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Health Risk Assessment of Heavy Metals in African Catfish (*Clarias gariepinus*) from Fish Ponds in Port Harcourt, Rivers State, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This study aims to evaluate the health risks linked to heavy metal concentrations in *Clarias gariepinus* harvested from earthen and concrete fishponds in Port Harcourt, Rivers State, Nigeria. The concentration of heavy metals was determined through atomic absorption spectrometry, and the associated health risks were evaluated using various exposure models, including Estimated Daily Intake (EDI), Target Hazard Quotient (THQ), and Hazard Index (HI). The results showed that

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in earthen ponds, cadmium (0.174–0.301 mg/kg) and lead (0.112–0.84 mg/kg) levels were below WHO/FEPA limits, while nickel, zinc, and copper concentrations were also within safe ranges. However, iron in sample B (11.464 mg/kg) exceeded the standard, posing potential risks. In concrete ponds, cadmium (1.257 mg/kg) and lead (5.376 mg/kg) levels were significantly above the recommended limits, highlighting serious health risks. Zinc and copper concentrations remained safe, but iron levels (10.068 mg/kg) surpassed the standard, indicating health concerns. Analysis of the EDI for all heavy metals across the earthen and concrete ponds revealed that all values were below safe limits, confirming the safety of consuming African catfish from these ponds. The THQ values for all metals were below 1, indicating no significant non-carcinogenic health risks. Similarly, the HI values for both pond types were well below the threshold of 1.0, confirming negligible cumulative risk from heavy metal exposure. In conclusion, there is no non-carcinogenic risk associated with the consumption of African catfish from earthen and concrete fishponds for the residents of Port Harcourt. Despite the low health risk, regular monitoring is recommended, especially due to the potential for bioaccumulation of cadmium and lead, which can pose long-term health concerns.

Keywords: Heavy metals; earthen pond, concrete pond; Africa catfish; human health risk assessment; target hazard quotient; estimated daily intake (EDI).

1. INTRODUCTION

Environmental pollution, population growth, and the depletion of natural resources rank among the leading global challenges. Pollution, whether direct (e.g., industrial discharge or sewage) or indirect (e.g., runoff from agricultural areas or urban areas), adversely impacts aquatic ecosystems and, consequently, poses risks to human health (Leonard & Mahengea, 2022). Among major pollutant, pollution of the aquatic environment with heavy metals has become a worldwide problem in recent years because heavy metals are indestructible and most have a toxic effect on organisms (Onuoha, 2017). They can enter the human body through inhalation, ingestion, and dermal absorption (Leonard & Mahengea, 2022). Some heavy metals, such as copper and cobalt, are required in small amounts for enzymatic activity but become enzyme inhibitors at higher concentrations. For example, at high levels, copper may cause oxidative stress, disrupting cellular functions and damaging tissues. In contrast, metals like cadmium and lead have no recognized beneficial role in living organisms and are toxic even at low levels (Ifeyinwa et al., 2023).

African catfish (*Clarias gariepinus*) is one of the most widely farmed fish species in Nigeria due to its rapid growth rate, adaptability to various environmental conditions, and high market demand. It is commonly raised in both earthen and concrete ponds, which are susceptible to contamination by heavy metals from surrounding environments. Fish, being at the top of the aquatic food chain, have the ability to accumulate these metals in their tissues, especially in the liver, gills, and muscles. Consumption of contaminated fish can lead to significant health risks for humans, particularly in regions where fish is a staple protein source.

Studies have shown that ponds across the globe are often contaminated with heavy metals, leading to significant adverse effects on the fish harvested from these environments (Leonard & Mahengea, 2022; Onuoha, 2017; Saah et al., 2021). Fishponds in Port Harcourt, Rivers State, Nigeria, which serve as habitats for fish consumed by the local population, may be no exception to heavy metal contamination. Given the economic and nutritional importance of African catfish, the health risks associated with heavy metal poisoning through the consumption of fish from these ponds are of significant concern. Therefore, it is crucial to investigate the levels of contamination in these fishponds to assess potential health risks. This study aims to assess the health risks associated with heavy metal concentrations in *Clarias gariepinus* from earthen and concrete fish ponds in Port Harcourt, thereby providing valuable data to inform public health policies and sustainable aquaculture practices.

2. MATERIALS AND METHODS

2.1 Study Area

The study was conducted in Port Harcourt (Fig. 1), the capital of Rivers State, Nigeria. Located in the Niger Delta region, Port Harcourt is located at approximately 4.8155° N latitude and 7.0493° E longitude. Port Harcourt stands as a prominent industrial center in Nigeria, home to the Trans-

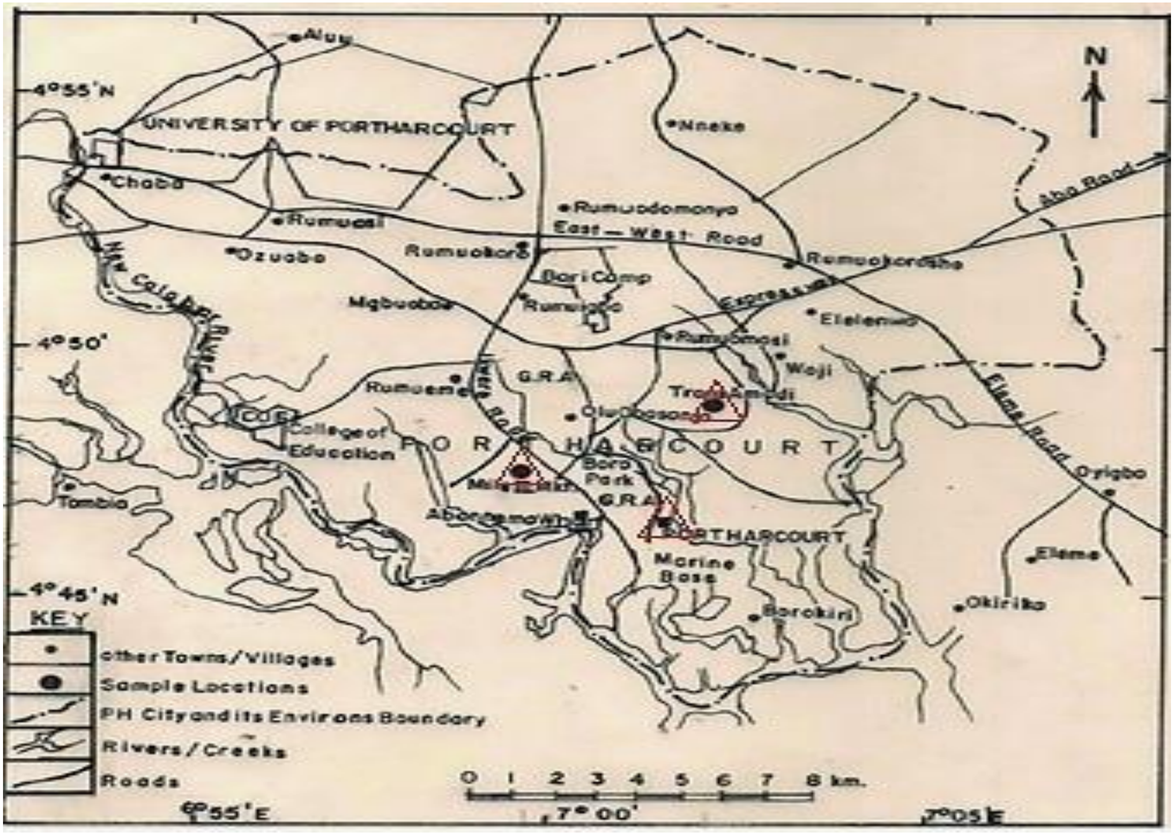

Fig. 1. Map of Port Harcourt City and it environ showing sample locations

Amadi Industrial Estate located approximately 4 miles (6 km) to the north. This expansive 2,500-acre (1,000-hectare) site serves as a manufacturing hub for a wide range of products, encompassing tires, aluminum goods, glass containers, and paper. Additionally, the city is a key producer of steel structural components, corrugated tin, paints, plastics, enamelware, wooden and metal furniture, cement, concrete products, and various other items. Notably, Nigeria's inaugural oil refinery, established in 1965, is situated at Alesa-Eleme, just 12 miles (19 km) to the southeast of Port Harcourt. The city is well-connected via pipelines that transport both oil and natural gas to Port Harcourt, where an additional refinery is located, as well as to the port of Bonny, situated 25 miles (40 km) to the south-southeast. Port Harcourt is also known as a hub for boatbuilding and fishing industries.

2.2 Collection and Determination of Heavy Metals in Fish Samples

Six catfish samples (1.2 kg each), three from earthen ponds and three from concrete ponds, were collected and dried in an oven at 70–105°C overnight. After cooling, the samples were ground into powder, and 1 g was weighed into 100 mL beakers for heavy metal analysis. A digestion process using HNO3, HClO4, and H_2O_2 was performed. Initially, 2 g of homogenized sample were placed in a digestion tube with 10 cm³ of HNO_3 and left overnight. The mixture was heated at 125°C until clear, then treated with additional reagents (HNO_3, $HClO_4$, H_2O_2, HCl) at 135°C for 1 hour until organic matter was destroyed. The solution was evaporated to near dryness, cooled, and dissolved in 5 cm³ of 1 mol/L HNO_3. The digested samples were filtered using Whatman No. 1 paper, diluted to 25 cm³ with 0.25 mol/dm³ HNO_3, and stored for analysis by Atomic Absorption Spectrometry (AAS). The procedure followed the methodology outlined by (Osakwe et al., 2014).

2.3 Human Health Risks Assessment

Estimation of Dietary Intake: The Estimated Daily Intake (EDI) of heavy metals refers to the quantity of a substance in food, calculated per unit of body weight (typically expressed in mg/kg body weight), that humans can consume daily throughout their lifetime without significant health risks (Benard et al., 2020). In this study, the daily intake was considered for African catfish collected from earthen and concrete ponds. The estimated daily intake (EDI) of Ni, Pb, Cd, Cu, Fe, and Zn was calculated according to the following equation:

$$EDI\ (mg/Kg - bw/day) = \frac{MI_F x CM_F}{BW}$$

Where
MI_F = Mass of the fish ingested per day;
CM_F = concentration of metal in fish;
BW = Average body weight of 60 Kg for adult in Nigeria was used.

Estimated Daily Intake of Metals (DIM) of fish was estimated as the fish consumption rate in Nigeria which is 48g/person/day according to Akinsorotan et al., (2024).

Target Hazard Quotient (THQ): The Target Hazard Quotient (THQ) represents the non-carcinogenic health risk associated with the consumption of heavy metals (HMs) (Njoga et al., 2021). The Target Hazard Quotient (THQ) for the heavy metals from the consumption of catfish in the study area was calculated following the guidelines recommended by USEPA, (United States Environmental Protection Agency, 2021), using the specified formula.

$$\mathrm{THQ} = 10^{-3} \mathrm{x} \frac{\mathrm{EF\ x\ ED\ x\ MI\ x\ CM}}{\mathrm{ORD\ x\ BW\ x\ AT}}$$

Where EF = Exposure frequency (365 days/year);

ED is the exposure duration (51.86 years), which corresponded to average life expectancy of a Nigerian;

AT = averaging exposure time for non-carcinogens (365 days/year x ED). The oral reference dose (ORD) is an estimate of daily exposure to human population (including sensitive sub-group) that is likely to be without an appreciable risk of deleterious effect during life time. 10^{-3} is the unit conversion factor.

The oral reference doses (ORDs) (mg/kg/day) utilized in the study were as follows: Cd (0.001), Cu (0.04), Zn (0.3), Ni (0.02), Pb (1.5), and Fe (0.7), as established by Osakwe et al. (2014) and USEPA, (United States Environmental Protection Agency, 2021). The Target Hazard Quotient (THQ) has a benchmark value of 1. A calculated THQ value of less than 1 indicates minimal or no non-carcinogenic health risk, whereas a value equal to or greater than 1 suggests a potential for non-carcinogenic adverse health effects from fish consumption (Adamu et al., 2023).

Hazard Index (HI): The Hazard Index (HI) assesses the potential health risk posed to humans by the combined effects of multiple pollutants, as fish may be contaminated with several heavy metals (HMs) that produce similar adverse health effects. The hazard index (HI) is expressed as the sum of the target hazard quotients (THQ):

$$\mathrm{HI} = \sum_{\mathrm{i}} \mathrm{THQ_i}$$

Where *i* is the distinct heavy metals tested. An HI value of less than 1 indicates minimal or no non-carcinogenic health risk, while a value equal to or greater than 1 suggests a potential for adverse health effects (Adamu et al., 2023).

2.4 Statistical Analysis of Experimental Data

Experimental data in this research work where analyzed using descriptive statistics such as the mean, standard deviation, Pearson correlation coefficient matrix as found in the Excel software.

3. RESULTS AND DISCUSSION

3.1 Detection and Distribution of Heavy Metals in African Catfish

The levels of heavy metals (Cr, Cd, Pb, Ni, Mn and Zn) in African catfish obtained from Earthen and Concrete Ponds in Port Harcourt, River State Nigeria are presented in Table 1 and 2.

The results in Table 1 indicate that cadmium concentrations in all samples (0.174–0.301 mg/kg) remain well below the WHO (World Health Organization, 2003) and FEPA (Federal Government Protection Agency, 2003) standard of 0.5 mg/kg, suggesting minimal risk from cadmium exposure. Similarly, lead levels (0.112–0.84 mg/kg) are far below the WHO (World Health Organization, 2003) and FEPA (Federal Government Protection Agency, 2003) standard of 2.0 mg/kg limit, indicating that lead contamination is not a major concern in the area. Nickel concentrations, ranging from 0.259 to 0.956 mg/kg, are significantly lower than the 2.0 mg/kg limit set by WHO (World Health Organization, 2003) and FEPA (Federal Government Protection Agency, 2003). Zinc levels (0.112–0.557 mg/kg) were significantly below the 30.0 mg/kg standard. Copper concentrations (0.008–0.082 mg/kg) also remained much lower than the WHO (World Health Organization, 2003) and FEPA (Federal Government Protection Agency, 2003) standard

Table 1. Heavy Metal Levels in African Catfish from Earthen Ponds in Port Harcourt Compared to WHO standards

	Sample code	Cd (mg/kg)	Pb (mg/kg)	Ni (mg/kg)	Zn (mg/kg)	Cu (mg/kg)	Fe (mg/kg)
Range	A	0.174-0.176	0.112-0.122	0.634-0.636	0.556-0.557	0.050-0.052	1.402-1.407
Mean		0.175	1.121	0.635	0.558667	0.051	1.404333
SD		0.001	0.001	0.001	0.001528	0.001	0.002517
Range	B	0.48-0.50	0.298-0.30	0.259-0.261	0.112-0.1124	0.08 -0.82	11.462 – 11.466
Mean		0.193	0.299	0.26	0.113	0.081	11.46433
SD		0.24855	0.001	0.001	0.001	0.001	0.002082
Range	C	0.299-0.301	0.837-0.840	0.954-0.956	0.528-0.530	0.008 -0.012	3.304 -3.308
Mean		0.3	0.838333	0.595	0.529	0.01	3.305667
SD		0.001	0.001528	0.001	0.001	0.002	0.002082
WHO/FEPA Standard (mg/kg)		0.5	2.0	2.0	30.0	3.0	0.5

Table 2. Heavy Metal Levels in African Catfish from Concrete Ponds in Port Harcourt Compared to WHO standards

	Sample code	Cd (mg/kg)	Pb (mg/kg)	Ni (mg/kg)	Zn (mg/kg)	Cu (mg/kg)	Fe(mg/kg)
Range	A	0.250-0.253	1.074-1.076	0.663-0.666	0.606-0.609	0.048-0051	2.012-2.016
Mean		1.257	5.376	3.323	3.038	0.25	10.068
SD		2.264	9.676	5.983	5.467	0.45	18.122
Range	B	0.318-0.320	1.518-1.50	0.29-0.833	0.663-0.665	0.025-0.028	1.786-1.806
Mean		0.319667	1.517667	0.830667	0.664	0.026667	1.797333
SD		0.001528	0.002517	0.002082	0.001	0.001528	0.010263
Range	C	0.187-0.861	0.692-0.694	0.190-0.192	0.548-0.550	0.041-0.043	2.30-2.317
Mean		0.412	0.693	0.191	0.549	0.042	2.310667
SD		0.388846	0.001	0.001	0.001	0.001	0.009292
WHO/FEPA Standard (mg/kg)		0.5	2.0	2.0	30.0	3.0	0.5

of 3.0 mg/kg, indicating no immediate health concerns. However, iron concentrations in sample B (11.464 mg/kg) exceeded the WHO (World Health Organization, 2003) and FEPA (Federal Government Protection Agency, 2003) standard 3.0 mg/kg limit, which may present risks.

The results in Table 2 present heavy metal concentrations in African catfish from concrete ponds in Port Harcourt, Rivers State, Nigeria.

From the findings, Cadmium (Cd) levels ranged from 0.250 to 0.253 mg/kg in sample A, with a mean concentration of 1.257 mg/kg, significantly exceeding the WHO (World Health Organization, 2003) and FEPA (Federal Government Protection Agency, 2003) standard of 0.5 mg/kg. This poses a serious health risk, as cadmium is a highly toxic heavy metal that accumulates in the body and can cause kidney damage and bone diseases (Järup, 2003). Similarly, Lead (Pb) levels ranged from 1.074 to 1.076 mg/kg in sample A, with a mean concentration of 5.376 mg/kg, which is far above the recommended limit of 2.0 mg/kg. Lead exposure is associated with neurotoxic effects, particularly in children, and long-term exposure can result in cardiovascular and renal damage (Tchounwou et al., 2012). Nickel concentrations ranged from 0.190 to 0.833 mg/kg, with mean values of 3.323 mg/kg, 0.8307 mg/kg, and 0.191 mg/kg for Samples A, B, and C, respectively. Sample A exceeded the WHO (World Health Organization, 2003) and FEPA (Federal Government Protection Agency, 2003) standard of 2.0 mg/kg, suggesting a potential health risk, while Samples B and C were within the safe limit. Zinc (Zn) concentrations in sample A ranged from 0.606 to 0.609 mg/kg, with a mean of 3.038 mg/kg, which is well below the WHO (Tchounwou et al., 2012) and FEPA (Federal Government Protection Agency, 2003) standard of 30.0 mg/kg. Copper (Cu) concentrations in sample A were 0.25 mg/kg, which is within safe limits, as it is far below the standard of 3.0 mg/kg. Iron (Fe) levels ranged from 2.012 to 2.016 mg/kg, with a mean concentration of 10.068 mg/kg, which far exceeds the WHO (World Health Organization, 2003) and FEPA (Federal Government Protection Agency, 2003) standard of 0.5 mg/kg.

3.2 Assessment of Human Health Risks in African Catfish (*Clarias gariepinus*)

Estimation of Dietary Intake (EDI): The Estimated Daily Intake (EDI) values of heavy metals in African catfish (*Clarias gariepinus*) from earthen ponds in Port Harcourt, River State, Nigeria, are presented in Table 3. The findings show that the EDI for cadmium (Cd) across all samples ranges from 0.000110 to 0.000240 mg/kg-bw/day, which is significantly lower than the recommended Average Daily Intake (ADI) of 0.06 mg/kg/day. Although cadmium is toxic at higher concentrations and can regulate gene expression, damage DNA through free radical generation, induce oxidative stress, and promote cell proliferation, the observed levels in the catfish samples pose no significant health risk. The EDI for nickel (Ni) in all samples ranges from 0.000208 to 0.000476 mg/kg-bw/day, which is well below the recommended ADI of 0.074 mg/kg/day to 0.100 mg/kg/day. This indicates that nickel exposure from consuming African catfish is within safe limits, and the risk to health is minimal. Copper (Cu) levels in the fish samples range from 0.000008 to 0.000065 mg/kg-bw/day, which is considerably lower than the Tolerable Upper Intake Level (UL) of 10 mg/kg/day for adults. This suggests that copper intake from these fish poses no risk to human health. Lead (Pb) levels in the fish samples range from 0.000238 to 0.000707 mg/kg-bw/day, which is below the recommended ADI of 0.21 mg/kg/day. These values indicate that the consumption of African catfish does not pose a significant risk from lead exposure, as the intake is well within the safety threshold. The EDI for zinc (Zn) in the fish samples ranges from 0.000090 to 0.000441 mg/kg-bw/day, which is much lower than the Tolerable Upper Intake Level of 40 mg/kg/day for adults. Similarly, the EDI for iron (Fe) in the fish samples ranges from 0.001044 to 0.009144 mg/kg-bw/day, which is also well below the Tolerable Upper Intake Level of 45 mg/kg/day for adults (Institute of Medicine, Food and Nutrition Board, 2001; Olufunmilayo & Olubunmi, 2024).

The Estimated Daily Intake (EDI) values of heavy metals in African catfish (*Clarias gariepinus*) from concrete ponds (Table 4) indicate that all metals, including cadmium (Cd), lead (Pb), nickel (Ni), zinc (Zn), copper (Cu), and iron (Fe), are well below their respective Tolerable Upper Intake Levels (UL) or Recommended Average Daily Intake (ADI) values. This finding aligns with the results reported by Olufunmilayo & Olubunmi, (Olufunmilayo & Olubunmi, 2024). However, the levels of lead (Pb), cadmium (Cd), and nickel (Ni) in their study were higher in comparison to the established limits, suggesting a divergence in the findings for these specific metals.

Table 3. Estimated Daily Intake (EDI) of Heavy Metals in African Catfish (*Clarias gariepinus*) from Earthen Ponds in Port Harcourt, River State, Nigeria

Sample Code	Cd (mg/kg-bw/day)	Pb (mg/kg-bw/day)	Ni (mg/kg-bw/day)	Zn (mg/kg-bw/day)	Cu (mg/Kg-bw/day)	Fe (mg/Kg-bw/day)
A	0.000110	0.000707	0.000398	0.000441	0.000027	0.001044
B	0.000154	0.000238	0.000208	0.000090	0.000065	0.009144
C	0.000240	0.000672	0.000476	0.000424	0.000008	0.002625

Table 4. Estimated Daily Intake (EDI) of Heavy Metals in African Catfish (*Clarias gariepinus*) from Concrete Ponds in Port Harcourt, River State, Nigeria

Sample Code	Cd (mg/Kg-bw/day)	Pb (mg/Kg-bw/day)	Ni (mg/kg) (mg/Kg-bw/day)	Zn (mg/kg) (mg/Kg-bw/day)	Cu (mg/kg) (mg/Kg-bw/day)	Fe (mg/Kg-bw/day)
A	0.001003	0.004304	0.002656	0.002427	0.000200	0.008064
B	0.000255	0.001211	0.000664	0.000531	0.000021	0.001441
C	0.000328	0.000552	0.000152	0.000439	0.000033	0.001841

From the findings in this study, the EDI values for all heavy metals in the African catfish samples are within safe consumption limits, and no significant health risks are posed by the intake of these metals from the fish.

Target Hazard Quotient (THQ): The target hazard quotient (THQ) is calculated by the formulation established by the United States Environmental Protection Agency. The Target Hazard Quotient (THQ) assesses the non-carcinogenic health risks associated with exposure to heavy metals through consumption of African catfish (*Clarias gariepinus*). A THQ value below 1 indicates no significant health risk, whereas a value exceeding 1 suggests potential health risks (United States Environmental Protection Agency, 2000). In this study, the THQ values for Cd, Pb, Ni, Zn, Cu, and Fe were evaluated for fish samples obtained from earthen and concrete ponds. The result for the THQ as obtained from the earthen pond is presented in Table 4.

The findings from Table 4 reveals that all THQ values are well below 1, suggesting minimal risk to human health from these heavy metals. Among the metals analyzed, cadmium (Cd) exhibited the highest THQ values across the samples, ranging from 0.002500 in Sample A to 0.004286 in Sample C. These values, though below the risk threshold, highlight the bioaccumulative potential of Cd and the need for continued monitoring, as chronic exposure to Cd can result in adverse health effects, including kidney dysfunction and bone fragility (Järup, 2003). Lead (Pb) levels were notably low, with THQ values ranging between 0.000003 (Sample B) and 0.000011 (Sample A), indicating negligible risk. This aligns with findings from Ogoyi et al*.* (2011), who reported low THQ values for Pb in aquatic organisms from similar settings. It also aligns with findings in previous study, which emphasize the importance of limiting Pb exposure due to its cumulative effects on the nervous system, even at low levels (Rejomon et al., 2010). Similarly, nickel (Ni) demonstrated low THQ values, with Sample A showing the highest value of 0.000454, while Sample B had the lowest at 0.000186, which remain significantly below the threshold. Despite this, the bioaccumulative nature of nickel necessitates monitoring due to its potential carcinogenic effects (Cempel & Nikel, 2006). The essential trace metals zinc (Zn) and copper (Cu) exhibited very low THQ values, with Zn ranging from 0.000005 (Sample B) to 0.000027 (Sample A) and Cu ranging from 0.000004 (Sample C) to 0.000029 (Sample B). These levels suggest no significant health concerns and highlight their role as essential nutrients when consumed in appropriate quantities (Prashanth et al., 2015). Iron (Fe), another essential element, showed slightly higher THQ values compared to other metals, particularly in Sample B (0.000234). However, these values are far below the threshold of concern, supporting the notion that Fe exposure from fish consumption is unlikely to pose health risks.

Table 5 presents the Target Hazard Quotient (THQ) values for heavy metals in *Clarias gariepinus* samples from concrete ponds. The results indicate that the THQ values for most metals are well below 1, suggesting minimal health risk associated with their consumption.

Table 5. Target Hazard Quotient (THQ) values for heavy metals in *Clarias gariepinus* samples from earthen ponds

Sample Code	Cd	Pb	Ni	Zn	Cu	Fe
A	0.002500	0.000011	0.000454	0.000027	0.000018	0.000029
B	0.002757	0.000003	0.000186	0.000005	0.000029	0.000234
C	0.004286	0.000008	0.000425	0.000025	0.000004	0.000067

Table 6. Target Hazard Quotient (THQ) values for heavy metals in *Clarias gariepinus* samples from concrete ponds

Sample Code	Cd	Pb	Ni	Zn	Cu	Fe
A	0.017957	0.000051	0.002374	0.000145	0.000089	0.000205
B	0.004567	0.000014	0.000593	0.000032	0.000010	0.000037
C	0.005886	0.000007	0.000136	0.000026	0.000015	0.000047

Among the metals analyzed, cadmium (Cd) exhibited the highest THQ values, with Sample A showing a significant value of 0.017957. This is notably higher than the values observed in the earthen pond samples, pointing to a greater risk of Cd accumulation in fish from concrete ponds. Despite this, the values are still below the threshold of 1, indicating that the health risk from Cd exposure is still low but warrants further monitoring, given its toxic effects, especially with long-term exposure (Järup, 2003). Lead (Pb) values were very low across all samples, ranging from 0.000007 (Sample C) to 0.000051 (Sample A), suggesting negligible risk from Pb exposure. Nickel (Ni) showed higher values than Pb, particularly in Sample A (0.002374), which suggests a slight increase in potential risk compared to the earthen pond samples, but it remains well below 1. Zinc (Zn) and copper (Cu) levels remained consistently low across all samples, with THQ values indicating no significant risk of toxicity. Iron (Fe) showed low THQ values, similar to those observed in earthen ponds, suggesting no health concerns related to Fe exposure from the fish.

The analysis of THQ values for these heavy metals in *Clarias gariepinus* samples suggests that fish from earthen and concrete ponds in the study area are safe for consumption concerning heavy metal exposure.

Hazard Index (HI): The Hazard Index (HI) values for heavy metals in African catfish obtained from earthen and concrete ponds, as presented in Table 6, are both significantly below the acceptable threshold of 1.0. This indicates that the cumulative non-carcinogenic risk from the analyzed heavy metals is negligible for consumers of the fish. The Hazard Index (HI) values for heavy metals in African catfish from both earthen (0.001013) and concrete ponds (0.001593) are well below the safety threshold of 1, indicating negligible health risks. The slightly higher HI for fish from concrete ponds may be influenced by differences in pond construction materials, feed quality, or management practices, as noted in similar aquaculture studies (Ogwuegbu & Muhanga, 2005; Chopra et al., 2011). Although the HI values are low, the presence of heavy metals like cadmium and lead, even at trace levels, is concerning due to their potential to bioaccumulate and cause adverse health effects over time (Tchounwou et al., 2012), warrants regular monitoring to prevent long-term health impacts. The cumulative risk assessment using HI is a valuable approach for evaluating multiple contaminants and ensuring public health safety (Zheng et al., 2007).

The results signifies that there is currently no substantial evidence suggesting a non-carcinogenic risk due to heavy metal exposure through the consumption of catfish sourced from either pond type.

Table 7. Hazard Index (HI) of the heavy metals in African Catfish obtained from Earthen and Concrete Ponds

Pond Type	HI
Earthen	0.001013
Concrete	0.001593

4. CONCLUSION

This study concludes that heavy metal concentrations in African catfish (*Clarias gariepinus*) from both earthen and concrete ponds exhibit variations. In earthen ponds, cadmium and lead levels were within acceptable limits, while nickel, zinc, and copper concentrations were safe. However, iron levels in one sample exceeded the permissible standard, posing potential health risks. In concrete ponds, cadmium and lead concentrations were significantly higher than recommended, indicating serious health concerns. While zinc and copper concentrations remained safe, iron levels again surpassed the standard, signaling potential risks. The health risk assessment reveals that both the total hazard quotient (THQ) and hazard index values fall below acceptable thresholds of 1.0, indicating no significant non-carcinogenic health risks associated with the consumption of African catfish from earthen and concrete fishponds for the residents of Port Harcourt. Analysis of the Estimated Daily Intake (EDI) values for all metals across both pond types further supports this conclusion, as all EDI values were below their respective Tolerable Upper Intake Levels (UL) or Recommended Average Daily Intake (ADI), confirming the safety of consuming fish from these ponds. These findings suggest that while there is evidence of heavy metal contamination, the immediate health risk to consumers is minimal. Nonetheless, continuous monitoring of heavy metal levels is essential to prevent long-term impacts, especially from bioaccumulation of metals like cadmium and lead. Sustainable aquaculture practices should also be prioritized to mitigate future risks.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that they have no known competing financial interests or non-financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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