seasons). Toxic metal concentrations were determined using Atomic Absorption spectrophotometry (Cd, Cr, Cu, Ni, Pb and Zn) and Atomic Emission Spectrophotometry (for As and Hg), and the results obtained were compared with national and international standards. The ecological and human health risk indices of the toxic metals present in the samples from the Dam were evaluated and interpreted. Tilapia from the dam posed the highest but medium ecological and human health risk due to Pb concentration of up to 7.11 mg/kg; ecological risk index of 35.55 and hazard quotient of 50.78. Overall ecological and human health risks were low due to the low concentrations of other toxic metals determined. As, Cd, Cr, Cu, Hg, Ni and Zn concentrations were all below WHO limits in the LUD water; Ni and Pb were above limits in the African Catfish and Tilapia samples. The data obtained were analyzed using one-way analysis of variance (ANOVA) and significant differences accepted at $p \leq 0.05$. There was no statistical difference in the concentrations of toxic metals in water but there was significant difference between the concentrations of toxic metals in the fish and sediment samples. Correlation was found to exist between toxic metals in the water, fish and sediment analyzed from the dam. The ecological and human health risks of toxic metals in Lower Usuma dam require regular checks and monitoring hence, it was recommended by the researcher, that this and similar research work be carried out annually by NESREA and also, as research work by other students of Environmental and Analytical chemistry.

Keywords

Toxic, Metals, AAS, AES, Concentration, Ecological Risk, Human Health Risk, Lower Usuma Dam, Contamination Factor, Water, Sediment, Fish

1. Introduction

A dam is a reservoir constructed for storage and impounding of water for domestic, agricultural and industrial uses by people living in a community or environment. Dams are also constructed to prevent floods, to supply drinking and domestic water, to generate energy and for irrigation purposes. The idea of dam construction or a water storage structure or a reservoir is intended for all year round water supply for domestic, irrigation and industrial uses and other recreational activities like fishing, swimming and navigational purposes (Umaru et al., 2014).

Three rivers transfer water into the Lower Usuma Dam, one of the known dams in Nigeria; the River Usuma, River Gidna and River Gurara (Gurara dam). Like an artificial lake that it is, the dam receives water all year round without any outflow, in addition to the concrete and metal components of the construction. The Gurara water transfer provides for the transfer of raw water from Gurara dam in Kaduna state to Lower Usuma dam in Federal Capital Territory (FCT), Abuja through a 75 km conduit pipeline to augment water supply to FCT as a result of rapid population growth. Besides this arrangement for dam-to-dam inflow, inlet of water from the other natural sources follows a natural course (Okunlola et al., 2014). Care must be taken, however, to ensure that such collection of water does not accumulate toxic substances from the diverse sources.

Heavy (Toxic) metal refers to any metallic chemical element that has a relatively high density and toxic or poisonous at low concentrations. They cannot be degraded or destroyed and can enter our bodies through food, drinking water and air. Heavy metals are dangerous because they tend to bioaccumulate. Bioaccumulation is an increase in the concentration of a chemical in a biological organism over time, compared to the chemical's concentration in the environment (Amadi, 2011). The role of trace metals in biochemical life processes of aquatic plants and animals and their presence in trace amounts in the aquatic environment are essential. However, at high concentrations, these trace metals become toxic (Jaishankar et al., 2014). Toxic metals in the aquatic environment exist in sediment, suspended particulate ($>0.45 \mu\text{m}$), hydrous oxides and humic colloids, and in true solution (Morais et al., 2012).

Toxic metals are found naturally in the earth and may enter into the environment through mining activities, industrial discharge and from household applications. They become concentrated as a result of human activities and can enter plant, animal, and human tissues through inhalation, diet, and manual handling. Then, they can bind to and interfere with the functioning of vital cellular components. Dams are sinks for toxic metals that are continuously washed off from

rocks and soils that are directly exposed to surface waters. The common sources of toxic metals are from dead and decomposing vegetation, animal matter, wet and dry fallouts of atmospheric particulate matters and from man's activities. The hazardous nature of heavy metals has been recognized because of their bio-accumulative nature in biotic systems.

This study seeks to determine the concentrations of toxic metals in the water, sediments and fishes living in the Lower Usuma dam Abuja, Nigeria, which local residents consume and assess the ecological and human health risk indices of such toxic metals.

2. Materials and Methods

2.1. Materials

2.1.1. Reagents

Only chemicals of analytical reagent grade (99.9% purity) were utilized and they were obtained from reputable chemical distribution companies. The following reagents were used for the analyses: Trioxonitrate (V) acid (analytical grade), hydrogen peroxide, tetraoxosulphate (VI) salts of As, Cd, Cr, Pb, Hg, Zn, Ni and Cu. Doubly distilled, de-ionized water was used in the preparation of all solutions in the experiments.

2.1.2. Apparatus

An AA 6800 SHIMADZU Atomic Absorption spectrophotometer (AAS) was used for Cd, Cr, Cu, Ni, Pb and Zn determinations while an Agilent 4210 MP-AES Atomic Emission Spectrophotometer (AES) was used for As and Hg determinations. Other pieces of apparatus used include, plastic sample bottles, measuring tape, electronic weighing scale, thermometer, Whatman No 41 filter paper, funnels, beakers, measuring cylinders, stirring rod, dropping pipette, standard volumetric flasks (for preparing reagents) and a time piece.

2.1.3. Description of the Study Area

The Lower Usuma dam is located within Ushafa community Abuja, between latitude 7°25'16"E and longitude 9°01'12"N and it covers a land mass of 2,500,000 m². It is located at about the highest point of the Nigerian Federal Capital Territory, about 15 km northwest of Abuja on 570 m altitude. It is sited on a virgin location where human activity is minimal, thereby ensuring non pollution of the environment and freedom from industrial impurity. Though, pollution may be transported with the water from the contributory rivers.

The barrier system consists of two (2) dams: the main dam and the saddle dam. The main dam has a length of 1.3 km and a height of 47 m, with a crown that is 10 m wide. The saddle dam is 470 m long and has a height of 15 m. The lake has a width of 3.5 km and a length of 3 km and holds 1.2×10^8 m³ of raw water. The water from the Dam flows to the Lower Usuma dam waterworks, where the water is treated before being distributed to Abuja for diverse uses. The total capacity of the waterworks is 1.0×10^4 m³/hr (Ibrahim et al., 2014).

The major occupation of the neighboring inhabitants is farming and hunting. The immediate area comprises of Clinton village, Ushafa kasa, Ushafa Sama and Ushafa new extension, while the entire community is made up of Cogo, Jigo, Pwambara, Peyi and Usuma dam quarters. **Figure 1** shows a map of the study area and sampling points.

2.2. Methods

2.2.1. Sampling and Digestion of Water

Water sampling was done according to the procedure described by [Ndimele and Kumolu-Johnson \(2012\)](#). Water samples from the dam were randomly collected from twelve points at a depth of about 0.3 m below the water surface. Samples from four locations were homogenized and each put into three 500 ml plastic bottles during the periods, July 2019 (Rainy season) and January 2020 (Dry season). Prior to sampling, the bottles were cleaned with 10% nitric acid and rinsed with distilled water. The bottles were then rinsed three times with the dam water at the time of sampling. Samples were collected by direct immersion of the sampling bottle into the dam. Immediately after sample collection, 2 mL nitric acid (AR grade) was added to the water samples to reduce adsorption of metals onto the walls of the plastic bottles. The sample bottles were then labeled to indicate date of sampling and the sampling site after which the samples were transported in an ice-box to the laboratory and stored at 4°C awaiting analysis. Digestion of the water samples was done in triplicate using concentrated nitric acid (Analytical Grade) according to the method described by [Zhang \(2007\)](#).

2.2.2. Sampling and Digestion of Sediment Samples

Sediment samples were taken from the bottom surface of the dam (0 - 5 cm thick) using an Eckman grab according to [Osman and Kloas \(2010\)](#) during the periods, July 2019 (Rainy season) and January 2020 (Dry season). For each sample, three sediment grabs were randomly taken from the banks and mid-dam,

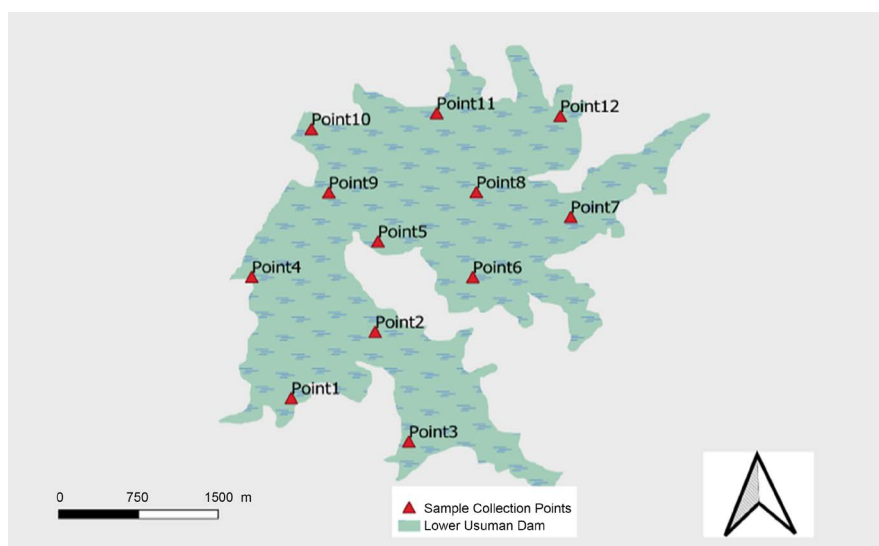


Figure 1. Lower Usuma Dam (showing sampling points).

homogenized and kept in clean polyethylene bags. The surface layer was chosen for this study, because this layer controls the exchange of metals between sediments and waters as well as constitutes a reserve of metals to which benthic organisms are exposed (George et al., 2013). The polythene bags were then labeled to indicate sampling point and date of sampling. Samples were stored in an ice box for transportation to the laboratory. In the laboratory, the samples were kept in a freezer at -20°C until they were processed for heavy metal analysis.

During digestion, the sediment samples were thawed at room temperature (25°C - 28°C) and put into pre-acid cleaned evaporating beakers. The sediments were then dried at a temperature of 50°C in an oven until a constant weight was obtained. The dried sediment samples were ground using a porcelain mortar and pestle and sieved through a 2 mm mesh plastic sieve.

Digestion was done using concentrated nitric acid (Analytical grade) and hydrochloric acid in the ratio 1:3 (aqua regia). 2 g of dry sediment was weighed using an electronic weighing balance into a 50 mL acid cleaned beaker. 9 mL of a freshly prepared mixture of HNO_3 and HCl was added to the sediment and the mixture boiled gently over a water bath till the volume dropped to 20 mL. The digested sample was filtered using a Whatman 0.42 μm filter paper into a 50 mL volumetric flask and topped up to the mark with distilled-deionised water. The filtrate was analyzed for heavy metals using AAS. A blank solution was similarly prepared, using distilled water.

2.2.3. Sampling and Digestion of Fish Samples

Tilapia (*Oreochromis spilurus niger*) and African catfish (*Clarias gariepinus*) samples were obtained from the Lower Usuma dam by use of fishing nets that had been cast and left overnight. Fish samples were obtained from three main fishing zones in the dam twice: during the periods, July 2019 (Rainy season) and January 2020 (Dry season). The fish samples obtained were immediately kept in pre-acid cleaned polythene bags, sealed, labeled and kept in ice boxes for transportation to the laboratory. In the laboratory, the lengths and weights of the fishes were taken and the samples were kept in a deep freezer until when muscle tissues were extracted for analysis. Muscle tissues were chosen to be analyzed in this study because they are the most consumed part of the fishes. Significant levels of toxic metals, if present in the muscle tissues, will pose greater human health risk. The two fish species analyzed are the species mostly consumed from the dam all year round.

Table 1 shows the mean length and weight of the fishes.

The deep frozen fish samples for the two fish species (*Oreochromis spilurus niger* and *Clarias gariepinus*) were thawed at ambient laboratory temperature overnight. The skin of each fish sample was removed using a plastic knife (to avoid metal contamination) and this was followed by extraction of fish muscles. Fish muscles were put in pre-acid washed and oven-dried crucibles. The samples were then dried to a constant weight in an oven at 50°C . The dried fish samples were allowed to cool in a desiccator at room temperature.

Table 1. Mean length and weight of fish samples.

Fish type	Mean weight (kg)	Mean length (cm)
African Catfish	0.58	27
Tilapia	0.33	12

After cooling, 1 g of fish muscles was accurately weighed using an electronic weighing balance and transferred into a clean beaker. Dried fish samples for each fish species was digested in triplicate according to the method described in APHA (2005). To each weighed fish muscle, 18 mL of concentrated nitric acid was added and heated at 100°C on a hot plate in a fume hood chamber. A few drops of hydrogen peroxide (analytical grade) was added until there were no brown fumes.

The digested fish sample solutions were each filtered using Whatman 0.42 µm filter paper in a 50 mL volumetric flask and topped to the mark with distilled-deionised water. The filtrate was then put into 50 mL pre-acid cleaned plastic bottles.

2.2.4. Toxic Metal Assay

Stock standard solutions containing 1000 mg·L⁻¹ of As, Cd, Cr, Cu, Hg, Ni, Pb and Zn were prepared from the metal salts (Analytical Grade) using nitric acid. Working standards for all the metals were prepared from the stock solutions by serial dilutions in distilled water. To determine the instrument signal response to changes in concentration, calibrations were done using working standard solutions of known and increasing concentrations for each analyte element of interest. The actual concentration of each toxic metal in the sediment and fish samples in mg/kg were calculated using the formula:

$$\begin{aligned} \text{Actual concentration (mg} \cdot \text{kg}^{-1}\text{)} \\ = \frac{\text{Digested concentration (mg} \cdot \text{L}^{-1}\text{)} \times \text{Volume digested (L)}}{\text{Weight of dried sample (kg)}} \end{aligned} \quad (1)$$

2.2.5. Evaluation of Ecological and Human Health Risk Indices

Ecological risk index

The potential ecological risk coefficient (E_r^i) of a single element and the potential ecological risk index (RI) of the multielement were computed using the following equations:

$$C_f^i = C_s^i / C_n^i \quad (2)$$

$$E_r^i = T_r^i \times C_f^i \quad (3)$$

$$\text{RI} = \sum_{i=1}^n E_r^i \quad (4)$$

where,

C_f^i is the pollution coefficient of a single element of “ i ”;

C_s^i is the measured level (sedimentary/water/fish) of heavy metal;

C_n^i is the background level of heavy metal.

The average shale background concentration of global sediments was selected as the reference baselines in this study: C_n^i for Cu = 45, Zn = 95, Pb = 20, Cd = 0.3, Cr = 90, Ni = 68, As = 13, Hg = 0.4 (Turekian & Wedepohl, 1961; Harikumar et al., 2009; Ong & Kamaruzzaman, 2009; Jonathan et al., 2016). Average global shale values and average crustal abundance have been commonly used to provide elemental background concentrations (Uluturhan et al., 2011).

T_r^i is the toxic response factor for the given element of “ i ”, which accounts for the toxic requirement and the sensitivity requirement. The toxic response factors for As, Hg, Pb, Cd, Cr, Cu, Zn and Ni are 10, 40, 5, 30, 2, 5, 1 and 6 respectively (Hakanson, 1980; Xu et al., 2008; Izah et al., 2018).

Table 2 shows the grading of E_r^i and RI values.

Human health risk index

1) Chronic daily intake (CDI) indices: The CDI through water and fish ingestion was calculated according to the modified equation from Chrostowski (1994):

$$CDI = \frac{C \times DI}{BW} \quad (5)$$

where, C, DI and BW represent the concentration of heavy metal (mg/L), average daily intake rate (2 L/day) and body weight (70 kg), respectively (USEPA, 2009a).

The CDI for the sediment was calculated according to the modified equations of daily intake of sedimentary toxic metals through various exposure pathways (Wang et al., 2005) shown in **Table 3**.

Table 2. Risk grade indices and grades of potential ecological risk of heavy metal pollution (Hakanson, 1980).

E_r^i	Risk grade	RI value	Risk level	Risk degree
$E_r^i < 30$	Slight	RI < 40	A	Slight
$30 \leq E_r^i < 60$	Medium	$40 \leq RI < 80$	B	Medium
$60 \leq E_r^i < 120$	Strong	$80 \leq RI < 160$	C	Strong
$120 \leq E_r^i < 240$	Very strong	$160 \leq RI < 320$	D	Very strong
$E_r^i \geq 240$	Extremely strong	RI ≥ 320	E	Extremely strong

Table 3. Equations of daily intake of sedimentary toxic metals through various exposure pathways (Wang et al., 2005).

Exposure Pathway	Calculation Formula
Ingestion	$CDI_{Ingest} = \frac{CS \times IRS \times EF \times ED \times CF}{BW \times AT}$
Dermal Contact	$CDI_{Dermal} = \frac{CS \times SA \times AF \times ABS \times EF \times ED}{BW \times AT}$
Inhalation	$CDI_{Inhale} = \frac{CS \times ET \times EF \times ED}{PEF \times 24 \times AT}$

Where:

CDI = chronic daily intake

CS = exposure-point concentration (mg/kg)

EF = exposure frequency = 35 d/a (USEPA, 2011)

ED = exposure duration = 30 a (USEPA, 2011)

ET = exposure frequency = 24 h/d (USDOE, 2011)

AT = averaging time for non-carcinogens = $365 \times ED$ d (USEPA, 2011)

AT = averaging time for carcinogens = 365×70 d (USEPA, 2002)

BW = body weight = 70 kg (USEPA, 1992)

SA = exposed skin area = 5700 cm² (USEPA, 2011)

AF = adherence factor = 0.07 mg·cm⁻² (USEPA, 2011)

ABS = dermal absorption fraction = 0.03 (As), 0.0001 (other metals) (USEPA, 2011)

PEF = particle emission factor = 1.36×10^9 m³·kg⁻¹ (USEPA, 2002)

CF = units conversion factor = 10⁻⁶ mg·kg⁻¹ (USEPA, 2002)

IRS = 100 mg·d⁻¹ (USEPA, 2011)

2) Hazard quotient (HQ) indices: The HQ for non-carcinogenic risk was calculated by the following equation (USEPA, 2009b):

$$HQ = \frac{CDI}{RfD} \quad (6)$$

where, the non-cancer hazard quotient (HQ) is the ratio of exposure to hazardous substances, and RfD is the chronic reference dose of the toxicant (mg·kg⁻¹·d⁻¹).

According to database (USEPA, 2009b), the oral toxicity reference dose values (RfD) are Cr, Zn, Ni, Cu, As, Cd, Pb and Hg are 0.0003, 0.3, 0.02, 0.04, 0.0005, 0.001, 0.004 and 0.0005 mg/kg, respectively. The exposed population is assumed to be safe when $HQ < 1$ and unsafe when $HQ \geq 1$ (Khan et al., 2008).

3) Chronic hazard index (HI)

$$\text{Chronic Hazard Index (CHI/CHQ)} = \sum_{i=1}^k \frac{CDI_k}{RFD_k} \quad (7)$$

where, the chronic hazard index (HI) is the sum of more than one hazard quotient for multiple substances or multiple exposure pathways, CDI_k is the daily intake of a toxic metal (k) and RFD_k is the chronic reference dose for the heavy metal k . HI values ≥ 1 shows that there is a chance that non-carcinogenic risk may occur, and when $HI < 1$ the reverse applies.

4) Cancer risk: Cancer risk can be evaluated from:

$$\text{Cancer risk (CR)} = CDI \times SF \quad (8)$$

where:

Cancer risk (CR) represents the probability of an individual's lifetime health risk from carcinogens;

CDI is the chronic daily intake of carcinogens (mg·kg⁻¹·d⁻¹);

SF is the slope factor of hazardous substances (mg·kg⁻¹·d⁻¹).

Slope factor values for the carcinogens As, Ni, Cd and Cr are given as 1.5, 0.91, 15

and 0.5 respectively (EPA, 2009). Cu, Zn, Hg and Pb, being non-carcinogens, have no assigned value for slope factor (SF).

The cumulative cancer risk will be calculated from:

$$\text{Total Cancer Risk (TCR)} = \sum_{i=1}^k \text{CDI}_k \times \text{SF}_k \quad (9)$$

where:

CDI_k is the chronic daily intake ($\text{mg}\cdot\text{kg}^{-1}\cdot\text{d}^{-1}$) of a single toxic metal k ;

SF_k is the slope factor for the toxic metal k ($\text{kg}\cdot\text{d}^{-1}\cdot\text{mg}^{-1}$).

The acceptable or tolerable maximum limit for TCR, for regulatory purposes, is within the range of 10^{-6} - 10^{-4} (USEPA, 2001).

2.2.6. Statistical Analysis

Descriptive statistics were conducted to determine the average, range, mean and standard deviations of investigated toxic metals in the water, sediment and fish samples. Pearson's correlations matrix was performed to evaluate sources of heavy metals in the studied site, the dynamics of the contamination and potential relationship among measured variables. The test of significance and one-way ANOVA were also carried out on the data.

Statistical analysis was done using IBM SPSS 23 software.

3. Results

3.1. Toxic Metal Concentrations

Tables 4-7 show the toxic metal concentrations obtained for samples from the Lower Usuma dam during the period of study.

Table 4. Toxic metal concentrations in lower Usuma dam raw water.

Toxic Metal	Rainy Season Conc. (mg/L)	Dry Season Conc. (mg/L)	Mean Conc. (mg/L)	WHO/NSDWQ Limit (mg/L)
As	0.0001	0.0008	0.00045	0.01
Cd	-0.0021	0	-0.00105	0.003
Cr	-0.4918	0	-0.2459	0.05
Cu	0.0014	0	0.0007	2.0
Hg	-0.0002	-0.875	-0.4376	0.006
Ni	0.0282	0	0.0141	0.07
Pb	0.1986	0	0.0993	0.01
Zn	0.0011	0.02	0.01055	2.0

Table 5. Toxic metal concentration in tilapia from lower Usuma dam.

Toxic Metal	Rainy Season Conc. (mg/L)	Dry Season Conc. (mg/L)	Mean Conc. (mg/L)	Mean Conc. (mg/kg)	WHO Limit (mg/kg)
As	0.0001	0.000155	0.000128	0.0063	0.26
Cd	-0.002	0	-0.001	-0.0498	0.2

Continued

Cr	-0.0018	0.02	0.0091	0.4527	0.5
Cu	-0.004	0.0004	-0.0018	-0.0896	0.2
Hg	-0.0001	-0.215	-0.10755	-5.3507	0.6
Ni	0.0245	0	0.01225	0.6095	0.5
Pb	0.2358	0.05	0.1429	7.1095	1.0
Zn	0.0397	0.414	0.22685	11.2861	50

Table 6. Toxic metal concentration in African catfish from lower Usuma dam.

Toxic Metal	Rainy Season Conc. (mg/L)	Dry Season Conc. (mg/L)	Mean Conc. (mg/L)	Mean Conc. (mg/kg)	WHO Limit (mg/kg)
As	0.0001	0.00013	0.000115	0.00571	0.26
Cd	-0.0014	0	-0.0007	-0.03476	0.2
Cr	-0.1875	0.02	-0.08375	-4.15839	0.5
Cu	-0.0004	0.0007	0.00015	0.007448	0.2
Hg	0.0001	-0.255	-0.12745	-6.3282	0.6
Ni	0.0206	0.01	0.0153	0.759682	0.5
Pb	0.0815	0.07	0.07575	3.761172	1.0
Zn	0.0308	0.11555	0.073175	3.633317	50

Table 7. Toxic metal concentration in sediment from lower Usuma dam.

Toxic Metal	Rainy Season Conc. (mg/L)	Dry Season Conc. (mg/L)	Mean Conc. (mg/L)	Mean Conc. (mg/kg)	ICPR Limit (mg/kg)
As	0.0013	0.00145	0.001375	0.034	1.0
Cd	-0.0018	0.01	0.0041	0.102	0.1
Cr	-0.0015	0.15	0.07425	1.855	30.0
Cu	0.0004	0.017	0.0087	0.217	25.0
Hg	0.0001	-16.645	-8.32245	-207.957	0.5
Ni	0.0304	-0.1	-0.0348	-0.870	50.0
Pb	0.1297	0.175	0.15235	3.807	40.0
Zn	0.0022	2.49625	1.249225	31.215	90.0

3.2. Ecological Risk Index

Values for contamination factor (C_f^i) and Ecological risk index (E_r^i) determined are shown in **Tables 8-11**.

3.3. Human Health Risk Index

The Hazard Quotient (HQ) and Cancer Risk (CR) index values obtained are shown in **Tables 12-17**.

Table 8. Ecological risk index for toxic metals in water.

Toxic Metal	Mean	C_s^i	C_n^i	C_f^i	T_r^i	E_r^i	Risk Grade
As	0.00045	13	3.46×10^{-05}	10	3.46×10^{-04}	Slight	
Cd	-0.00105	0.3	-3.50×10^{-03}	30	-1.05×10^{-01}	Slight	
Cr	-0.2459	90	-2.73×10^{-03}	2	-5.46×10^{-03}	Slight	
Cu	0.0007	45	1.56×10^{-05}	5	7.78×10^{-05}	Slight	
Hg	-0.4376	0.4	-1.09	40	$-4.38 \times 10^{+01}$	Slight	
Ni	0.0141	68	2.07×10^{-04}	6	1.24×10^{-03}	Slight	
Pb	0.0993	20	4.97×10^{-03}	5	2.48×10^{-02}	Slight	
Zn	0.01055	95	1.11×10^{-04}	1	1.11×10^{-04}	Slight	

$$RI = \sum_{i=1}^n E_r^i = -43.844 ; \text{ Slight Ecological Risk.}$$

Table 9. Ecological risk index for toxic metals in catfish.

Toxic Metal	Mean	C_s^i	C_n^i	C_f^i	T_r^i	E_r^i	Risk Grade
As	0.00571	13	4.39×10^{-04}	10	0.057	Slight	
Cd	-0.0348	0.3	-1.16×10^{-01}	30	-1.043	Slight	
Cr	-4.1584	90	-4.62×10^{-02}	2	-8.317	Slight	
Cu	0.00745	45	1.66×10^{-04}	5	0.037	Slight	
Hg	-6.3282	0.4	-1.58×10^{-01}	40	-253.128	Slight	
Ni	0.75968	68	1.12×10^{-02}	6	4.558	Slight	
Pb	3.76117	20	1.88×10^{-01}	5	18.806	Slight	
Zn	3.63332	95	3.82×10^{-02}	1	3.633	Slight	

$$RI = \sum_{i=1}^n E_r^i = -235.396 ; \text{ Slight Ecological Risk.}$$

Table 10. Ecological risk index for toxic metals in tilapia.

Toxic Metal	Mean	C_s^i	C_n^i	C_f^i	T_r^i	E_r^i	Risk Grade
As	0.0063	13	4.85×10^{-04}	10	0.063	Slight	
Cd	-0.0498	0.3	-1.66×10^{-01}	30	-1.49	Slight	
Cr	0.4527	90	5.03×10^{-03}	2	0.91	Slight	
Cu	-0.0896	45	-1.99×10^{-03}	5	-0.45	Slight	
Hg	-5.3507	0.4	-1.34×10^1	40	-214.03	Slight	
Ni	0.6095	68	8.96×10^{-03}	6	3.66	Slight	
Pb	7.1095	20	3.55×10^{-01}	5	35.55	Medium	
Zn	11.2861	95	1.19×10^{-01}	1	11.29	Slight	

$$RI = \sum_{i=1}^n E_r^i = -164.51 ; \text{ Slight Ecological Risk.}$$

Table 11. Ecological risk index for toxic metals in sediment.

Toxic Metal	Mean	C_s^i	C_n^i	C_f^i	T_r^i	E_r^i	Risk Grade
As	0.197	13	1.52×10^{-02}	10	1.97	Slight	
Cd	0.102	0.3	3.40×10^{-01}	30	3.06	Slight	
Cr	1.855	90	2.06×10^{-02}	2	3.71	Slight	
Cu	2.129	45	4.73×10^{-02}	5	10.645	Slight	
Hg	-207.957	0.4	-5.20×10^{02}	40	-8318.28	Slight	

Continued

Ni	-0.870	68	-1.28×10^{-02}	6	-5.22	Slight
Pb	3.807	20	1.90×10^{-01}	5	19.035	Slight
Zn	31.215	95	3.29×10^{-01}	1	31.215	Medium

$$RI = \sum_{i=1}^n E_i^j = -8.3 \times 10^3; \text{ Slight Ecological Risk.}$$

Table 12. Human health risk index from consumption of toxic metals in LUD water.

Toxic Metal	MeanConc. (mg/L)	CDI	RfD	HQ	Safety	SF	CR
As	-0.0021	1.29×10^{-05}	0.0005	0.0257	Safe	1.5	1.93×10^{-05}
Cd	-0.4918	-3.00×10^{-05}	0.001	-0.03	Safe	15	-4.50×10^{-04}
Cr	0.0014	-7.03×10^{-03}	0.0003	-23.419	Safe	0.5	-3.51×10^{-03}
Cu	-0.0002	2.00×10^{-05}	0.04	0.0005	Safe	-	-
Hg	0.0282	-1.25×10^{-02}	0.0005	-25.0057	Safe	-	-
Ni	0.1986	4.03×10^{-04}	0.02	0.020143	Safe	0.91	3.67×10^{-04}
Pb	0.0011	2.84×10^{-03}	0.004	0.709286	Safe	-	-
Zn	-0.0021	3.01×10^{-04}	0.3	0.001005	Safe	-	-

$$\text{Chronic hazard index} = \Sigma HQ = -26.60; \text{ Total cancer risk} = \Sigma CR = -3.58 \times 10^{-3}.$$

Table 13. Human health risk index from consumption of toxic metals in LUD catfish.

Toxic Metal	MeanConc. (mg/kg)	CDI	RfD	HQ	Safety	SF	CR
As	0.00571	1.63×10^{-04}	0.0003	0.54381	Safe	1.5	1.09×10^{-04}
Cd	-0.03476	-9.93×10^{-04}	0.001	-0.99314	Safe	15	-6.62×10^{-05}
Cr	-4.15839	-1.19×10^{-01}	0.003	-39.6037	Safe	0.5	-2.38×10^{-01}
Cu	0.007448	2.13×10^{-04}	0.04	0.00532	Safe	-	-
Hg	-6.3282	-1.81×10^{-01}	0.0005	-361.611	Safe	-	-
Ni	0.759682	2.17×10^{-02}	0.02	1.08526	Unsafe	0.91	2.39×10^{-02}
Pb	3.761172	1.07×10^{-01}	0.004	26.86551	Unsafe	-	-
Zn	3.633317	1.04×10^{-01}	0.3	0.34603	Safe	-	-

$$\text{Chronic hazard index} = \Sigma HQ = -373.362; \text{ Total cancer risk} = \Sigma CR = -2.14 \times 10^{-01}.$$

Table 14. Human health risk index table from consumption of toxic metals in LUD tilapia.

Toxic Metal	MeanConc. (mg/kg)	CDI	RfD	HQ	Safety	SF	CR
As	0.0063	1.80×10^{-04}	0.0003	0.6	Safe	1.5	1.20×10^{-04}
Cd	-0.0498	-1.42×10^{-03}	0.001	-1.42286	Safe	15	-9.49×10^{-05}
Cr	0.4527	1.29×10^{-02}	0.003	4.311429	Unsafe	0.5	2.59×10^{-02}
Cu	-0.0896	-2.56×10^{-03}	0.04	-0.064	Safe	-	-
Hg	-5.3507	-1.53×10^{-01}	0.0005	-305.754	Safe	-	-
Ni	0.6095	1.74×10^{-02}	0.02	0.870714	Safe	0.91	1.91×10^{-02}
Pb	7.1095	2.03×10^{-01}	0.004	50.78214	Unsafe	-	-
Zn	11.2861	3.22×10^{-01}	0.3	1.074867	Unsafe	-	-

$$\text{Chronic hazard index} = \Sigma HQ = -249.602; \text{ Total cancer risk} = \Sigma CR = 4.50 \times 10^{-2}.$$

Table 15. Human health risk index table from ingestion of toxic metals in LUD sediment.

Toxic Metal	MeanConc. (mg/kg)	CDI _{ingestion}	RfD	HQ	Safety	SF	CR
As	0.03	2.02×10^{-09}	0.0003	4.03×10^{-06}	Safe	1.5	3.03×10^{-09}
Cd	0.10	6.01×10^{-09}	0.001	6.01×10^{-06}	Safe	15	9.02×10^{-08}
Cr	1.86	1.09×10^{-07}	0.003	3.63×10^{-04}	Safe	0.5	5.45×10^{-08}
Cu	0.22	2.98×10^{-08}	0.04	7.45×10^{-07}	Safe	-	-
Hg	-207.96	-2.85×10^{-05}	0.0005	-5.70×10^{-02}	Safe	-	-
Ni	-0.87	-5.11×10^{-08}	0.02	-2.55×10^{-06}	Safe	0.91	-4.65×10^{-08}
Pb	3.81	5.21×10^{-07}	0.004	1.30×10^{-04}	Safe	-	-
Zn	31.22	4.28×10^{-06}	0.3	1.43×10^{-05}	Safe	-	-

Chronic hazard index = $\Sigma HQ = -5.64 \times 10^{-02}$; Total cancer risk = $\Sigma CR = 1.01 \times 10^{-07}$.

Table 16. Human health risk index table from inhalation of toxic metals in LUD sediment.

Toxic Metal	MeanConc. (mg/kg)	CDI _{inhalation}	RfD	HQ	Safety	SF	CR
As	0.03	1.04×10^{-12}	0.0003	2.08×10^{-09}	Safe	1.5	1.56×10^{-12}
Cd	0.10	3.09×10^{-12}	0.001	3.09×10^{-09}	Safe	15	4.64×10^{-11}
Cr	1.86	5.60×10^{-11}	0.003	1.87×10^{-07}	Safe	0.5	2.80×10^{-11}
Cu	0.22	1.53×10^{-11}	0.04	3.83×10^{-10}	Safe	-	-
Hg	-207.96	-1.47×10^{-08}	0.0005	-2.93×10^{-05}	Safe	-	-
Ni	-0.87	-2.63×10^{-11}	0.02	-1.31×10^{-09}	Safe	0.91	-2.39×10^{-11}
Pb	3.81	2.68×10^{-10}	0.004	6.71×10^{-08}	Safe	-	-
Zn	31.22	2.20×10^{-09}	0.3	7.34×10^{-09}	Safe	-	-

Chronic hazard index = $\Sigma HQ = -2.91 \times 10^{-05}$; Total cancer risk = $\Sigma CR = 5.21 \times 10^{-11}$.

Table 17. Human health risk index table from dermal contact with toxic metals in LUD sediment.

Toxic Metal	Mean Conc. (mg/kg)	CDI _{dermal}	RfD	HQ	Safety	SF	CR
As	0.03	0.0881	0.0003	-176.26	Safe	1.5	1.32×10^{-01}
Cd	0.10	0.0009	0.001	0.88	Safe	15	1.31×10^{-02}
Cr	1.86	0.0159	0.003	-52.88	Safe	0.5	7.93×10^{-03}
Cu	0.22	0.0043	0.04	0.11	Unsafe	-	-
Hg	-207.96	-4.1487	0.0005	-8297.50	Safe	-	-
Ni	-0.87	-0.0074	0.02	-0.37	Safe	0.91	-6.77×10^{-03}
Pb	3.81	0.0759	0.004	18.99	Unsafe	-	-
Zn	31.22	0.0759	0.3	0.25	Safe	-	-

Chronic hazard index = $\Sigma HQ = -8048.51$; Total cancer risk = $\Sigma CR = 1.46 \times 10^{-01}$.

3.4. Statistical Analysis

Tables 18-30 show the results of t-test, ANOVA and Pearson correlation generated from the data in Section 3.1.

Table 18. Rainy Season t-test result of raw water and toxic metals concentration in tilapia.

	T	Df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Raw W	-0.47	7	0.65	-0.03	-0.20	0.13
Tilapia Fish	1.26	7	0.25	0.03	-0.03	0.11

Table 19. ANOVA result toxic metal concentration in tilapia from lower Usuma dam during rainy season.

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	0.05	5	0.009	53.80	0.02
Within Groups	0.00	2	0.000		
Total	0.05	7			

Table 20. Dry season t-test result of raw water and toxic metals concentration in tilapia.

	T	Df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Raw W	-0.97	7	0.36	-0.11	-0.37	0.15
Tilapia Fish	0.55	7	0.60	0.03	-0.11	0.18

Table 21. ANOVA result toxic metal concentration in tilapia from lower Usuma dam during rainy season.

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	0.211	5	0.042	422.31	0.002
Within Groups	0.000	2	0.000		
Total	0.211	7			

Table 22. Correlation between rainy and dry season of metal concentration in tilapia from lower Usuma dam.

		T F Rainy S	T F Dry S	Raw W R S	Raw W DS
T F Rainy S	Pearson Correlation	1	0.18	0.51	0.18
	Sig. (2-tailed)		0.66	0.20	0.67
	N	8	8	8	8
T F Dry S	Pearson Correlation	0.18	1	0.04	0.60
	Sig. (2-tailed)	0.66		0.93	0.120
	N	8	8	8	8
Raw W R S	Pearson Correlation	0.512	0.040	1	-0.065
	Sig. (2-tailed)	0.195	0.926		0.878
	N	8	8	8	8
Raw W DS	Pearson Correlation	0.180	0.596	-0.065	1
	Sig. (2-tailed)	0.670	0.119	0.878	
	N	8	8	8	8

Table 23. T-test result of toxic metal concentration in African catfish from lower Usuma dam.

	T	Df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Raw W R S	-0.47	7	0.65	-0.03	-0.20	0.13
C F Rainy S	-0.25	7	0.81	-0.01	-0.07	0.060

Table 24. Rainy season ANOVA result of raw water and toxic metals concentration in Tilapia.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.02	5	0.00	0.39	0.83
Within Groups	0.02	2	0.01		
Total	0.04	7			

Table 25. T-test result of toxic metal concentration in African catfish from lower Usuma Dam during dry season.

	T	Df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Raw W DS	-0.97	7	0.36	-0.11	-0.37	0.15
C F Dry S	-0.13	7	0.90	-0.01	-0.10	0.09

Table 26. Dry season ANOVA result of raw water and toxic metals concentration in catfish.

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	0.08	5	0.01	665.07	0.00
Within Groups	0.00	2	0.00		
Total	0.08	7			

Table 27. Correlation between rainy and dry season of metal concentration in catfish from lower Usuma dam.

		C F Rainy S	C F Dry S	Raw W R S	Raw W DS
C F Rainy S	Pearson Correlation	1	0.09	0.99	-0.03
	Sig. (2-tailed)		0.83	0.00	0.94
	N	8	8	8	8
C F Dry S	Pearson Correlation	0.09	1	0.02	0.93
	Sig. (2-tailed)	0.83		0.96	0.00
	N	8	8	8	8
Raw W R S	Pearson Correlation	0.99	0.02	1	-0.07
	Sig. (2-tailed)	0.00	0.96		0.88
	N	8	8	8	8

Continued

	Pearson Correlation	-0.03	0.9	-0.07	1
Raw W DS	Sig. (2-tailed)	0.94	0.00	0.88	
	N	8	8	8	8

Table 28. ANOVA result of toxic metal concentration in sediment from lower Usuma dam.

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	0.015	7	0.002	0.00	0.00
Within Groups	0.000	0	.		
Total	0.015	7			

Table 29. ANOVA result of toxic metal concentration in sediment from lower Usuma dam.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	259.216	7	37.031	0.00	0.00
Within Groups	0.000	0	.		
Total	259.216	7			

Table 30. Correlation between rainy and dry season of metal concentration in sediment.

		Raw W Rainy S	Raw W Dry S	Sed. Rainy S	Sed Dry S	T F Rainy S	T F Dry S	C F Rainy S	C F Dry S
Raw W R S	Pearson Correlation	1	-0.065	0.518	-0.059	0.512	0.040	0.991	0.021
	Sig. (2-tailed)		0.878	0.189	0.890	0.195	0.926	0.000	0.960
	N	8	8	8	8	8	8	8	8
Raw W DS	Pearson Correlation	-0.065	1	0.172	0.993	0.180	0.596	-0.032	0.932
	Sig. (2-tailed)	0.878		0.684	0.000	0.670	0.119	0.940	0.001
	N	8	8	8	8	8	8	8	8
Sed R S	Pearson Correlation	0.518	0.172	1	0.155	0.977	0.035	0.508	0.297
	Sig. (2-tailed)	0.189	0.684		0.714	0.000	0.934	0.199	0.475
	N	8	8	8	8	8	8	8	8
Sed D S	Pearson Correlation	-0.059	0.993	0.155	1	0.185	0.688	-0.012	0.962
	Sig. (2-tailed)	0.890	0.000	0.714		0.661	0.059	0.978	0.000
	N	8	8	8	8	8	8	8	8
T F Rainy S	Pearson Correlation	0.512	0.180	0.977	0.185	1	0.184	0.520	0.362
	Sig. (2-tailed)	0.195	0.670	0.000	0.661		0.663	0.187	0.378
	N	8	8	8	8	8	8	8	8
T F Dry S	Pearson Correlation	0.040	0.596	0.035	0.688	0.184	1	0.157	0.811
	Sig. (2-tailed)	0.926	0.119	0.934	0.059	0.663		0.710	0.015
	N	8	8	8	8	8	8	8	8
C F Rainy S	Pearson Correlation	0.991	-0.032	0.508	-0.012	0.520	0.157	1	0.091
	Sig. (2-tailed)	0.000	0.940	0.199	0.978	0.187	0.710		0.831
	N	8	8	8	8	8	8	8	8

Continued

	Pearson Correlation	0.021	0.932	0.297	0.962	0.362	0.811	0.091	1
C F Dry S	Sig. (2-tailed)	0.960	0.001	0.475	0.000	0.378	0.015	0.831	
	N	8	8	8	8	8	8	8	8

4. Discussion

4.1. Toxic Metal Concentrations

The levels of all but one of the toxic metals analyzed in the Lower Usuma dam water were below the WHO, NSDWQ and USEPA guidelines. The exception, Pb gave a reasonably higher mean concentration of 0.0993 mg/L, as against the WHO limit of 0.01 mg/L. In the Tilapia, Ni was slightly above limit at 0.609 mg/kg and the level of Pb was significantly high at 7.109 mg/kg. Ni in catfish was observed to be 0.759 mg/kg while Pb was 3.76 mg/kg. The WHO limits for Ni and Pb in fish are 0.5 mg/kg and 1.0 mg/kg, respectively (WHO, 2011). The presence of Ni and Pb in the fishes, above WHO and USEPA limits is attributed to the high level of the metals in the surrounding water and the known ability of fishes to bioaccumulate toxic metals in their tissues over time. Further investigation is needed to assess the metal speciation in the aquatic system as well as the effect of temperature and pH in bioaccumulation of these metals in the fish species (Ndimele et al., 2011a; Dhanakumar et al., 2015). Toxic metals of concern in the sediment were Cr, Pb and Zn, with the trend of toxic metal concentration in sediment being in the order: Zn > Pb > Cr > Cu > Cd > As > Ni > Hg.

Generally, most of the toxic metal concentrations were found to be higher in Tilapia and the sediment than water or Catfish from the dam. This highlights the benthic nature of Tilapia fish and its great capacity to bioaccumulate heavy metals (Mokhtar et al., 2009; Abdulali et al., 2012).

Sources of Ni and Pb contamination in the dam are probably due to disposal of tyres, batteries, garbage containing lead and soldered tins and fittings into the dam or its surroundings. It may also be due to contamination of any of the rivers that contribute water into the dam such as the high level of Pb in Guarara water transfer, as suggested by Okunlola et al. (2014).

4.2. Ecological Risk Index

Contamination factor (C_f^i) was below one for all the toxic metals under study, in the water, Catfish, Tilapia and sediment samples from the Lower Usuma dam. This means there is generally, LOW possibility of contamination from these metals through any of the media analyzed.

Ecological risk index (E_r^i) values for all the toxic metals in water and catfish were all below 30, showing slight risk of toxic metal poisoning from ingestion of water or the catfish. This indicates safety; water and catfish from the dam pose no ecological hazard to aquatic life or humans that come in contact with them. The same cannot be said of Tilapia or sediment from the dam as the ecological risk index for Pb in Tilapia and Zn in the sediment is greater than 30 but less

than 60. This accords MEDIUM ecological risk associated with ingestion of Tilapia fish or sediment from the lower Usuma dam. The risk indices for other toxic metals in Tilapia and sediment from the dam is observed to be slight.

The overall risk index (RI) for all the toxic metals in water, Catfish, Tilapia and the sediment from the Lower Usuma dam is to be graded as A (SLIGHT), since the values are way below 40.

4.3. Human Health Risk Index

The non-cancer risk or hazard quotient for As, Cd, Cr, Cu, Hg, Ni and Zn were below one in water, Catfish and Tilapia thereby conferring a SAFE status for them in the media mentioned. However, the hazard quotient for Pb in the media was greater than one, according Pb an UNSAFE grade. Continued consumption of water and fish directly from the dam (without treatment) may cause health effects associated with lead poisoning (see 2.3.2) but cancer will not necessarily occur.

Total cancer risk obtained for toxic metals in water, being within the acceptable or tolerable risk for regulatory purposes of 10^{-6} - 10^{-4} (USEPA, 2001), shows that water from the lower Usuma dam FCT poses NO cancer risk to its users, even without treatment.

Since the total cancer risk index value for toxic metals in catfish is below the acceptable or tolerable risk for regulatory purposes of 10^{-6} - 10^{-4} (USEPA, 2001), it can also be deduced that catfish from the lower Usuma dam FCT poses NO cancer risk to its consumers.

The cancer risk for the carcinogens As, Cd, Cr and Ni in Tilapia and sediment samples were found to be below the tolerable limit (10^{-6} - 10^{-4}). Though the hazard quotient for Pb grades Tilapia as unsafe, since Pb is not classified a carcinogen, as well as Cu, Hg and Zn, there is NO cancer risk from their consumption in Tilapia though, Pb poses significant non-cancer risk.

There is no cancer or non-cancer risk posed to humans or the dam ecosystem as a whole, either by ingestion, inhalation or dermal contact with sediment from the dam. This is because the chronic hazard index for all the toxic metals, determined using the equations proposed by Wang et al. (2005), were all below one and the total cancer risk (TCR) was below the range 10^{-6} - 10^{-4} (WHO, 2011).

4.4. Statistical Analysis

Table 18 presents the t-test result of the raw water and toxic metals concentration in tilapia fish from Lower Usuma Dam during the rainy season. The mean difference for raw water in rainy season stood at -0.03 with significant level of 0.65 while the mean for tilapia fish stood at 0.65 with a significant level of 0.25 which is greater than the significance level of 0.05 . Since the t-value for raw water stood at -0.47 with a significance level of 0.65 while the t value for metal concentration of tilapia fish is 1.26 , with a significant level of 0.25 which is less than the significance level of 0.05 . It can, therefore, be concluded that toxic metal

concentrations in the water affects the tilapia fishes in the Lower Usuma Dam during the rainy season.

Table 19 shows the summary of Analysis of Variance (ANOVA) on assessing the levels of toxic metals (As, Cd, Cr, Cu, Hg, Ni, Pb and Zn) in raw water, specifically in tilapia fish from the lower Usuma dam, Abuja, Nigeria. The calculated F-ratio is equal to 53.80 at p -value of 0.02. Since p -value stood at 0.02 which is below 0.05 level of significance, there is significant relationship between toxic metals in Tilapia fish and raw water in Lower Usuma Dam during rainy season as such when consumed, during raining season it does not have greater effect on human.

Table 20 presents the t-test result of the raw water and toxic metals Concentration in tilapia fish from Lower Usuma Dam during the dry season. The mean difference for raw water in dry season stood at -0.11 with significant level of 0.36 while the mean for tilapia fish stood at 0.03 with a significant level of 0.60 which is greater than the significance level of 0.05. The t-value for raw water stood at -0.97 with a significance level of 0.36 while the t value for metal concentration of tilapia fish is 0.55 with a significant level of 0.60 which is greater than the significance level of 0.05. Thus, toxic metal concentrations in water does affect the tilapia fishes in Lower Usuma Dam Raw Water during the dry season.

Table 21 shows the summary of Analysis of Variance (ANOVA) on assessing the levels of toxic metals (As, Cd, Cr, Cu, Hg, Ni, Pb and Zn) in water during dry season, specifically on tilapia fish from the lower Usuma dam, Abuja, Nigeria. In the analysis, the calculated F-ratio is equal to 422.31 at p -value of 0.02 which is below 0.05 level of significance. There is a significant relationship between toxic metals in tilapia fish and raw water in Lower Usuma Dam during dry season. The result shows that when it's consumed during dry season, it does not have greater effect on human.

Table 22 above shows the level of relationship between raw water of rainy and dry season and tilapia fish from the lower Usuma dam Abuja, Nigeria. The Pearson correlation coefficient of Tilapia fish (T F) in rainy season stood at 0.51 at a p -value of 0.20 which is less than the p -value of 0.05. This implies that there is 51% relationship between raw water and tilapia fish during rainy season. There is an average relationship between raw water containing metal concentration and tilapia fish during rainy season from the lower Usuma dam Abuja. The table above further revealed the level of relationship between raw water and tilapia fish during dry season from the lower Usuma dam Abuja, Nigeria. The Pearson correlation coefficient stood at 0.60 at a p -value of 0.12 which is greater than the p -value of 0.05. This implies that 60% relationship exists between raw water and tilapia fish during dry season from the lower Usuma dam Abuja. The researcher therefore conclude that there is a good relationship between raw water containing metal concentration and tilapia fish during dry season from the lower Usuma dam Abuja, Nigeria.

Table 23 presents the t-test result of the raw water and toxic metals' concen-

tration in African Catfish from Lower Usuma Dam during rainy seasons. The mean difference for raw water in rainy season stood at -0.47 with significant level of 0.65 while the mean for catfish stood at -0.03 with a significant level of 0.81 which is greater than the significance level of 0.05 . Since the t -value for raw water stood at -0.47 with a significance level of 0.65 while the t value for metal concentration of Catfish is -0.25 and a significant level of 0.81 which is also greater than the significance level of 0.05 . Thus, the researcher concludes that Toxic Metal Concentrations in water affect the catfish in Lower Usuma Dam Raw Water during rainy season.

Table 24 shows the summary of Analysis of variance (ANOVA) on assessing the levels of toxic metals (As, Cd, Cr, Cu, Hg, Ni, Pb and Zn) in raw water, specifically on Catfish from the lower Usuma dam, Abuja, Nigeria. In the analysis, the calculated F -ratio is equal to 0.39 at p -value of 0.83 . Since p -value stood at 0.83 which is greater than 0.05 level of significant. The researcher therefore concludes that there is no significant relationship between toxic metal in catfish and raw water in Lower Usuma Dam during rainy season. The result shows that catfish when consumed during rainy season might be harmful to humans.

Table 25 presents the t -test result of the raw water and toxic metals concentration in Catfish from Lower Usuma Dam during the dry season. The mean difference for raw water in the dry season stood at -0.97 with significant level of 0.36 while the mean for Catfish stood at -0.01 with a significant level of 0.90 which is greater than the significance level of 0.05 . The t -value for raw water stood at -0.97 with a significance level of 0.36 while the t value for metal concentration of Catfish is -0.13 and a significant level of 0.90 which is greater than the significance level of 0.05 . It can be concluded that toxic metal concentrations in water does affect the Catfish in Lower Usuma dam raw water during dry season.

Table 26 shows the summary of Analysis of variance (ANOVA) on assessing the levels of toxic metals (As, Cd, Cr, Cu, Hg, Ni, Pb and Zn) in raw water during dry season, specifically on Catfish from the lower Usuma dam, Abuja, Nigeria. In the analysis, the calculated F -ratio is equal to 665.07 at p -value of 0.00 . Since the p -value stood at 0.00 which is below 0.05 level of significance, there is significant relationship between toxic metal in cat fish and raw water in Lower Usuma Dam during the dry season. The result shows that catfish is good for consumption and it's not harmful for human consumption.

Table 27 above reveals the level of relationship between raw water of rainy and dry season and Catfish (C F) from the lower Usuma dam Abuja, Nigeria. The correlation coefficient of Catfish (C F) in rainy season (R S) stood at 0.99 at a p -value of 0.00 which is less than the p -value of 0.05 . This implies that there is 99% significant relationship between raw water and Catfish during Rainy season, which is an excellent relationship. The table further shows the level of relationship between raw water and Catfish during dry season from the lower Usuma dam Abuja, Nigeria. The correlation coefficient stood at 0.93 at a p -value of 0.00 which is less than the p -value of 0.05 . This implies that a 93% relationship exists between raw water and Catfish during dry season from the lower Usuma dam Abuja.

Table 28 presents the summary of Analysis of variance (ANOVA) on assessing the levels of toxic metals (As, Cd, Cr, Cu, Hg, Ni, Pb and Zn) in sediment from the lower Usuma dam. In the analysis, the calculated F-ratio is equal to 0.00 at p -value of 0.00 and p -value stood at 0.00, which is less than 0.05 level of significant. There is, therefore, a significant relationship between toxic metals in Catfish and raw water in Lower Usuma Dam during rainy season.

Table 29 reveals the summary of Analysis of variance (ANOVA) on assessing the levels of toxic metals (As, Cd, Cr, Cu, Hg, Ni, Pb and Zn) in sediment (Sed) in dry season (D S) from the lower Usuma dam, Abuja, Nigeria. In the analysis, the calculated F-ratio is equal to 0.00 at p -value of 0.00 and p -value stood at 0.00 which is less than 0.05 level of significance. That implies that there is a significant relationship between toxic metals and raw water in Lower Usuma Dam sediment during the dry season period.

Table 30 shows the intensity of relationship between raw water and sediment in rainy season from the lower Usuma Dam Abuja, Nigeria. The Pearson correlation coefficient of raw water and sediment during rainy season stood at 0.52 at a p -value of 1.9, which is greater than the p -value of 0.05. This implies that there is 52% relationship between raw water and sediment during the rainy season. Hence, there is an average relationship between raw water metal concentration and that of sediment during the rainy season from the lower Usuma dam Abuja.

The table reveals the relationship between Tilapia fish and sediment in rainy season from the lower Usuma dam Abuja, Nigeria. The Pearson correlation coefficient between Tilapia fish and sediment stood at 0.98 at a p -value of 0.00 which is less than the p -value of 0.05. This implies that there is 98% relationship between tilapia fish and sediment during the rainy season and there is a strong relationship between tilapia fish and sediment containing metal concentration during rainy season from the lower Usuma Dam Abuja.

The Pearson correlation coefficient between catfish and sediment stood at 51 with a p -value of 1.99 which is greater than the p -value of 0.05. This implies that there is 51% relationship between Catfish and sediment during the Rainy season which is an average relationship between catfish and sediment containing metal concentration during rainy season from the lower Usuma dam Abuja. The table revealed relationship between raw water and sediment in dry season from the lower Usuma dam Abuja, Nigeria. The Pearson correlation coefficient of raw water and sediment during the dry season stood at 0.99 at a p -value of 0.00 which is less than the p -value of 0.05. This implies that there is 99% excellent relationship between raw water and sediment during dry season and that is a strong relationship between raw water and sediment containing metal concentration during dry season from the lower Usuma dam Abuja. The table further reveals the level of relationship between Tilapia fish and sediment in dry season from the lower Usuma Dam Abuja, Nigeria. The Pearson correlation coefficient between Tilapia fish and sediment stood at 0.69 at a p -value of 0.06 which is greater than the p -value of 0.05. This implies that there is 69% relationship between toxic metal concentration in tilapia fish and sediment during dry season. There exists

a slightly above average relationship between toxic metal concentration in tilapia fish and sediment during the dry season from the lower Usuma dam Abuja.

The Pearson correlation coefficient between Catfish and sediment stood at 96 with a p -value of 0.00 which is less than the p -value of 0.05. This implies that there is 96% relationship between Catfish and sediment in the dry season. That represents an excellent relationship between toxic metal concentration in catfish and sediment during dry season from the lower Usuma dam Abuja.

5. Conclusion

Toxic metal concentrations of As, Cd, Cr, Cu, Hg, Ni, Pb and Zn in the water, African Catfish, Tilapia and sediment samples from the Lower Usuma dam Abuja were determined using Atomic Absorption Spectroscopy and Atomic Emission Spectroscopy. Ecological and human health risk indices were evaluated using the toxic metal concentrations obtained and the index values were interpreted.

As, Cd, Cr, Cu, Hg, Ni and Zn levels in the water were below WHO standard but Pb concentration was above limit. In the fish samples (African Catfish and Tilapia), Ni and Pb were present above the USEPA and WHO limits while other metals were present in low concentrations. Considering the potential toxicity of these two metals, that raises concern as the two fish species are the most consumed species by humans in the neighboring localities. Pb and Zn levels were observed to be high in the dam sediment.

Being a highly protected environment, it is unlikely that any person/organization goes to discharge metallic waste into the dam. Again, since lead pipes are not used for water transportation to/from the dam and there is no lead component in the construction of the dam, contamination must have come from one or more of the rivers whose waters are embanked in the dam. Industrial discharge into the river Usuma and the Gurara water is proposed to be chiefly responsible for toxic metal concentration in the dam.

Ecological and human health risk assessment revealed that the overall ecological risk is slight, non-cancer risk is low and cancer risk is non-existent.

It is recommended that the laboratories in the Usuma Dam Waterworks regularly check for levels of toxic metals in the treated water, to ensure that they are kept below WHO limits, before the water is distributed to the Federal Capital Territory for use.

Further research may be carried out to:

- 1) Find out the concentration of other toxic metals not covered in this study, and determine their levels in water, sediments and different fish species within the dam.
- 2) Determine variation of toxic metal concentrations in different fish organs such as the gills, liver, muscles, bones and intestines. Research can also be carried out, in addition, to find out the variations of toxic metal concentrations in sediments at different depths of the Lower Usuma dam.

3) Assess levels of toxic metals in crops grown around the Lower Usuma dam and irrigated with water from the dam.

4) Assess the health status of humans living around the Lower Usuma dam, to find out if there are health challenges arising from toxic metal poisoning.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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