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Health Risk Assessment Of Potentially Toxic Element Concentrations In Fish And Vegetables Obtained From Six Selected Dams In Osun State, Nigeria

Ishola A. Dimeji[1], Babatola B. Keji[2], Folorunsho A. Idowu[3]

[1]Department of Science Laboratory Technology
(Chemistry Unit)
Osun State Polytechnic, Iree,
Osun State,
Nigeria.

[2]Department of Science Laboratory Technology
(Physics Unit)
Osun State Polytechnic, Iree,
Osun State,
Nigeria.

[3]Department of Statistics
Osun State Polytechnic, Iree,
Osun State,
Nigeria.

Email: Ishow538@gmail.com

Abstract
This study aimed to assess the levels of certain heavy metals in tilapia fish (Oreochromis niloticus), as well as vegetables, and to evaluate the potential health risks associated with the presence of toxic elements from Dec. 2019 to June 2023. A total of 60 tilapia fish, 12 okra (Abelmoschus esculentus) and 12 bitter leaf (Vernonia amygdalina) from six major dams in Osun State were prepared for analysis using wet digestion with aqua-regia. The concentrations of heavy metals were measured using an Atomic Absorption Spectrophotometer (Shimadzu AA-630). The health risk associated with fish consumption was estimated using various parameters. Statistical analysis was conducted using the Statistical Package for Social Sciences (SPSS) version 16.0. The concentrations of micro elements followed the order of Fe > Zn > Cu > Mn in decreasing concentrations. These concentrations exceeded the permissible limits set by the World Health Organization (WHO) for Ni, Cd, Pb, and Cr, which are 0.6, 0.3, 0.3, and 0.7 mg L^{-1}, respectively. The results obtained for okra and bitter leaf were within the limits established by the World Health Organization (WHO). Therefore, the presence of these metals indicates the need for close environmental monitoring of the six selected dams.

Keywords: Heavy metals, toxicity, dam, plants, fish.

INTRODUCTION
Potentially toxic element (PTE) have the ability to infiltrate the aquatic ecosystem through multiple channels, including mining, agriculture, industry, and urban runoff (Belle et al., 2023). These factors can impact the water, sediment, and organisms in dams and reservoirs, which are commonly utilized for irrigation, drinking water provision, and aquaculture. The

**Author for Correspondence*

accumulation of Potentially toxic element (PTE) in fish and vegetables can provide health hazards to individuals who consume them, as certain PTE have the potential to induce cancer, neurological problems, kidney impairment, and other illnesses (Cabral et al., 2020). Hence, it is crucial to oversee the concentrations of PTE in reservoirs and their derivatives, and to evaluate the possible health hazards linked to their ingestion.

Nevertheless, there is a dearth of extensive and uniform data regarding the quantities of Potentially toxic element (PTE) in fish and vegetables sourced from dams across various areas and countries, particularly in poorer nations where environmental legislation and monitoring are sometimes insufficient. Furthermore, it is necessary to take into account the impacts of additional factors, including as the production of hydropower, the phenomenon of global warming, and the migration of fish, on the distribution and availability of potentially toxic elements (PTEs) in dams and their associated products. These factors have the ability to modify the physical, chemical, and biological attributes of the aquatic environment, thereby impacting the exposure and absorption of potentially toxic elements (PTE) by fish and vegetables. This information is supported by sources such as Saba et al., (2023) and Kawaza et al., (2016). Hence, the objective of this study is to address the existing knowledge gap by conducting a thorough and comparative examination of the concentrations of potentially toxic elements (PTEs) in fish and vegetables sourced from six specific dams in Osun State, Nigeria. Additionally, this study aims to assess the health risks associated with consuming these food items, while considering the impact of hydropower generation, global warming, and fish migration on the distribution and availability of PTEs.

RESEARCH METHODOLOGY

Fish Sample Collection

A survey was conducted in the region to gather information about the various fish species present in the six dams, which exhibited distinct characteristics. Among the fish species observed, tilapia (Oreochromis niloticus) was the most frequently encountered. For each dam, a total of ten fish samples were collected and utilized for analysis. The sampled fish were obtained from local fishermen and were carefully transported to the laboratory. To maintain their freshness, the fish samples were placed in a thermos flask containing ice chips during transportation. Upon arrival at the laboratory, the materials were stored at a temperature of -30°C in an electric refrigerator to facilitate subsequent analysis (Bukola et al., 2015).

Preparations of Fish Samples

The fish samples underwent a process in which they were cleansed using distilled water and then subjected to drying in a 105 °C oven for 24 hours until a stable weight was attained. After the drying phase, the bones and scales of the fish were eliminated, and the remaining components, including the muscle, head, tail, gills, and eyes, were baked in the oven. Subsequently, using a mortar and pestle, the remaining portions of the fish sample were ground into a fine texture. The ground fish sample was then carefully transferred and stored in a dry crucible, appropriately labeled, until it was ready for digestion or further analysis (Jenyo-Oni and Oladele, 2016).

Digestion of the Fish Samples

The digestion process involved the utilization of the aqua regia method. In this method, 2 grams of the finely ground materials were subjected to digestion using a mixture of hydrochloric acid (HCl) and nitric acid (HNO_3) in a 3:1 ratio. The mixture was heated to a temperature of 180 °C. Once the digestion process was completed, the resulting residue was

allowed to cool and subsequently filtered into a 25 mL volumetric flask. Distilled water was added to the flask to reach the desired volume. The filtrate, containing the dissolved components, was carefully transferred to a sample vial that had been pre-cleaned. To maintain its integrity, the vial was stored under refrigerated conditions until it was ready for analysis (Jenyo-Oni and Oladele, 2016).

Plant Sample Collection

The collection process involved hand-picking the plants from reliable sources. Subsequently, the okra and bitter leaf samples were carefully cleansed using tap water to remove any surface impurities. To ensure thorough cleaning, they were then rinsed extensively with distilled water. Following the cleaning process, the plant samples were placed in cellophane bags for transportation to the laboratory, maintaining their freshness and integrity. To prepare the plant samples for further analysis, specific procedures were employed, which will be outlined in section.

Preparations of Plant Samples

The two samples underwent a drying process in an oven set at a consistent temperature of 105°C until a constant weight was achieved. Following the drying phase, they were finely pulverized into a powder using a laboratory grinder. To ensure proper identification, the powdered samples were placed in polythene bags that were appropriately labeled. Subsequently, the bags containing the samples were stored in a desiccator, which helps maintain a dry environment and preserve the integrity of the samples (Jenyo-Oni and Oladele, 2016).

Digestion of the Plant Samples

For each sample, precisely 2g was measured and placed into platinum crucibles that had been thoroughly cleaned. The crucibles were then subjected to ashing at temperatures ranging from 450 to 500°C. Following the ashing process, the crucibles were allowed to cool to room temperature within a desiccator. Subsequently, the resulting ash was dissolved in 5ml of 20% hydrochloric acid, and the solution was carefully transferred into a 100ml volumetric flask. To ensure complete transfer of the solution, the crucible was thoroughly rinsed with distilled water and the rinsate was transferred to a separate 100ml volumetric flask. Distilled water was then added to the flask, bringing it to the desired volume, and the contents were mixed thoroughly by shaking. The analysis of the heavy metal contents in the samples was carried out in triplicate using an Atomic Absorption Spectrophotometer (AAS) following the standard procedure (Jenyo-Oni and Oladele, 2016).

AAS analysis

The digested fish and plant samples were subjected to analysis in triplicate using an Atomic Absorption Spectrophotometer (AAS), specifically the Shimadzu AA-630 model. The AAS instrument was calibrated using standard solutions containing predetermined amounts of the respective heavy metals. Calibration was performed prior to every three analyses, ensuring accuracy and consistency in the measurements. The heavy metals analyzed included Fe, Cu, Zn, Mn, Ni, Cr, Cd, and Pb. The results obtained from the analysis were reported in milligrams per liter (mg L^{-1}) as the unit of measurement (Oladele and Digun-awet, 2017).

Human Health Risk Assessments

The calculation of the estimated daily intake (EDI) for each element involved utilizing the formula CDI = [C x DI] / [BW]. This calculation aimed to determine the daily human exposure to these elements through the fish pathway Brikia et al., (2017). The Chronic daily intake (CDI),

expressed in units of mg kg-1/day, was used to quantify the risk of human exposure. In this formula, CDI represents the human exposure risk, C represents the concentration of the heavy metal in fish (measured in mg L^{-1}), DI represents the daily intake rate (assumed to be 0.2 kg/day/person), and BW represents the body weight. For adult individuals, the average body weight used was 68 kg, while for children; the assumed body weight was 15 kg. These parameters were input into Equation 1 to calculate the CDI values Brikia et al., (2017)

$$CDI = (C \times DI) / (BW) \quad (1)$$

Hazard Quotient (HQ)

The evaluation of health risks related to fish consumption focused on assessing the non-carcinogenic hazards. This assessment was performed using the hazard quotient (HQ) equation, as denoted by Equation 2.

$$HQ = CDI/ RfD \quad (2)$$

Target Carcinogenic Risk (TCR)

The RfD values for oral toxicity, expressed in milligrams per kilogram per day (mg/kg/day) based on USEPA IRIS 2011, are as follows: 0.005 for Cd, 0.003 for Cr, 0.02 for Ni, 0.04 for Cu, 0.8 for Fe, 0.14 for Mn, 0.0035 for Pb, and 0.3 for Zn. To assess the safety of human health, the hazard quotient (HQ) is utilized. If HQ is less than 1, it is considered safe. If HQ falls within the range of 1 to 5, it is classified as low risk. For HQ values between 5 and 10, it is categorized as medium risk. HQ values exceeding 10 are deemed high risk (USEPA, 2011).

The estimation of the potential cancerous health risk associated with fish consumption involved the utilization of a toxicity index called the slope factor (SF). This index was used to calculate the potential risk of an individual developing cancer over their lifetime due to exposure to potential carcinogens. This calculation was performed using Equation 3.

$$TCR=SF\times CDI \quad (3)$$

The oral carcinogenic slope factor (SF) values obtained from (USEPA, 2015), were as follows: 0.38 for Cd, 0.5 for Cr, 1.7 for Ni, and 0.009 $(mg/kg/day)^{-1}$ for Pb. These slope factors were used to convert the Chronic Daily Intake (CDI) values into the incremental risk of an individual developing cancer. The Total Cancer Risk (TCR) values were then assessed, and if they exceeded the USEPA recommended safe limit of 1×10^{-4} for cancer risk, it indicated a potential carcinogenic risk.

Statistical analysis

For statistical analysis, the Statistical Package for Social Sciences (SPSS) version 16.0 was employed to conduct the concentration of essential micro-elements and Potentially toxic elements in fish and okra.

RESULTS AND DISCUSSION

The chemical parameters of the fish samples were examined and the findings were presented in tables labeled 1 and 2. Table 3-6 summarizes the Human health risk assessment parameters. Similarly, the results for the plants samples were documented in tables 7-10.

Concentration of Essential Micro Elements in Fish Samples

Concentration of essential micro elements in Fish Samples. The concentrations of essential micro elements (Fe, Cu, Zn, and Mn) detected in fish from the selected dams in Osun State were arranged in descending order as Fe > Zn > Cu > Mn, as presented in Table 1. The

concentration of Fe ranged from 94.3 to 16.6 mg L^{-1}, Zn ranged from 17.0 to 5.50 mg L^{-1}, Cu ranged from 26.4 to 4.40 mg L^{-1}, and Mn ranged from 4.90 to 1.30 mg L-1, as shown in Table 1. These findings indicate variations in the bioavailability of these metals to aquatic organisms, with Fe exhibiting the highest accumulation. Similar observations were reported by (Oladele and Digun-awet, 2015) regarding high Fe concentration in fish, which is consistent with its presence in surface soil, bottom sediment, and pond waters. (Etim and Adie, 2019) also reported elevated Fe concentration in fish, aligning with its concentrations in other environmental components. The present study is in line with the findings of (Omwoma, 2017), which highlighted higher levels of essential metals compared to non-essential metals in fish samples. However, all the tested micro elements exceeded the WHO permitted limits of 0.3 mg L^{-1} for Fe, 5.0 mg L^{-1} for Cu, 2.3 mg L^{-1} for Zn, and 0.5 mg L^{-1} for Mn, as shown in Table 1. Excessive copper accumulation can be toxic to aquatic animals, causing hepatic cirrhosis and hemolytic anemia in humans. Fish exposed to copper may experience growth and reproduction issues as well as enzyme activity disruption. Moreover, high Fe accumulation has been linked to neurological diseases, including Alzheimer's disease (Oladele and Digun-awet, 2017). Zinc serves as a cofactor for numerous enzymes involved in RNA and DNA metabolism, particularly at higher concentrations (Prasad, 2018). Excess manganese (Mn) can be harmful and toxic, leading to neurological and psychological disorders. Statistical analysis revealed no significant differences ($p > .05$) in the concentrations of Fe, Zn, Cu, and Mn among the six dams.

Table 1: Concentrations of Essential Micro-Elements in Surface Water from Six Selected Dams in Osun State

	EKO-ENDE	IBA	ILESA	ESA ODO	EDE	IKIRE	WHO[4]
Fe	0.47 ± 0.02^{b}	0.66 ± 0.01^{c}	0.35 ± 0.02^{ab}	0.12 ± 0.03^{a}	0.24 ± 0.02^{a}	0.22 ± 0.00^{a}	1.0
Cu	0.92 ± 0.01^{b}	1.16 ± 0.02^{c}	1.11 ± 0.01^{c}	0.16 ± 0.03^{a}	0.82 ± 0.02^{b}	0.94 ± 0.04^{b}	2.0
Zn	1.34 ± 0.01^{c}	1.46 ± 0.00^{c}	0.42 ± 0.00^{a}	0.32 ± 0.01^{a}	0.71 ± 0.01^{b}	0.60 ± 0.00^{b}	5.0
Mn	0.06 ± 0.01^{ab}	0.08 ± 0.02^{b}	0.08 ± 0.02^{b}	0.04 ± 0.01^{a}	0.13 ± 0.11^{b}	0.16 ± 0.01^{c}	0.5

Values are in mg L^{-1} (Mean ± SD). In each row, different letters indicate significant difference ($p < 0.05$) for each element.
Source: Author Analysis, 2023.

Concentrations of Potentially Toxic Elements (PTE) in Fish

Table 2 presents the concentrations of potentially toxic elements (PTE) (Cd, Cr, Ni, and Pb) in the sampled tilapia fish. Overall, the elements exhibited the following order of concentrations in fish: Ni > Cd > Pb > Cr. Ni concentrations were the highest in all dams, ranging from 3.92 to 3.15 mg L^{-1}, Cd concentration ranged from 14.2 to 0.41 mg L^{-1}, Pb concentration ranged from 3.73 to 2.36 mg L-1, and Cr concentration varied from 2.31 to 1.18 mg L^{-1} (Table 2). All these elements exceeded the WHO permitted limits of 0.6 mg L^{-1} for Ni, 0.3 mg L^{-1} for Cd, 0.3 mg L^{-1} for Pb, and 0.7 mg L^{-1} for Cr. The presence of lead in the fish samples may be attributed to abandoned parts of major pumping machines and equipment scattered in the dams' surroundings or the use of fertilizers, herbicides, and pesticides in farming activities near the dams. Lead can be harmful to the kidneys and the nervous system. This observation aligns with the findings of (Oladele and Digun-awet, 2015), which indicate that gills are the primary site of lead bioaccumulation. Cadmium (Cd) exposure primarily occurs through food intake and can induce cancer and organ damage in humans. High levels of nickel in the environment can lead to its accumulation in various fish tissues. Chromium accumulation in the kidneys

can cause itai-itai illness and bone thinning (Onyinyechi et al., 2018). The presence of Pb, Ni, Cr, and Cd in the fish samples indicates that the dams and their aquatic resources have been subjected to pollution from various sources, including both point and non-point pollution. This finding is consistent with the results reported by (Durodola et al., 2019), which highlight the introduction of contaminants (both synthetic and organic) into aquatic environments due to industrialization and agricultural advancements. There were no significant differences ($p > .05$) in the concentrations of Pb, Ni, Cr, and Cd among the six dams.

Table 2. Concentrations of potentially toxic elements (PTE) in fish fauna from six selected dams in Osun State

	EKO-ENDE	IBA	ILESA	ESA-ODO	EDE	IKIRE	WHO, 2011
Cd	0.41 ± 0.30^{a}	0.45 ± 0.33^{a}	0.78 ± 0.68^{b}	3.10 ± 1.99^{c}	14.2 ± 32.9^{d}	0.91 ± 0.82^{b}	0.3
Cr	1.18 ± 0.50^{a}	1.32 ± 0.28^{a}	1.64 ± 1.06^{b}	1.20 ± 0.50^{a}	2.31 ± 1.32^{c}	1.83 ± 1.30^{b}	0.7
Ni	3.34 ± 2.16^{ab}	3.16 ± 2.53^{a}	3.92 ± 3.01^{b}	3.40 ± 2.09^{ab}	3.45 ± 2.45^{ab}	3.15 ± 2.24^{a}	0.6
Pb	2.48 ± 1.06^{a}	2.36 ± 0.94^{a}	2.75 ± 1.67^{b}	2.99 ± 0.99^{bc}	3.73 ± 2.40^{c}	2.74 ± 1.98^{b}	0.3

Values are in mg L^{-1} (dry weight) (Mean ± SD). In each row, different letters indicate significant difference ($p<.05$) for each element.

Table 3: Non-Carcinogenic Risk of the Elements in adult

	EKO-ENDE	IBA	ILESA	ESA-ODO	EDE	IKIRE
Cd	0.003	0.003	0.006	0.024	0.110	0.007
Cr	0.007	0.008	0.010	0.007	0.014	0.011
Ni	0.006	0.005	0.070	0.006	0.060	0.005
Pb	0.810	0.771	0.899	0.977	0.219	0.895

Table 4: Non-Carcinogenic Risk of the Elements in children

	EKO-ENDE	IBA	ILESA	ESA-ODO	EDE	IKIRE
Cd	0.014	0.016	0.027	0.109	0.498	0.032
Cr	0.031	0.035	0.044	0.032	0.062	0.049
Ni	0.026	0.025	0.025	0.027	0.030	0.025
Pb	0.674	0.496	0.074	0.430	0.526	0.060

Table 5: Non-Carcinogenic Risk of the Elements in adult

	EKO-ENDE	IBA	ILESA	ESA-ODO	EDE	IKIRE
Cd	0.003	0.003	0.006	0.024	0.110	0.007
Cr	0.007	0.008	0.010	0.007	0.014	0.011
Ni	0.006	0.005	0.070	0.006	0.060	0.005
Pb	0.810	0.771	0.899	0.977	0.219	0.895

Table 6: Non-Carcinogenic Risk of the Elements in children

	EKO-ENDE	IBA	ILESA	ESA-ODO	EDE	IKIRE
Cd	0.014	0.016	0.027	0.109	0.498	0.032
Cr	0.031	0.035	0.044	0.032	0.062	0.049
Ni	0.026	0.025	0.025	0.027	0.030	0.025
Pb	0.674	0.496	0.074	0.430	0.526	0.060

Concentration of Essential Micro Elements in Okra Samples

Table 7 presents a summary of the concentrations of essential micro elements (Cu, Zn, Fe, and Mn) in the okra samples. The elements were found to occur in decreasing order of concentrations as follows: Cu > Zn > Fe > Mn (mg kg^{-1}). The concentration values ranged from

1.940 to 1.660 for Cu, 0.094 to 0.066 for Zn, 0.070 to 0.020 for Fe, and 0.006 to 0.001 for Mn. These concentrations of Cu, Zn, Fe, and Mn were all below the WHO permissible limits of 10.0 mg kg^{-1}, 0.60 mg kg-1, 0.30 mg kg^{-1}, and 0.05 mg kg^{-1}, respectively, across the six dams (Table 7). There were no statistically significant differences ($p > .05$) in the concentrations of Zn, Fe, Cu, and Mn among the six dams.

Table 7. Concentration of essential micro elements in Okra samples (*Abelmoschus esculentus*) from six selected dams (mg kg^{-1})

	EKO-ENDE	IBA	ILESA	ESA-ODO	EDE	IKIRE	WHO, 2011
Cu	1.780±0.021^{a}	1.750±0.120^{a}	1.940±0.010^{a}	1.870±0.420^{a}	1.660±0.310^{a}	1.930±0.220^{a}	10.0
Fe	0.050±0.012^{ab}	0.070±0.001^{b}	0.030±0.014^{a}	0.050±0.012^{ab}	0.060±0.051b^{ab}	0.020±0.012^{a}	0.30
Zn	0.078±0.210^{a}	0.075±0.120^{a}	0.094±0.010^{a}	0.087±0.420^{a}	0.066±0.310^{a}	0.093±0.220^{a}	0.60
Mn	0.004±0.110^{a}	0.001±0.100^{a}	0.002±0.000^{a}	0.005±0.020^{ab}	0.003±0.002^{a}	0.006±0.001^{ab}	0.05

Values are in mg kg^{-1} (Mean ± SD). In each row, different letters indicate significant difference ($p<.05$) for each element. Source: Author Analysis, 2020

Table 8 provides information on the concentrations of potentially toxic elements (PTE) (Cd, Cr, Ni, and Pb) in the okra samples. Generally, the concentrations of the elements in okra followed the order of Ni > Pb > Cr > Cd. Ni concentrations were the highest in all dams, ranging from 0.218 to 0.121 mg kg^{-1}. The concentrations of Pb, Cr, and Cd in mg kg^{-1} ranged from 0.220 to 0.030, 0.081 to 0.041, and 0.010 to 0.002, respectively (Table 8). The contents of Ni, Pb, Cr, and Cd were all below the WHO permitted limits of 10 mg kg^{-1}, 2.0 mg kg^{-1}, 1.30 mg kg-1, and 0.022 mg kg^{-1}, respectively. The concentrations of Cd, Pb, Cr, and Ni did not exhibit substantial differences ($p > .05$) among the six dams.

Table 8. Concentrations of potentially toxic elements (PTE) in okra (*Abelmoschus esculentus*) from six selected dams in Osun State (mg kg^{-1})

	EKO-ENDE	IBA	ILESA	ESA-ODO	EDE	IKIRE	WHO, 2011
Cr	0.064 ± 0.021^{ab}	0.061±0.010^{ab}	0.041± 0.101^{a}	0.041±0.101^{a}	0.081± 0.020^{b}	0.050± 0.102^{a}	1.30
Ni	0.127 ± 0.021^{a}	0.121±0.014^{a}	0.131±0.514^{a}	0.131±0.514^{a}	0.138± 0.014^{a}	0.218±0.072^{ab}	10.00
Pb	0.220 ± 0.014^{a}	0.060±0.051^{b}	0.060±0.051^{b}	0.060±0.014^{b}	0.030± 0.051^{a}	0.060± 0.050^{b}	2.0
Cd	0.010 ± 0.001^{a}	0.002±0.001^{a}	0.003± 0.000^{a}	0.004±0.001^{a}	0.003±0.000^{a}	0.002±0.001^{a}	0.022

Values are in mg kg^{-1} (Mean ± SD). In each row, different letters indicate significant difference ($p<.05$) for each element. Source: Author Analysis, 2020

Table 9 presents the concentrations of micro elements (Fe, Zn, Cu, and Mn) in Bitter Leaf across the six dams in Osun State. The elements were found to occur in decreasing order of concentrations as follows: Cu > Zn > Fe > Mn. Cu exhibited the highest concentrations across all tested dams, ranging from 1.480 to 1.110 mg kg^{-1}. This finding aligns with the results reported by (Stofejova et al., 2021). There were no significant differences ($p < .05$) in the concentrations of Cu, Zn, Fe, and Mn among the sampling sites, indicating a common source for these elements. The concentrations of essential micro elements (Zn, Fe, and Mn) in Bitter Leaf across the six dams ranged from 0.142 ± 0.000 to 0.074 ± 0.011 mg kg^{-1} for Zn, 0.217 ± 0.021 to 0.010 ± 0.000 mg kg-1 for Fe, and 0.005 ± 0.000 to 0.001 ± 0.000 mg kg-1 for Mn (Table 9).

Table 9. Concentration of essential micro elements in Bitter Leaf (*Vernonia amygdalina*)from six selected dams (mg kg^{-1})

	EKO-ENDE	IBA	ILESA	ESA-ODO	EDE	IKIRE	WHO,2011
Cu	1.110±0.000^{a}	1.360±1.000^{a}	1.480±0.101^{a}	1.350±0.111^{a}	1.120±0.120^{a}	1.180±0.122^{a}	10.0
Fe	0.217±0.021^{c}	0.055±0.030^{ab}	0.051±0.111^{ab}	0.060±0.001^{ab}	0.010±0.000^{a}	0.022±0.012^{a}	0.30
Zn	0.101±0.001^{ab}	0.112±0.020^{ab}	0.098±0.001^{a}	0.074±0.011^{a}	0.131±0.003^{ab}	0.142±0.000^{ab}	0.06
Mn	0.004±0.012^{a}	0.004±0.100^{a}	0.003±0.110^{a}	0.001±0.000^{a}	0.005±0.000^{ab}	0.002±0.000^{a}	0.05

Values are in mg kg^{-1} (Mean ± SD). In each row, different letters indicate significant difference ($p<.05$) for each element. Source: Author Analysis, 2020

CONCLUSION

The findings of this study provide valuable information to raise awareness among communities relying on the dams as their primary source of drinking water and fish, particularly tilapia, to mitigate potential adverse health risks associated with contaminated water and fish. The concentrations of the analyzed heavy metals in plants were within the permissible limits set by the World Health Organization (WHO). The hazard quotient (HQ) values for the heavy metals in fish across all dams were below 1, indicating an acceptable non-carcinogenic risk to human health. However, the obtained TCR values exceeded the recommended safe limit of 1×10^{-4} by the United States Environmental Protection Agency (USEPA) for cancer risk, suggesting the possibility of a carcinogenic risk.

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