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Metal Accumulation in Ekiti State's Three Major Dams' Water and Sediments, the Ecological Hazards Assessment and Consequences on Human Health

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Health risk assessment

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ABSTRACT

Water is indispensable to life. Consequently, water and sediment contamination poses severe ecological threats to life. Thus, this investigation aimed to evaluate metal deposition in the sediments and surface water in Ekiti State's three dams and to analyze its potential ecological effects on man's bodily, social, and mental well-being. Metal levels in sediments and dam water were determined using Atomic Absorption Spectroscopy (AAS). Average values of the metals in Egbe, Ero, and Ureje dams, except for K, Mn, and Pb (in Ureje dam), were lower than the acceptable boundaries of local and foreign establishments. The values of the risk quotient (HQ) on the skin and consumption contacts with all metals (except Mn for ingestion exposure for children) were less than one in the Egbe, Ero, and Ureje dams for both adults and children. Consumption HQ values were higher than skin HQ values in the three dams for children and grown-ups. The total hazard index (HI) posed adverse non-carcinogenic risk to children in the catchment area of the dams while the adults were not affected by the non-carcinogenic hazard. The highest cancer hazard was found in the Ureje dam, while the lowest was in the Ero dam. Further, adults were prone to higher cancer risk than children. Using multiple pollution indices revealed that the sediments in Egbe, Ero, and Ureje dams were less contaminated by harmful metals in dry and wet periods. There is a need to reduce current polluting anthropogenic activities around the dams.

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1 Introduction

Contamination of freshwater and sediment poses a severe ecological risk to countless water bodies in the developing world and toxicity to the ecosystem (Olayinka-olagunju et al. 2021). Water is indispensable to life, and potable drinking water is essential for human existence. As a result, potable drinking water is not supposed to pose any significant threat to human life or well-being. Metal contamination in aquatic environments has become a global issue. It is worsening at an alarming rate (Al-Afify and Abdel-Satar 2022), with consequent threats to the food chain of animals (Olayinka-olagunju 2021). Metals are non-biodegradable substances that naturally occur in the upper part of the lithosphere and are constantly deposited through anthropogenic activities and become integrated into the sediment, water, and aquatic biota, causing aquatic ecosystem contagion (Briffa et al. 2020). Metals occur in small amounts in nature and are formed primarily by rock and soil weathering (Masindi and Muedi 2018; Obasi and Akudinobi 2020). Thus, sources of metals in our environments are natural and anthropogenic (Ali et al. 2019).

However, anthropogenic sources are the primary donors of metal to the environment. Metals such as Cu, Mn, Ni, Mn, Fe, and Zn are required in minimal sums as microelements by plants and animals. In contrast, metals without useful functions are exceedingly hazardous in the minutest quantities (Khalef et al. 2022). Metals in significant amounts in the environment could be dangerous and detrimental to the effective operations of natural ecosystems and human health (Velma and Tchounwou 2010; Vieira et al. 2012) as a result of their toxic effects, extended persistence, bio-accumulative properties, and bio-magnification in the food chain. Aquatic ecosystems are an essential feature of our environment because they serve as reservoirs for such resources as minerals, fisheries, and portable water. Thus, their protection as a sensitive resource is critical for long-term development. The entrance of metals into water ecosystems follows different pathways, either from point or non-point sources (Mustapha and Getso 2014). In water, metals can inflict considerable harm to biological environs and, consequently, the well-being of human populations (Kawser et al. 2016; Dehghani et al. 2017). The two most expected ways humans can be exposed to metals in an aquatic environment are through ingestion and dermal absorption (Li and Zhang 2010^a, Benoit et al. 2019). Sustainable utilization of water environments contributes to man's comprehensive state of bodily, social, and mental well-being and existence.

Sediments are an essential and dynamic element in aquatic ecosystems and have been frequently used as environmental indices for metal pollution assessment in natural water (Morillo et al. 2004; Islam et al. 2015; Tao et al. 2012; Proshad et al. 2019; Radomirović et al. 2021). Sediments have become sinks for heavy metals and sometimes act as carriers and environmental sources of heavy metals (Algül and Beyhan 2020). Increased anthropogenic and agricultural activities in Ekiti State contribute to increased discharge of chemical pollution into the ecosystem, which may likely result in higher metal levels in water sources and sediments. The contaminant concentrations in sediments are functional ecological hazard indices related to contamination in water environments (Stamatis et al. 2019). Metal levels in water are occasionally below detectable levels; hence sediments are helpful in the estimation of the degree of metal pollution in water ecosystems (Tunde and Oluwagbemiga 2020). The necessity to evaluate the bottom sediment quality concerning metal pollution prompted the development of several geochemical and ecotoxicological indicators, the application of which is advantageous for environmental pollution hazard assessment and water source safety public policy (Cymes et al. 2012). These indices include metal levels in the water, Geo-accumulation index (Igeo), index of metal pollution (MPI), possible ecological hazard index, contamination factor, degree of contamination (Cd), and sediment quality criteria (SQGs). In addition, these indicators are helpful in the environmental hazards assessment, evaluation of the decline in physicochemical and biological soil quality, creation of opportunities for societal and ecological awareness, and future ecosystems sustainability prediction (Kowalska et al. 2018, Radomirović et al. 2021).

Further, these indices have been used by numerous researchers in measuring the ecological risks of pollution by metals in water environments (Cymes et al. 2012; Likuku et al. 2013; Harikrishnan et al. 2016; Yang et al. 2016; Bubu et al. 2017; Samuel et al. 2019; Radomirović et al. 2021). Despite their widespread use, there is no report on any of these indices on the population living in the catchment area of the Egbe, Ero, or Ureje dams. Therefore, this research was designed to (1) assess the level of metal accretion in the surface water and sediments of Egbe, Ero, and Ureje dams, (2) analyze seasonal fluctuations, and assess any ecological, environmental, and health problems that may be connected with them, and (3) contribute to future management and study of metals in the State's dams.

2 Materials and Methods

2.1 Area of Study

Ekiti State is situated in the eastern part of the Greenwich Meridian in the north of the Equator between longitudes 4° 45' - 5° 45' east and latitudes 7° 15' - 8° 5'. Ekiti State shares a border with Kwara, Kogi, and Osun States in the north, east, and south, respectively. The studied area has several metamorphic and igneous rocks which are situated underneath stratified rocks in southwestern Nigeria. This investigation was carried out in Egbe, Ero and Ureje dams, the three major dams in the Ekiti State. The locations of the dams in the Ekiti State map are shown in Figure 1. Fishing, recreational,

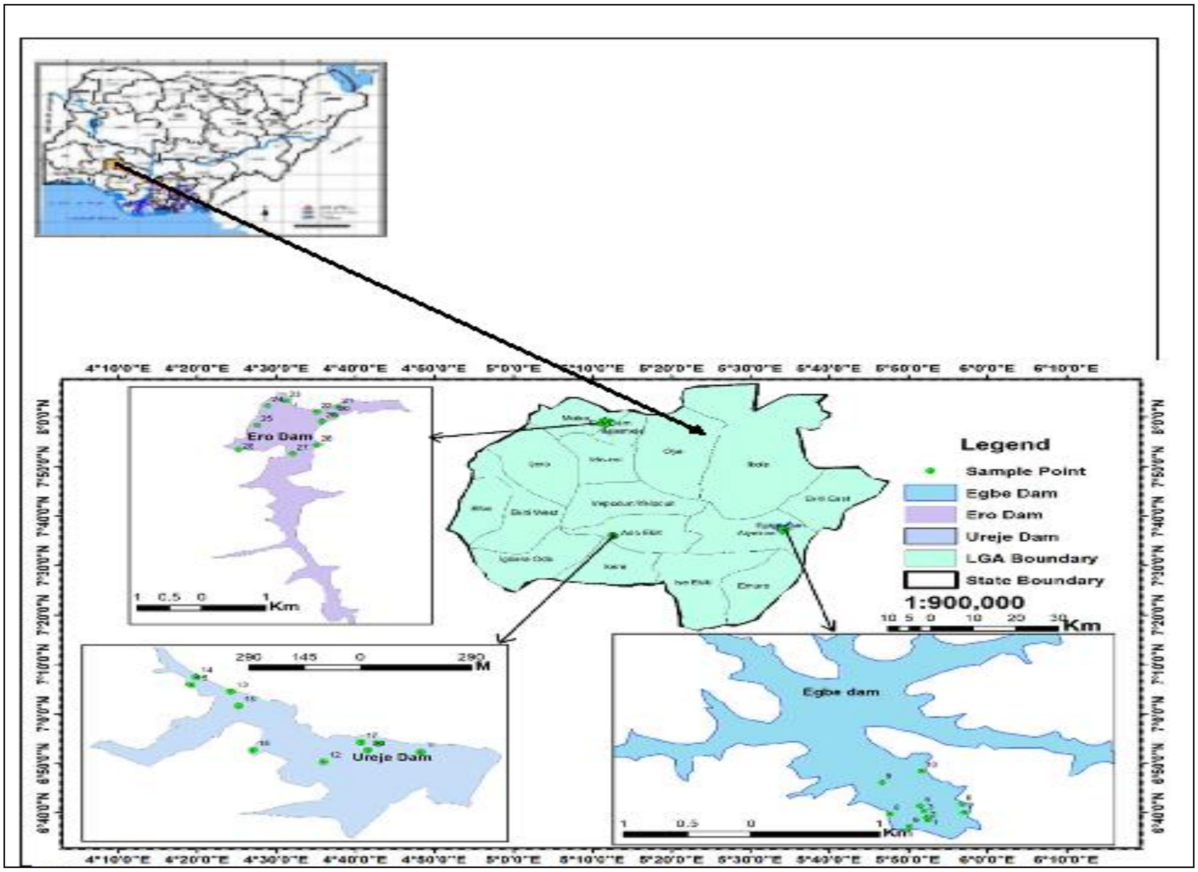

Figure 1 Ekiti State map showing the dams (Egbe, Ero, and Ureje) and the sampling sites in Ekiti state, Southwest Nigeria.

agricultural, domestic activities, and sewage disposal are all common occurrences, particularly in human communities around the dams. Insecticides and agricultural-based chemicals are used regularly in the dams' catchment areas for various agricultural and domestic operations. There is also the dumping of household solids and liquid wastes directly into the dams without proper treatment. In addition, runoff from farms is also offloaded directly into the dams.

2.2 Water and Sediment Sample Collection

Ten sites were selected from each dam based on discussions with fishermen because they operate adjacent to the residential and farming regions alongside high pollution levels and increased fishing activities. Water samples were taken from about 30 cm beneath the water surface from the ten sites into 2-liter polypropylene containers between 8 a.m. and 10 a.m. The GPS of sampling sites was taken using Garmin hand-held GPS. The containers were cleaned with distilled water and washed with 10% nitric acid before utilization for water collection. Dams water was used to rinse the containers thrice before being submerged in the dam to collect water samples during the sampling period. A composite subdivision of water was formed monthly by blending the collected samples from multiple sites to obtain a representative sample (Prakash et al. 2011; Said et al. 2012; Ndimele and Kumolu-Johnson 2012; Olafisoye et al. 2016; Tichkule and Bakare 2017). The containers of the samples were correctly registered to designate the period and site of sampling. After collecting the water sample, 2 mL of strong nitric acid was added to inhibit the adherence of metals to the sides of the container and to stop microbiological growth in the water samples.

With the aid of the Eckman clutch sampler, sediment samples were collected from various sites at a depth of 20-50cm for 24 months. Each of the three dams had a composite sediment sample deposited into a polythene bag, which was then correctly registered to denote the sampling period and location. The appropriately stored samples were conveyed in a container, which was thoroughly insulated and packed with ice cubes into the research laboratory and preserved at -20 °C in a freezer, pending heavy metal analysis.

2.3 Water Sample Preparation

For water sample preparation, 2 ml of undiluted nitric acid and 4 ml of undiluted Hydrochloric acid were added to the 100 ml water sample. The sample was enclosed and heated to 95 ^{o}C to decrease the volume by 20 ml. After cooling, the interior of the beaker was rinsed down with distilled water, and silicates and other soluble components were filtered out using Whatman paper. The sample filtrate was increased to 100 mL and used for metal/mineral analysis.

2.4 Sediment Sample Preparation

The sediments were heated at 105°C, homogenized by lightly crushing them in a mortar, and then prepared for evaluation of metal content. Sediment digestion was carried out according to APHA (2005). A carefully weighed gram of the sample was added 5 ml of strong and undiluted nitric acid. Samples were dried by heating them to a temperature of 120 °C. The acid addition and heating method was repeated three times. This was followed by the addition of 25 ml of distilled water to boost the filtrate volume derived from adding of roughly 50 ml of water to the remaining material and filtering with a 0.45 m Whitman filter.

2.5 Metal Content Analysis in Water and Sediment Samples

AAS (Buck Scientific Model 211 VGP) and a Flame Photometer FP902 PG was used in metal content appraisal in water and silt. Solutions of each element in known concentrations of 1.0, 0.8, 0.6, 0.4, and 0.2 mgL^{-1} were prepared from a highly concentrated solution. AAS was utilized to analyze each processed metal's filtrate and a series of reference solutions. The metal discovery limits in each sample were 0.0001 using the AAS model. Magnesium, manganese, iron, copper, zinc, calcium, lead and cadmium ions were measured in the sample filtrate and standard solutions using cathode lamps at wavelengths of 285.21, 279.48, 248.00, 324.75, 213.86, 422.67, 217.00 and 228.80 for the metals respectively. The AAS was auto-zeroed with distilled water before standard solutions were added from the lowest to the highest concentrations to assess each element. The AAS gave the matching absorbance to the concentrations of the various solutions, and the graph of different concentrations against the absorbance was designed. The metal concentrations in the sample were calculated in parts per million using the standard graph as a guide (Greenberg et al. 1985).

2.6 Human Health Hazard Appraisal Indicators

Toxicology indicators were used to evaluate the health hazard effects of non-carcinogenic and cancer-causing metal on the dams (Dorme et al. 2011; Wongsasuluk et al. 2014). Quantification of pollution in metal, probable cancer-causing, and non-carcinogenic health hazards induced by heavy metal ingestion and skin absorption in the Egbe, Ero, and Ureje dams was accomplished by Risk Quotients, Risk Index, and the incremental lifespan tumor hazard. Health consequences due to metals in the dams' surface were evaluated through ingestion and skin contact according to USEPA (2004) and Li and Zhang (2010[b]). Below in equations 1 and 2 are the formulae for the computations of the mean diurnal dose for consumption and cutaneous contact, respectively.

$$(Cn \times Ef \times Ed \times Ir \times) / (Bwt \times At) = ADDing \qquad (1)$$

$$(Cn \times Et \times Ef \times Sa \times Pc \times Ed \times Cf) / (Bwt \times At) = ADDderm \qquad (2)$$

Here ADDing is the mean diurnal dose from water consumption (g/kg/d); ADDderm is the mean diurnal dose from skin contact (g/kg/d); Cn is the level of the metal in the dam (g/L). For adults, Ir, which is the rate of water consumption, was taken to be 2.2 L/d; Ef is the contact rate is 365 days/year; Ed is the contact period of 70 years; Bwt is the mean body weight i.e. 70 kg; At is the averaging time (Ed x Ef). A year is taken to be 365 days, averaging time (25,550 days). Sa is the exposed dermal area of 18,000 cm^2; Et is the contact time of 0.58 h/d. Cf is the entity change factor (0.001 L/cm^3); and pc is the coefficient of skin permeability (cm/h), which are 0.0006, 0.001, 0.001, 0.001, 0.001 and 0.0001 for Zn, Cu, Mn, Fe, Cd, and Pb respectively (Iqbal and Shah 2013; Liang et al. 2011; Hadzi et al., 2015).

For children, Ir = 1.8, Ed = 6yrs, Bwt = 15kg, At = 2190, Et = 1, Sa = 6,600 (Tay et al. 2019).

$$\text{Risk Quotient through consumption or skin (HQ)} = ADD/RfD \qquad (3)$$

Where RfD is the ingestion/dermal reference measure (mg/L/day), procurement of ingestion reference measures (RfDi) of metals was according to Li and Zhang (2010[b]) while skin absorption reference measure (RfDd) were computed from the following equation 4.

$$RfD_d = RfD_i \text{ x } ABS_g \qquad (4)$$

Here, ABSg is the digestive system assimilation factor of metals, for this, USEPA (2004) recommended values were applied.

The potential damage to man's health from several metals was determined from the hazard index (summation of all hazard quotients of the metals). A hazard index < 1, signifies no substantial non-carcinogenic hazard

To assess Cancer-causing hazards, (S.F. is multiplied by ADD) in mg/kg/day (Wongsasuluk et al. 2014; Adamu et al. 2015). Therefore,

$$CRing = ADDing \text{ x Slope factor} \qquad (5)$$

$$CRderm = ADDderm \text{ x Slope factor} \qquad (6)$$

Here CRing is the cancer-causing hazard due to consumption, and CRderm is the cancer-causing hazard due to skin contact. The slope factor in mg/kg/day is 0.0085 for Pb and 6.3 for Cd (Bamuwamye et al. 2017; Ayenuddin Haque et al. 2018). The cancer-causing acceptable hazard range is between 1×10^{-6} and

Table 1 Risk grade, value and assessment standard

Hazard Rankings	Variety of hazard value	Acceptability
Rank I (Exceptionally small hazard)	$<10^{-6}$	Total admit
Rank II (Small hazard)	10^{-6}, 10^{-5}	unwillingness to be carefulness about the threat
Rank III (Small moderate hazard)	10^{-5}, 5×10^{-5}	Care less about the threat
Rank IV (Moderate hazard)	5×10^{-5}, 10^{-4}	Caution about the threat
Rank v (Moderate high hazard)	10^{-4}, 5×10^{-4}	Caution concerning the threat willing to spend
Rank VI (Great hazard)	5×10^{-4}, 10^{-3}	Be responsiveness to the threat and proffer solution
Rank VII (Exceedingly great threat)	$>10^{-3}$	Refuse the hazard and resolve it.

Source: Li et al. (2017).

1×10^{-4} (Li et al. 2017). The hazard grade and assessment standard are shown in Table 1.

2.7 Appraisal of Metal Pollution in Sediments

The following pollution indices determined sediment contamination and the degree of pollution:

2.7.1 Index of Metal pollution (MPI)

The formula of Usero et al. (1997) was employed to determine the index of metal contamination (MPI).

$$\text{MPI} = (\text{Cm1 x Cm2} \times \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..\text{Cmn})^{\frac{1}{n}} \quad (7)$$

In which n = total number of metals studied; Cm1= concentration value of metal no. 1; Cm2 = concentration of metal no. 2, Cmn is the concentration of nth metal.

2.7.2 Pollution factor and degree of pollution

Contamination or pollution factor is the proportion of the sediment's metal content to the metal's background value. In contrast, contamination degree is the addition of the contamination factors (C.F.) of all metals in the sediment divided by the number of metals investigated.

$$\text{Contamination Factor} = \frac{\text{Evaluated of metal level in sediments}}{\text{Background value of the metal}} \quad (8)$$

Where the background metal value is equivalent to the average world's surface rock

The degree of pollution = the summation of the metal contamination factors (9)

2.7.3 Index of Pollution Load (PLI)

This can be obtained from the contamination factor of metals concerning the background rate in sediment. It gives an aggregate measure of the total level of metal harmfulness in specific sediment and is evaluated as the n^{th} root of the multiplication of the pollution factors. Tomlinson et al. (1980) proposed an index of pollution.

$$\text{PLI} = (\text{CF1x CF2 x CF3 x}\ldots\ldots\ldots\text{x CFn})^{1/n} \quad (10)$$

in which, n = total no. of metals; CF = pollution factor.

2.7.4 Geo-accumulation Index (Igeo)

Geo-accumulation Index is useful in evaluating sediment pollution by metal by relating current metal concentration with pre-industrial concentrations. The following formula computed the geo-accumulation index (Mùller 1979)

$$\text{Igeo} = \log 2\left[\frac{\text{Cn}}{1.5 \text{ x Bn}}\right] \quad (11)$$

in which Cn is the level of metal "n" in sediment, Bn is the metal "n" background value (Turekian and Wedepohl, 1961), 1.5 is to make up for differences in the background data due to lithological discrepancies.

Table 2 Indicators and corresponding degrees of Pollution factor and Degree of Contamination

Pollution factor (C_f^i)	Degree of single-metal pollution	Degree of pollution (Cd)	Degree of multiple-metal pollution
$C_f^i < 1$	Factor of pollution is low	Cd <6	Degree of pollution is low
$1 < C_f^i < 3$	Factor of pollution is reasonable	$6 \leq \text{Cd} < 12$	Degree of pollution is reasonable
$3 < C_f^i < 6$	Factor of pollution is substantial	$12 \leq \text{Cd} < 24$	Degree of pollution is substantial
$C_f^i > 6$	Factor of pollution is very great	Cd > 24	Degree of pollution is very high

Source: Hakanson (1980).

Table 3 Indices and corresponding Geo-accumulation Ranks

Index of geo-accumulation (*I*geo)	Ranks
Igeo < 1	Rank 0: un8contaminated
0 <Igeo≤ 1	Rank 1: uncontaminated - reasonably contaminated
1 <Igeo≤ 2	Rank 2: reasonably contaminated
2 <Igeo≤ 3	Rank 3: reasonably-powerfully contaminated
3 <Igeo ≤ 4	Rank 4: powerfully contaminated
4 <Igeo ≤ 5	Rank 5 powerfully to exceptionally contaminated
Igeo > 5	Rank 6: exceptionally contaminated

Source: Mùller (1979).

2.7.5 The ecological hazard index (ERI)

The ecological hazard index (E.R.), together with the potential ecological hazard index (E_{RI}) were derived from the contamination Factor (C.F.) and toxicity factor (*Tr*).

Contamination factor, $\mathrm{C.F.}_f^i = C_D^i / C_R^i$ (Hakanson, 1980) (12)

where C_D^i is the metal level in the sediment of each location; C_R^i is the background metal level in the sediment of each site; $\mathrm{C.F.}_f^i = C_D^i / C_R^i$ is the pollution of a metal.

Monomial Probable Ecological Hazard Factor, $E_r^i = T_r^i \times \frac{C^i}{C_o^i}$

Here E_r^i is the monomial probable ecological hazard factor of metal i; C^i and C_0^i are the concentration of metal "i" and its reference concentration in sediment respectively; T_r^i is the toxicity factor of the metal "i".

The Ecological Hazard Index, $E_{RI} = \sum_{i=1}^{n} E_r^i$ (13)

Here E_{RI} is the summation of the probable ecological hazard index for the elements in the sediments.

2.7.6 Ecotoxicological metals appraisal by sediment quality guidelines

The levels of metal obtained in sediment in an ecotoxicological context and the obtained results were related to the consensus-based sediment quality guiding principle. The effect range medium quotient (ERMQ) and the probable effect level quotient (PELQ) were used (Soliman et al. 2015).

$$\text{ERM-Q or PEL-Q} = \sum \left[\frac{Ci}{ERMi\ or\ PELi} \right] / n \qquad (14)$$

Here, *Ci* is the level of metal "*i*" in sediments, *ERMi*, *PELi* are the reference values for metal "*i*", and n is the total number of metals in the sediment.

Table 4 Indices and Corresponding Classes of Potential Ecological Hazard

Ecological hazard factor (E_r^i)	Ecological risk level of single-factor pollution	Potential ecological risk index (ERI)	Potential ecological risk of multiple-factor pollution
$E_r^i < 40$	Little hazard	ERI < 150	Little hazard
$40 \leq E_r^i < 80$	Reasonable hazard	150 ≤ ERI <300	Reasonable hazard
$80 \leq E_r^i < 160$	Great hazard	300 ≤ ERI < 600	Great hazard
$160 \leq E_r^i < 320$	Great hazard	ERI ≥ 600	Significantly high risk
$E_r^i \geq 320$	Serious risk		

Source: Hakanson (1980).

Table 5 Indicators of toxic possibility for aquatic organisms

Mean-effect range quotient (*m*-ERM-q)	Harmfulness to aquatic biota	Mean-effect range quotient (*m*-PEL-q)	Harmfulness to aquatic biota
mean-PELQ < 0.1	12% possibility of toxicity	mean-ERMQ < 0.1	10% possibility of toxicity
mean-PELQ = 0.11–0.5	30% possibility of toxicity	mean-ERMQ = 0.11–1.5	25.5% possibility of toxicity
mean-PELQ = 0.5–1.5	46% possibility of toxicity	mean-ERMQ = 1.51–2.3	50% possibility of toxicity
mean-PELQ > 1.5	74% possibility of toxicity	mean-ERMQ > 2.3	76% possibility of toxicity

Source: Long et al. (1995).

2.8 Statistical Analysis

The means of metal contents in water and sediment and the determination of significant differences between different dams were resolved using descriptive statistics and analysis of variance, respectively. The variations in various parameters between the two seasons were shown by T-test.

3 Results

3.1 Metals in Water

The dam's water contained detectable amounts of sodium, calcium, potassium, iron, manganese, zinc, magnesium, copper, lead, and cadmium. In water samples, seasonal levels of metals differ among the dams in dry and wet seasons (Table 6). The sequence of seasonal metal concentration in Egbe dam during the dry season was: Ca > Na > K > Mg > Zn > Mn > Fe > Cu > Pb > Cd, and in the sequence of Ca > Na > K > Mg > Zn > Mn > Fe > Cu > Pb > Cd during the rainy season. Ero dam exhibited seasonal metal sequence: Ca > Na > K > Mg > Zn > Mn > Fe > Cu > Pb > Cd during the dry season and in the pattern: Ca > Na > K > Mg > Zn > Mn > Fe > Cu > Pb > Cd in the rainy season. In Ureje dam, the sequence of the seasonal concentration of metals was: Ca > Na > K > Mg > Fe > Zn > Mn > Cu > Pb, Cd during the dry season and in the sequence: Ca > Na > K > Mg > Zn > Mn, Fe > Cu > Pb, Cd during the wet season. Except for values of Na, K, and Cd for Egbe dam; Na, Mg, Ca, Mn, Fe, and Zn for Ero dam; and Na, Ca, Fe, and Cd for Ureje dam, the mean metal concentrations in the three dams during the dry period were not substantially different at $P < 0.05$ from that of the rainy seasons. The mean values of metals except for K, Mn, and Pb (in Ureje dam) were lower than the allowable boundaries of local and international establishments.

3.2 Health Hazard Assessment

The metal's health hazards in water from the three dams were valued through consumption and skin exposure. The results presented in Tables 7 and 8 evaluate the health hazards of non-carcinogenic metals exposure in adults and children in Egbe, Ero, and Ureje dams, Ekiti State. The study revealed that the risk quotient (HQ) values for ingestion and skin contact with metals were < 1 in the three dams for both grown-ups and children, except the HQ value for consumption exposure to Mn for children. Consumption HQ values were more outstanding than skin HQ values in children and grown-ups in all three dams. The computed risk index (HI) for consumption of metals for adults in the three dams was 0.65, 0.52, and 0.79 for Egbe, Ero and Ureje dams, respectively (Table 7). In contrast, the calculated values of HI for skin contact were 0.048, 0.044, and 0.049 for Egbe, Ero, and Ureje dams, respectively. The total HI (ingestion and dermal) was 0.70, 0.57, and 0.84 for Egbe, Ero, and Ureje dams, respectively.

The HI values for the consumption of metals for children in the dams were shown in Table 8. It was reported as 2.48 (Egbe dam), 2.00 (Ero dam), and 3.01 (Ureje dam), while the computed values of HI for dermal exposure were 8.15 × 10^{-2} (Egbe dam), 7.60 × 10^{-2} (Ero dam) and 8.49 × 10^{-2} (Ureje dam). Further, the total HI (ingestion and dermal) for children was 2.56 (Egbe dam), 2.08 (Ero dam), and 3.09 (Ureje dam), thus, indicating non-carcinogenic risk to children's health.

Table 6 Mean seasonal metals levels in the water of Egbe, Ero, and Ureje dams and their allowable limit

	EGBE DAM		ERO DAM		UREJE DAM						
Metal (mg/L)	Arid period	Wet period	Arid period	Wet period	Arid period	Wet period	CANADA 2006	WHO 1993, 2006	NSDWQ 2007	NESREA 2009	USEPA 2018
Na	29.14 ± 1.41^{a}	24.36 ± 1.05^{b}	28.63 ± 1.09^{a}	37.47 ± 2.98^{b}	16.75 ± 0.73^{a}	26.64 ± 1.56^{b}	200	200	200	200	
Mg	5.12 ± 0.12^{a}	4.97 ± 0.24^{a}	3.65 ± 0.10^{a}	5.51 ± 0.39^{b}	4.92 ± 0.31^{a}	5.16 ± 0.08^{a}		30	20		
K	13.95 ± 0.71^{a}	18.07 ± 1.05^{b}	21.81 ± 1.66^{a}	27.84 ± 3.28^{a}	13.45 ± 1.11^{a}	22.15 ± 3.30^{a}	10	10		10	
Ca	44.43 ± 2.23^{a}	50.69 ± 3.17^{a}	41.67 ± 2.23^{a}	51.94 ± 2.66^{b}	26.93 ± 2.54^{a}	36.77 ± 2.32^{b}		75			
Mn	0.24 ± 0.02^{a}	0.28 ± 0.01^{b}	0.27 ± 0.01^{a}	0.28 ± 0.01^{a}	0.28 ± 0.02^{a}	0.27 ± 0.02^{a}	0.05	0.05	0.2	0.05	0.05
Cu	0.19 ± 0.02^{a}	0.22 ± 0.03^{a}	0.07 ± 0.01^{a}	0.13 ± 0.02^{b}	0.27 ± 0.01^{a}	0.20 ± 0.01^{b}	0.3	0.3	0.3	0.3	0.3
Fe	0.18 ± 0.01^{a}	0.19 ± 0.02^{a}	0.06 ± 0.01^{a}	.055 ± 0.00^{a}	0.15 ± 0.01^{a}	0.16 ± 0.02^{a}	1.0	2.0	1.0	1.0	1.0
Zn	0.33 ± 0.03^{a}	0.28 ± 0.03^{a}	0.18 ± 0.03^{a}	0.29 ± 0.02^{b}	0.25 ± 0.02^{a}	0.28 ± 0.01^{a}			3.0		
Cd	0.001 ± 0.00^{a}	0.00 ± 0.00^{b}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.001 ± 0.00^{a}	0.00 ± 0.00^{b}	0.005	0.003	0.003	0.003	
Pb	0.005 ± 0.00^{a}	0.003 ± 0.00^{a}	0.002 ± 0.00^{a}	0.006 ± 0.00^{a}	0.001 ± 0.00^{a}	0.02 ± 0.01^{a}	0.01	0.01	0.01	0.01	

*Metal concentrations in dry and wet periods with similar superscription are not significantly different.

USEPA – United States Environmental Protection Agency; WHO, World Health Organization; NSDWQ - Drinking water quality standard for Niger; NESREA - National Environmental Standards and Regulations Enforcement Agency

Table 7 Risk Quotient and cancer hazard of metals for adults in Egbe, Ero, and Ureje dams' water, Ekiti State, Southwest Nigeria

Metal	Mn	Fe	Cu	Zn	Cd	Pb	HI
RfDi (mg/kg/d)	2.40×10^{-2}	7.00×10^{-1}	4.00×10^{-2}	3.00×10^{-1}	5.00×10^{-4}	1.40×10^{-3}	
RfDd (mg/kg/d)	9.60×10^{-4}	1.40×10^{-1}	8.00×10^{-3}	6.00×10^{-2}	2.50×10^{-5}	4.20×10^{-4}	
Egbe dam							
ADDing	8.17×10^{-3}	6.44×10^{-3}	5.81×10^{-3}	9.59×10^{-3}	1.57×10^{-5}	1.26×10^{-4}	
ADDderm	3.88×10^{-5}	3.06×10^{-5}	2.76×10^{-5}	2.73×10^{-5}	7.46×10^{-8}	5.97×10^{-8}	
HQing	3.40×10^{-1}	9.20×10^{-3}	1.45×10^{-1}	3.20×10^{-2}	3.14×10^{-2}	8.98×10^{-2}	6.47×10^{-1}
HQderm	4.04×10^{-2}	2.18×10^{-4}	3.45×10^{-3}	4.55×10^{-5}	2.98×10^{-3}	1.42×10^{-4}	4.72×10^{-2}
Ero dam							
ADDing	8.64×10^{-3}	3.14×10^{-3}	1.81×10^{-3}	7.39×10^{-3}	0.00	1.26×10^{-4}	
ADDderm	4.10×10^{-5}	1.49×10^{-5}	8.58×10^{-6}	2.10×10^{-5}	0.00	5.97×10^{-8}	
HQing	3.60×10^{-1}	4.49×10^{-3}	4.52×10^{-2}	2.46×10^{-2}	0.00	8.98×10^{-2}	5.24×10^{-1}
HQderm	4.27×10^{-2}	1.07×10^{-4}	1.07×10^{-3}	3.51×10^{-4}	0.00	1.42×10^{-4}	4.44×10^{-2}
Ureje dam							
ADDing	8.64×10^{-3}	7.39×10^{-3}	4.87×10^{-3}	8.33×10^{-3}	1.57×10^{-5}	3.30×10^{-4}	
ADDderm	4.10×10^{-5}	3.51×10^{-5}	2.31×10^{-5}	2.37×10^{-5}	7.46×10^{-8}	1.57×10^{-7}	
HQing	3.60×10^{-1}	1.06×10^{-2}	1.22×10^{-1}	2.78×10^{-2}	3.14×10^{-2}	2.36×10^{-1}	7.88×10^{-1}
HQderm	4.27×10^{-2}	2.50×10^{-4}	2.89×10^{-3}	3.95×10^{-4}	2.98×10^{-3}	3.73×10^{-4}	4.96×10^{-2}

Here: ADDing is the mean diurnal dose through ingestion; ADDderm is the mean diurnal dose through skin contact; HQing is the risk quotient for consumption; HQderm is the risk quotient for skin exposure; CDI is the chronic daily intake; *RfDing* is the reference dose for consumption; *RfDderm*, is the reference dose due to skin exposure; CRing is the carcinogenic risk due to consumption; CRderm is the carcinogenic hazard due to skin exposure; HI, Risk index.

Table 8 Hazard Quotient and cancer-causing hazard of metals for children in surface water from Egbe, Ero, and Ureje dams, Ekiti State, southwest Nigeria

Metal	Mn	Fe	Cu	Zn	Cd	Pb	HI
RfDi (mg/kg/d)	2.40×10^{-2}	7.00×10^{-1}	4.00×10^{-2}	3.00×10^{-1}	5.00×10^{-4}	1.40×10^{-3}	
RfDd (mg/kg/d)	9.60×10^{-4}	1.40×10^{-1}	8.00×10^{-3}	6.00×10^{-2}	2.50×10^{-5}	4.20×10^{-4}	
Egbe dam							
ADDing	3.12×10^{-2}	2.46×10^{-2}	2.22×10^{-2}	3.66×10^{-2}	6.00×10^{-5}	4.80×10^{-5}	
ADDderm	6.64×10^{-5}	5.23×10^{-5}	4.72×10^{-5}	4.67×10^{-5}	1.28×10^{-7}	1.02×10^{-7}	
HQing	1.30	3.51×10^{-2}	5.55×10^{-1}	1.22×10^{-1}	1.20×10^{-1}	3.43×10^{-1}	2.48
HQderm	6.91×10^{-2}	3.74×10^{-4}	5.90×10^{-3}	7.78×10^{-4}	5.10×10^{-3}	2.43×10^{-4}	8.15×10^{-2}
Ero dam							
ADDing	3.30×10^{-2}	1.20×10^{-2}	6.90×10^{-3}	2.82×10^{-2}	0.00	4.80×10^{-5}	
ADDderm	7.00×10^{-5}	2.55×10^{-5}	1.47×10^{-5}	3.60×10^{-5}	0.00	1.02×10^{-7}	
HQing	1.38	1.71×10^{-2}	1.73×10^{-1}	9.40×10^{-2}	0.00	3.43×10^{-1}	2.00
HQderm	7.31×10^{-2}	1.82×10^{-4}	1.83×10^{-3}	6.00×10^{-4}	0.00	2.43×10^{-4}	7.60×10^{-2}
Ureje dam							
ADDing	3.30×10^{-2}	2.82×10^{-2}	1.86×10^{-2}	3.18×10^{-2}	6.00×10^{-5}	1.26×10^{-3}	
ADDderm	7.00×10^{-5}	6.00×10^{-5}	3.96×10^{-5}	4.06×10^{-5}	1.28×10^{-7}	2.68×10^{-7}	
HQing	1.38	4.03×10^{-2}	4.65×10^{-1}	1.06×10^{-1}	1.20×10^{-1}	9.00×10^{-1}	3.01
HQderm	7.31×10^{-2}	4.28×10^{-4}	4.94×10^{-3}	6.76×10^{-4}	5.10×10^{-3}	6.38×10^{-4}	8.49×10^{-2}

Here: ADDing, mean diurnal dose through consumption; ADDderm, mean diurnal dose through skin exposure; HQing, hazard quotient for consumption; HQderm, hazard quotient for skin exposure; CDI, chronic daily intake; *RfDing*, reference dose for ingestion; *RfDderm*, reference dose as a result of skin exposure; CRing, cancer-causing hazard due to consumption; CRderm, carcinogenic risk due to skin contact.

Table 9 Incremental life tumor hazards in children and grown-ups via consumption and skin contact to the water of the dams

		Egbe dam		Ero dam		Ureje dam	
Element	Medium	Children	Adult	Children	Adult	Children	Adult
Cd	Ingestion	3.24×10^{-5}	9.89×10^{-5}	0.00	0.00	3.24×10^{-5}	9.89×10^{-5}
	Dermal	6.87×10^{-5}	4.07×10^{-7}	0.00	0.00	3.49×10^{-7}	2.81×10^{-6}
Pb	Ingestion	3.49×10^{-7}	1.07×10^{-6}	3.49×10^{-7}	1.07×10^{-6}	6.87×10^{-8}	4.70×10^{-7}
	Dermal	7.44×10^{-11}	5.07×10^{-10}	7.44×10^{-11}	5.07×10^{-10}	1.95×10^{-10}	1.33×10^{-10}
∑ILCR		3.24×10^{-5}	1.04×10^{-4}	3.49×10^{-7}	1.07×10^{-6}	3.28×10^{-5}	1.02×10^{-4}

ILCR- Incremental lifetime cancer risk

Table 9 summarizes the cancer-causing health hazard evaluation of Cd and Pb for adults and children in Egbe, Ero, and Ureje dams, Ekiti State. In Egbe dam, lifespan tumor hazard computed through consumption of Cd and Pb was 9.89×10^{-5} and 1.07×10^{-6} for adults and 3.24×10^{-5} and 3.49×10^{-7} for the children, respectively. Cancer hazards computed via skin contact of Cd and Pb were 4.70×10^{-7} and 5.07×10^{-10} for adults and 6.87×10^{-5} and 7.44×10^{-11} for the children respectively. In Ero dam, lifespan tumor hazard computed through consumption of Cd and Pb was nil and 1.07×10^{-6} for adults (Table 9), while it was nil and 3.49×10^{-7} for the children, respectively. Cancer risk calculated through dermal contact of Cd and Pb was nil and 5.07×10^{-10} for adults and nil and 7.44×10^{-11} for children, respectively. Further, in Ureje dam, lifespan tumor hazard computed through consumption of Cd and Pb were 9.89×10^{-5} and 2.81×10^{-6} for adults and 3.32×10^{-5} and 3.49×10^{-7} for the children, respectively. Cancer risk calculated through dermal contact of Cd and Pb were 4.70×10^{-7} and 1.33×10^{-10} for adults and 6.87×10^{-8} and 1.95×10^{-10} for the children, respectively. In Egbe dam, the aggregate tumor hazard of the investigated metals was 1.01×10^{-4} for the adult and 3.24×10^{-5} for the children; in Ero dam, the aggregate tumor hazard was 1.07×10^{-6} for the adult and 3.49×10^{-7} for the children, and in Ureje dam, the aggregate tumor hazard was 1.02×10^{-4} for the adult and 3.28×10^{-5} for the children. The results of the study showed more significant cancer hazards for adults in comparison to children. The collective cancer hazard value in Egbe, Ero, and Ureje dams was slightly above the suitable tumor hazard range of 1.00×10^{-6} to 1.00×10^{-4}.

3.3 Metals in Sediment

Seasonal levels of different metals in the dams' sediments during both seasons are given in Table 10. The average seasonal concentration of Na, Mg, K, Ca, Mn, Fe, Cu, Zn, Cd, and Pb in the sediments during the dry season in Egbe dam was 6.00 ± 0.73, 1.98 ± 0.10, 5.51 ± 0.82, 11.02 ± 1.61, 0.50 ± 0.07, 74.32 ± 8.78, 0.44 ± 0.02, 0.31 ± 0.02, 0.05 ± 0.01 and 0.21 ± 0.02 ppm respectively. The sequence of the mean metal concentrations in the dry season in Egbe dam was Fe > Ca > Na > K > Mg > Mn > Cu > Zn > Pb > Cd. Further, the average level of Na, Mg, K, Ca, Mn, Fe, Cu, Zn, Cd, and Pb during the dry season in Ero dam was 10.31 ± 0.98, 1.32 ± 0.24, 10.56 ± 0.77, 14.31 ± 1.23, 0.39 ± 0.07, 61.17 ± 8.05, 0.19 ± 0.02, 0.48 ± 0.08, 0.04 ± 0.01, 0.13 ± 0.02 ppm respectively and the sequence of the mean metal concentrations in the dry season in Ero dam was Fe > Ca > K > Na > Mg > Zn > Mn > Cu > Pb > Cd. In the case of Ureje dam, the average level of Na, Mg, K, Ca, Mn, Fe, Cu, Zn, Cd, and Pb during the dry season were 5.59 ± 1.44, 2.12 ± 0.36, 7.49 ± 2.71, 11.93 ± 3.39, 0.45 ± 0.05, 92.51 ± 18.62, 0.31 ± 0.02, 0.43 ± 0.05, 0.05 ± 0.03 and 0.14 ± 0.03 ppm respectively. The trends of mean seasonal metals concentration in the dry season in Ureje dam was Fe > Ca > K > Na > Mg > Mn > Zn > Cu > Pb > Cd.

The trends of the rainy season are similar to the dry season. During the rainy season in Egbe dam, the mean seasonal levels of Na, Mg, K, Ca, Mn, Fe, Cu, Zn, Cd, and Pb in sediments were 7.29 ± 0.56, 2.24 ± 0.14, 9.30 ± 1.25, 10.68 ± 0.68, 0.62 ± 0.08, 88.30 ± 6.89, 0.37 ± 0.03, 0.38 ± 0.03, 0.06 ± 0.01, 0.18 ± 0.02 ppm respectively. The sequence of mean metal concentration in the rainy season in Egbe dam was Fe > Ca > K > Na > Mg > Mn > Zn > Cu > Pb > Cd. Further, in the case of Ero dam, the average levels of Na, Mg, K, Ca, Mn, Fe, Cu, Zn, Cd, and Pb in Ero dam were 9.99 ± 0.46, 1.45 ± 0.16, 13.31 ± 0.93, 18.29 ± 1.84, 0.39 ± 0.05, 69.46 ± 10.23, 0.19 ± 0.01, 0.54 ±0.05, 0.07 ± 0.01, 0.28 ± 0.04 ppm respectively. The trend of mean metal concentration in the rainy season in Ero dam was Fe > Ca > K > Na > Mg > Zn > Mn > Cu > Pb > Cd. The average concentration of Na, Mg, K, Ca, Mn, Fe, Cu, Zn, Cd, and Pb in Ureje dam during the rainy period was 7.72 ± 1.29, 3.30 ± 0.46, 12.49 ±2.93, 12.85 ± 1.80, 0.80 ± 0.12, 134.31 ± 23.73, 0.31 ± 0.01, 0.44 ± 0.03, 0.12 ± 0.03, 0.19 ± 0.02 ppm respectively. The trends of mean seasonal metal concentration in the rainy season in Ureje dam were Fe > Ca > K > Na > Mg > Mn> Zn > Cu > Pb > Cd.

Sediment metal levels of the dams varied widely and exhibited fluctuations between the different dams. Metals showed a similar pattern of concentrations in the dams, with the highest values recorded in Fe and Na and the lowest in Cd and Pb. Studied metals had higher levels in the wet period than the dry period except for Ca, Cu, and Pb in the Egbe dam and Na in the Ero dam.

Table 10 Seasonal metal concentrations in sediment from Egbe, Ero, and Ureje dams, Ekiti State, southwest Nigeria

	Egbe Dam		Ero Dam		Ureje Dam	
Metal (ppm)	Arid period	Wet period	Arid period	Wet period	Arid period	Wet period
Na	6.00 ± 0.73^{a}	7.29 ± 0.56	10.31 ± 0.98^{b}	9.99 ± 0.46	5.59 ± 1.44^{a}	7.72 ± 1.29
Mg	1.98 ± 0.10^{a}	2.24 ± 0.14^{a}	1.32 ± 0.24^{bc}	1.45 ± 0.16^{be}	2.12 ± 0.36^{a}	3.30 ± 0.46^{c}
K	$5.51 \pm {}^{*}0.82$	$9.30 \pm {}^{**}1.25$	$10.56 \pm {}^{**}0.77$	$13.31 \pm {}^{**}0.93$	7.49 ± 2.71	12.49 ± 2.93
Ca	11.02 ± 1.61	10.68 ± 0.68^{a}	14.31 ± 1.23	18.29 ± 1.84^{b}	11.93 ± 3.39	12.85 ± 1.80^{a}
Mn	0.50 ± 0.07	0.62 ± 0.08^{ab}	0.39 ± 0.07	0.39 ± 0.05^{a}	$0.45 \pm {}^{*}0.05$	$0.80 \pm {}^{**}0.12^{b}$
Fe	74.32 ± 8.78	88.30 ± 6.89^{a}	61.17 ± 8.05	69.46 ± 10.23^{a}	92.51 ± 18.62	134.31 ± 23.73^{b}
Cu	0.44 ± 0.02^{a}	0.37 ± 0.03^{a}	0.19 ± 0.02^{be}	0.19 ± 0.01^{b}	0.31 ± 0.02^{c}	0.31 ± 0.01^{ac}
Zn	$0.31 \pm {}^{*}0.02$	$0.38 \pm {}^{**}0.03^{a}$	0.48 ± 0.08	0.54 ± 0.05^{b}	0.43 ± 0.05	0.44 ± 0.03^{ab}
Cd	0.05 ± 0.01	0.06 ± 0.01^{a}	$0.04 \pm {}^{*}0.01$	$0.07 \pm {}^{**}0.01^{ab}$	0.05 ± 0.03	0.12 ± 0.03^{b}
Pb	0.21 ± 0.02^{a}	0.18 ± 0.02^{a}	$0.13 \pm {}^{*}0.02^{b}$	$0.28 \pm {}^{**}0.04^{b}$	0.14 ± 0.03^{b}	0.19 ± 0.02^{a}

Mean metal concentration during the dry and rainy seasons with different superscripts (*) show a significant difference at $P < 0.05$; Sites with similar alphabet superscripts in the same season show no significant difference at $P < 0.05$

Table 11 Contamination load index (PLI), degree of pollution, and contamination factor, of metals in the dams' sediments during dry and wet periods

	Egbe Dam		Ero Dam		Ureje Dam		
	Contamination Factor		Contamination Factor		Contamination Factor		
Metal (ppm)	Arid period	Wet period	Arid period	Wet period	Arid period	Wet period	Aver. Shales conc.
Na	6.25×10^{-4}	7.59×10^{-4}	$1.07 x 10^{-3}$	1.04×10^{-4}	5.82×10^{-4}	8.04×10^{-4}	9,600
Mg	7.30×10^{-4}	1.49×10^{-4}	8.79×10^{-5}	9.63×10^{-4}	1.41×10^{-4}	2.20×10^{-4}	15,000
K	2.07×10^{-4}	3.49×10^{-4}	3.97×10^{-4}	5.00×10^{-4}	2.81×10^{-4}	4.70×10^{-4}	26,600
Ca	4.99×10^{-4}	4.83×10^{-4}	6.48×10^{-4}	8.28×10^{-4}	5.40×10^{-4}	5.82×10^{-4}	22,100
Mn	5.90×10^{-4}	7.24×10^{-4}	4.54×10^{-4}	4.57×10^{-4}	5.32×10^{-4}	9.45×10^{-4}	850
Fe	1.57×10^{-3}	1.87×10^{-3}	1.30×10^{-3}	1.47×10^{-3}	1.96×10^{-3}	2.85×10^{-3}	47,200
Cu	9.70×10^{-3}	8.13×10^{-3}	4.14×10^{-3}	4.11×10^{-3}	6.88×10^{-3}	6.96×10^{-3}	45
Zn	$3.22 x 10^{-3}$	4.03×10^{-3}	5.03×10^{-3}	5.64×10^{-3}	4.55×10^{-3}	4.65×10^{-3}	95
Cd	1.70×10^{-1}	2.01×10^{-1}	1.20×10^{-1}	2.36×10^{-1}	1.81×10^{-1}	4.02×10^{-1}	0.3
Pb	1.07×10^{-2}	9.17×10^{-3}	6.54×10^{-3}	1.42×10^{-2}	6.78×10^{-3}	9.29×10^{-3}	20
Deg. Cont.	1.98×10^{-1}	2.27×10^{-1}	1.39×10^{-1}	2.65×10^{-1}	2.03×10^{-1}	4.28×10^{-1}	
PLI	1.84×10^{-3}	2.08×10^{-3}	1.72×10^{-3}	2.16×10^{-3}	1.86×10^{-3}	2.63×10^{-3}	

Here Aver. Shales conc. - Average shales level, PLI – Contamination load index; deg. Cont – Degree of pollution.

3.4 Sediment Pollution Evaluation of the three Dams

3.4.1 Contamination factor, Pollution Degree, and Indicator of Pollution Load

The metal contamination factors (C.F.) of Na, Mg, K, Ca, Mn, Fe, Cu, Zn, Cd, and Pb indicated low C.F. < 1 in all the dams in the dry and rainy periods. Contamination degree (mCd) was highest in the Ureje dam and lowest in the Ero dam in the arid period. During the rainy season, the Ureje dam had the highest level of contamination, and the Egbe dam had the lowest (Table 11). The contamination load index revealed that sediment pollution is highest in the Ureje dam during the rainy season.

3.4.2 Index of geo-accumulation (Igeo)

Igeo values did not change with the seasons. The Igeo values for Egbe, Ero, and Ureje area sediments vary from metal to metal and month to month. In the three dams, all the metals were in Igeo grade less than zero, thus signifying that the dams' sediments did not experience contagion by these metals during dry and rainy seasons.

3.4.3 Probable Ecological Hazard Index

The ecological hazard factor (E_i^r) sequence of the sediments' metals of the Egbe, Ero, and Ureje dams in dry and rainy periods was Cd > Pb > Zn > Cu >Mn. The ecological risk factor of Cd, Cu, Pb, Zn, and Mn in the three dams was lower than 40. The probable ecological hazard index values of the metals are < 150 in the dams during the dry and rainy periods, thus, posing a low environmental risk to the three dams.

3.4.4 Ecological Risk Assessment according to sediment quality guidelines

According to Long et al.(1995), different mean ERMQ values: < 0.1, 0.11–0.5, 0.5–1.5, and > 1.5 are related to 12 %, 30 %, 46 %, and 74 % possibility of harmfulness correspondingly. Likewise, different values of mean PELQ: < 0.1, 0.11–1.5, 1.51–2.3, and > 2.3 correspond to 10 %, 25.5, 50 %, and 76 % also show the possibility of harmfulness, respectively. The computed values of mean-ERMQ of Cu, Zn, Cd, and Pb in the dry season were 2.20×10^{-3} (Egbe dam), 1.50×10^{-3} (Ero dam), and 2.10×10^{-3} (Ureje dam) and they follow the orders of Egbe dam > Ureje dam > Ero dam. The computed values of mean-ERMQ of Cu, Zn, Cd, and Pb) in the rainy season were 2.40×10^{-3} (Egbe dam), 2.70×10^{-3} (Ero dam), and 3.90×10^{-3} (Ureje dam) and they follow the orders of Ureje dam > Ero dam > Egbe dam. Likewise, the values of mean-PELQ obtained were 5.00×10^{-3} (Egbe dam); 3.50×10^{-3} (Ero dam), and 5.00×10^{-3} (Ureje dam) during the dry season with the inclination of Egbe dam, Ureje dam > Ero dam. While in the case of the rainy season, the mean-PELQ values of 5.50 × 10-3 (Egbe dam), 6.50 × 10-3 (Ero dam), and 9.80 × 10-3 (Ureje dam) were obtained with the inclination of Ureje dam,> Ero dam > Egbe dam.

4 Discussion

Except for K and Mn in all three water bodies and Pb in Ureje dam during the rainy period, the mean metal levels in the water of the three dams during the dry and wet periods did not exceed the WHO recommendation and allowed limits for potable water. However, the K, Mn, and Pb levels in the dams were above the WHO-endorsed limit. Hence, the water from the three dams might be unsafe to drink, and the fish might not be safe to eat without proper treatment. Further, seasonal variations were reported in the metal levels in the three dams. Except for Na, Mg, Zn, Cd, and Pb in Egbe dam; Cu in Ero dam; and Mn, Fe, and Cd in Ureje dam, the rainy season showed slightly more significant amounts of heavy metals than the dry season. Therefore, draining water after precipitation is likely a primary means of carrying metals into the dams. A similar observation was made by Kiema et al. (2017) on the impacts of human activities and periods on the dissemination of metal in the sedimentary coastline of Lake Victoria, Kisumu City, Kenya.

Further, Na quantities recorded during both seasons were within the usual range for freshwater (Chapman and Kimstach 1992), and on aesthetic concern, 200 mg of sodium/L was established by WHO's (2006) water guideline. Naturally, K occurs in low concentrations in waterways because potassium-rich rocks are highly resistant to weathering, and concentrations of K in freshwater are usually below 10 mg/L (Chapman and Kimstach 1992). However, the higher values were established in the three dams compared to the WHO recommended values. It is most likely due to the use of potassium fertilizers for agriculture, which enter freshwaters via runoff from agricultural land. Frequently, magnesium accompanies calcium in various fluids, but its content is usually lesser than calcium (Qureshimatva et al. 2015), as seen in this study. The Mg concentrations in this study are within the range of natural magnesium concentrations in freshwaters, and it ranging from 1 to below 100 mg/L (Chapman and Kimstach 1992).

Manganese in the dams was higher than the recommended level. Bolaji et al. (2017) made a similar observation for the Ureje dam. Though the concentrations of Mn in the dams are higher than the recommended standard boundary of 0.2 mg/L (NSDWQ 2007), the presence of the manganese in water obtained from a faucet is obvious when its concentration is higher than 0.05 mg/L by tinting and adding taste, aroma to tap water (SCDPH 2021). But, manganese well-being consequences pose no apprehension pending when concentrations are almost 10 times greater. Thus, the present level of manganese in the dams affects their aesthetic value. The presence of cadmium and zinc and their relative concentrations were reported by Svobodová et al. (1993) that cadmium in surface waters is usually found together with zinc but at much lower concentrations. The dams in this investigation were subjected to similar observations.

In the Ureje dam catchment area, the water carried by runoffs into the dam was affected by several practical socio-economic and waste dumping activities such as car garages, automobile workshops, schools, construction works, car washing, domestic wastewater, and garbage around the dam and these activities are related to the observed higher value of Pb than the WHO allowable boundary (0.01 mg/L) during the rainy season. Leachates from lead-acid batteries, which are carelessly abandoned by battery chargers and disposed of at the garbage dumps in this urban community, are possible sources of Pb.

In the Egbe, Ero, and Ureje dams, the values of consumption HQ were more significant than the values of skin HQ in children and grown-ups. A comparable report was given by Liang et al. (2011) in their work on the water of Taihu Lake, China. In adults and children, the values of hazard quotient (HQ) for metals through consumption and skin contact were less than one in Egbe, Ero, and Ureje dams. It is signifying the contamination level in the surface water of the Egbe, Ero, and Ureje dams had little antagonistic health consequences. However, HQ values for Mn in consumption exposure for children that were greater than one in the dams had adverse health effects. The average HI is less than 1 for all three dams that's why for skin exposure and consumption of dams water does not show aggregate probable antagonistic health hazards to adult. As a result, the dams pose a non-carcinogenic risk to adults' health that can be overlooked. There is an aggregate risk of adverse health effects on children owing to uninterrupted ingesting contact. Still, there is no cumulative risk of adverse health effects through skin contact with water users among children across the three dams. For Egbe, Ero, and Ureje dams, the total HI (ingestion and dermal) for children was 2.56, 2.08, and 3.09, indicating a non-carcinogenic risk to children's health.

In adults and children, the tumor hazard associated with Cd and Pb exposure by oral intake was higher than the cutaneous exposure. Obiri et al. (2010) reported a similar observation in Ghanaian surface water, and they linked it to differences in genetic, immunologic, dietary, hormonal status, and other factors that influence the form and manner in which harmful consequences of a given chemical appear. Joseph et al. (2022) reported similar results from cancer risk associated with metals in water from a borehole in a community in Akwa Ibom State. The results of the cumulative cancer risk in Egbe, Ero, and Ureje dams showed greater tumor risk in grown-ups than in children. Cumulative cancer risk values in Egbe, Ero, and Ureje dams were slightly higher than the acceptable tumor hazard range 1.00E-06 to 1.00E-04. According to Li et al. (2017), Egbe and Ureje dams are in medium risk grade, while the Ero dam is in extremely low-risk rate. However, every carcinogenic substance, such as Pb and Cd, can develop cancer at any dose higher than nil. That's why Pb and Cd have been linked to a lifetime carcinogenic risk (IARC 2011; Cao et al. 2014).

Higher metal levels in dams' sediments than metal concentrations in dams' water reflected that sediments operate as tanks or basins to metals in these water environments (Gupta et al. 2009). It also affects water quality and bioaccumulation of metals along the trophic levels with lasting health implications on human beings and the health of aquatic ecosystems (Fernandes et al. 2007). Metal concentrations obtained from the sediments varied and exhibited fluctuations among the dams. Except for K and Zn in Egbe dam, K, Cd, and Pb in Ero dam, and Mn in Ureje dam, a significant difference did not occur in the mean value of metals in sediment between dry and wet seasons. However, a substantial number of the metals were higher in rainy than dry seasons. Wardhani et al. (2021) reported higher Cd concentrations in the sediment from Saguling reservoir, West Java Province, in the rainy season compared to the dry season. While Gunes (2021) reported greater metal levels in Bartin River in the rainy period when related to a dry period, this might be attributed to natural runoff from various sources during the rainy season that entered the aquatic systems. Asaolu and Olaofe (2005) made similar observations on the coastal areas of Ondo state, and Adefemi (2013) conducted previous investigations on the major dams in Ekiti state, Nigeria. These results are in contrast to Aladesanmi et al. (2016)'s findings on streams and adjacent fish ponds in Osun state, which found that higher metal readings during the dry season were due to a slow water circulation that allows particles to settle. The peak values of Fe out of all elements in the dams' sediments in both seasons established the widespread Fe occurrence in Nigerians' soil reported by various workers (Adefemi et al. 2007; Adeyeye and Ayoola 2013; Aladesanmi et al. 2016; Yahaya et al. 2021).

Employment of various sediment pollution indices indicated that the sediments of Egbe, Ero, and Ureje dams were less polluted by lethal metals during the dry and rainy periods. However, due to accumulative anthropogenic activities in the dams and their surroundings, the dams' sediments may still be subject to future deterioration. Furthermore, the presence of metals, particularly cadmium and lead, which are carcinogenic (IARC 2011; Cao et al. 2014; Kim et al. 2020) points to the need for proper management strategies and continuous dam monitoring for optimal fish production and the protection of the health of the aquatic biota and that of their consumers.

Conclusion

The presence of metals in the dams in quantities higher than recommended levels and the observed carcinogenic risks especially in Ureje dam necessitates appropriate action to reduce current pollution state and guard against further deterioration due to accumulative anthropogenic activities in the dams, as well as their surroundings.

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