Original Research Article

Assessing the Health Risks of Emerging Trace Elements in Fish, Bobo Croaker (*Pseudotolithus elongatus*) from Buguma Creek, Southern Nigeria

Abstract

This study investigates the health risks associated with trace elements in Bobo Croaker (*Pseudotolithus elongatus*) from Buguma Creek, Southern Nigeria. Fish samples were conducted monthly from May to August 2023, and muscle tissues were analyzed for potential health risks posed by elevated levels of hazardous metals. Heavy metal concentrations of As, Fe, Zn, Pb, and Cd were analyzed using atomic absorption spectrophotometry (AAS). Cd was found in the EDIs of heavy metals in *P. elongatus* from three stations for adults and children, with minimal variation between stations. For adults, there were no significant discrepancies, but for children, there were substantial differences, especially at Stations 2 and 3. The EDI value for Zn varies significantly across all stations, with the highest value being recorded at Station 3. Fe showed notable differences between stations, while Cu and As had consistent EDI values. The study reveals potential health risks for both adults and children due to heavy metals, with Cd, Pb, and Zn exposure exceeding safe thresholds for both adults and children, while Pb and As have values below safe thresholds, indicating negligible cancer risk. The study calls for further evaluations and mitigation strategies, emphasizing the importance of sustainable practices and acceptable exposure limits, particularly at Stations 2 and 3, to protect vulnerable populations. HI values surpass 1 for both age groups, indicating potential health risks from trace elements in *P. elongatus*, particularly for Cadmium. The study highlights the potential health risks from trace elements in *P. elongatus*. It emphasizes the importance of sustainable practices and acceptable exposure limits, particularly at Stations 2 and 3, to protect vulnerable populations.

Keywords: *Trace Elements, Bobo Croaker, Health Risks, Buguma Creek.*

1. INTRODUCTION

Hazardous metals are a class of organic chemicals produced and released into the environment during the incomplete combustion of organic materials such as crude oil, coal, wood, and even smaller organic molecules such as methane [1]. These toxic metals are often found in different components of the environment, including soil, air, water, and biota, and are predominantly derived from anthropogenic sources. Their residues can also be detected in various food items, making them ubiquitous substances in the environment [2].

Heavy metals can be discovered in coastal waters as a result of accidental oil spills or human disposal of petroleum residues (petrogenic source. They can also be released naturally or through the combustion of fuel and other organic substances (pyrogenic source) [3, 4]. Toxic metals are known to be released by the combustion of jet fuel as well as emissions from generators and motor vehicles. Secondary thermochemical reactions at temperatures above 700°C produce large amounts of these metals [5].

Toxic metals are typically found in complicated combinations and are occasionally synthesised. Metals are colourless, white, or pale yellow-green solids in their pure form. They can be found in coal tar, crude oil, creosote, and roofing tar, as well as colours, plastics, and insecticides [6]. These compounds have also been found to occur during gasification and combustion processes [7]. Because they are widespread in the environment, including the air, water, and soil, they are present in practically all types of foods [8].

The rural parts of Niger Delta communities have seen tremendous industrial expansion, commercial activity, and population growth, resulting in massive garbage output. Improper trash disposal has resulted in the pollution of air, land, and water resources. Water contamination is caused by industries and abattoirs in the region discharging untreated or insufficiently treated wastewater and effluents from artisanal crude oil refining into waterways[9]. Heavy metals are present in some of this untreated wastewater, posing harm to aquatic life, humans, and the general ecological balance. Heavy metals are of special concern since they are non-degradable, poisonous, and persistent, and they can harm aquatic ecosystems.

While studies have detected toxic metals in other seafood from other coastal areas of Nigeria [10, 11, 12], there is presently a notable absence of literature addressing the health and ecological risks associated with heavy metals in water, sediment, and shellfish in Buguma Creek. Consequently, the primary objective of this research is to address and bridge this information gap.It is critical to examine the potential health and ecological concerns associated with toxic metals in water and sediment, as well as the toxicity of certain fish species, which are known to store these metals in their tissues and may thus harm human health.

2. MATERIALS AND METHODS

2.1. Study Area

The research was conducted within Buguma Creek, located in Asari-Toru Local Government of Rivers State, Nigeria. This creek system encompasses the primary channel, known as Amanayabo Okolo, along with interconnected creeks such as Ido Canal and Jordan Creek, which surround and interconnect Buguma and Ido communities [13, 14]. The vegetation in Buguma Creek is predominantly composed of red mangrove (*Rhizophora sp*.), White mangrove (*Avicennia sp.*), black mangrove (*Laguncularia sp*.), and Nypa palm (*Nypafructicans*). The local community relies directly on the creek for various activities, including recreation, transportation, open defecation, spiritual practices, and livelihood purposes.

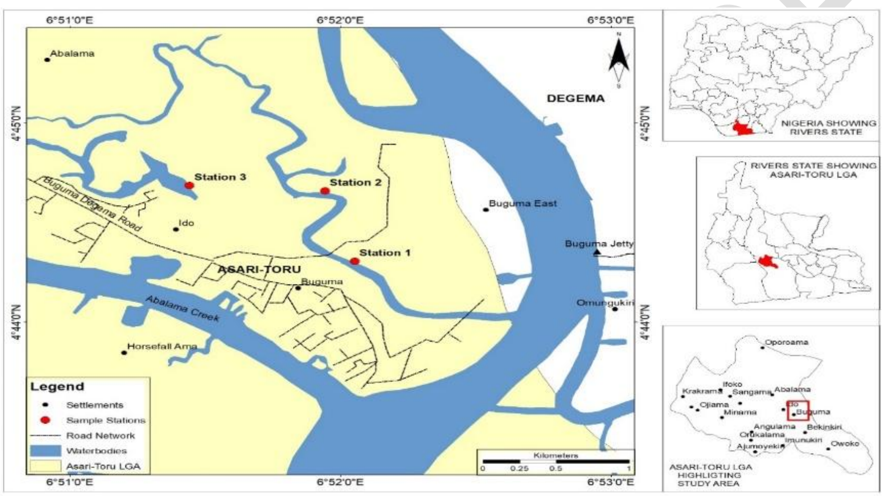

Figure 1. A map illustrating the study area in Buguma Creek, Asari-Toru Local Government Area, Rivers State, Nigeria, was created to display the locations of the sampling stations (Station 1, Station 2, and Station 3).

2.2. Sampling and Digestion of Fish Samples

Bobo croaker fish (*Pseudotolithus elongatus*) specimens were procured from Lower Buguma Creek through the utilization of fishing nets that had been abandoned overnight after being cast. Fish samples were collected twice every two months from May 2023 to August 2023 from three primary fishing zones in the creeks. The acquired fish samples were promptly preserved in pre-acid cleansed polythene bags, which were subsequently sealed, labelled, and placed in ice cases prior to being transported to the laboratory. The lengths (24 cm) and masses (0.59 kg) of the fish were recorded in the laboratory, and the specimens were stored in a deep freezer until the muscle tissues were excised for examination. Since muscle tissues are the most ingested portion of the fish, they were selected for analysis in this research. Increased levels of hazardous metals in muscle tissues would result in heightened dangers to human health. The analyzed fish sample is a species that is ingested predominantly throughout the year from the impoundment.

Following the process of chilling, one gram of fish musculature was precisely weighed using an electronic balance and subsequently transferred into a sterile receptacle. Triplicate digestion of dried fish samples from each fish species was performed in accordance with the methodology specified in [15]. A volume of 18 mL of concentrated nitric acid was introduced per weighed fish muscle, and the resulting mixture was elevated to 100˚C on a hot plate contained within a fume shroud chamber. A few droplets of analytical-grade hydrogen peroxide were introduced until the absence of brown emissions was detected. In 50 mL volumetric containers containing digested fish sample solutions, each solution was filtered individually through Whatman 0.42 μm filter paper before being filled to the mark with distilled-deionized water. Following this, the filtrate was transferred to 50 mL pre-cleaned plastic vials using acid.

2.3. Analysis of Heavy Metals

The atomic absorption spectrophotometer (AAS) was employed to determine the concentrations of the following metals: arsenic (As), iron (Fe), zinc (Zn), lead (Pb), and cadmium (Cd). The procedure followed the guidelines outlined in the [15] manual. The instrument was configured and operated in strict adherence to the manufacturer's specifications.

2.4. Human Health Risk Indices Assessment

2.4.1 Estimated daily intake

The heavy metal levels were computed in order to evaluate the adverse health effects of heavy metal exposure on humans. Obesity, intentional and unintentional inhalation, and dermal absorption are all routes through which heavy metals can enter the human body [16]. The assessment of the health risk resulting from heavy metal exposure via various pathways is facilitated by estimated daily intake (EDI; mg kg^{-1}/day). [17] developed the method, which is represented in Equation 1, for determining the EDI of metals in the consumable tissues of Bobo croaker (*Pseudotolithus elongatus*) in this study.

$$EDI = (EF \times ED \times FIR \times Cm) / (BAW \times AT) \quad (1)$$

The variables under consideration are as follows: EF represents the frequency of exposure (365 days per year); ED denotes the duration of exposure as adopted by [18]; equivalent to the average life expectancy of a Nigerian adult at 54.5 years); FIR signifies the rate of fish ingestion (for Nigerians, 0.02 kg/person/day; this value was also adopted from [18] and applies to edible tissues of shellfish; Cm signifies the metal concentration in edible tissues of Bobo croaker (*P. elongatus*) in milligrammes; and BAW denotes The concentrations of metals identified in this research, which were previously expressed as dry weight (0.02 kg/person/day), were recalculated to fresh weight using the mean moisture content of fish from the study areas. This was done to ensure that the unit used for the fish ingestion rate remained consistent with the measured concentration data. As per the risk assessments and recommendations of the National Centre for Environmental Assessment, the United States Environmental Protection Agency, and the Office of Research and Development, this action was taken regarding the consumption of fish. The conversion of metal concentrations measured in dry weight to wet weight was done using a moisture content percentage of 13.458, according to Equation 8.

$$Cww = Cdw\,[(100 - W) / 100] \quad (2)$$

Cww represents the wet weight concentration, Cdw represents the dry weight concentration, and W is the moisture content.

2.4.2 Hazard Quotients (HQ)

Hazard quotients (HQ) were utilized to evaluate the health risks linked to human exposure to heavy metals in samples obtained from Lower Buguma Creek, in accordance with the [19] definition of non-carcinogenic hazards. Designed to quantify cumulative non-carcinogenic exposures, the hazard index (HI) represents the sum of all exposed hazard quotients along the different routes of exposure.

$$HQ = \frac{CDE}{RfD} \quad (3)$$

2.4.3 The Hazard Index (HI)

The hazard index (HI) represents the sum of all potential dangers associated with pollutant absorption. The following equation, which is a sum of non-carcinogenic effects, is used to calculate it:

$$\mathrm{HI} = \sum \mathrm{HQIng} + \mathrm{HQInh} + \mathrm{HQDerm} \quad (4)$$

The US EPA classifies non-carcinogenic effects (HI <1) as acceptable risk and does not require any policy action from a human health standpoint [19]. Negative consequences are indicated by HI > 1, which necessitates additional chemical-specific evaluation. A HI > 4 is considered to have a high negative effect, as per the [19].

2.3.4 Carcinogenic risk assessment (CR)

CR is the lifetime cancer risk probability associated with the ingestion or inhalation of Bobo Croaker (*P. elongatus*) containing Cd, Pb, and As. SF (mg/kg/day) represents the toxicity value, which is the cancer slope factor. The dose-response relationship is quantified. Certain investigated metals, namely As and Cd, have been designated as carcinogens, whereas [20] has identified Pb as a probable carcinogen for humans. The oral SFs utilized were as follows: 0.0085 per mg/kg-day for Pb, 1.5 per mg/kg-day for As, and 15 per mg/kg-day for Cd. The CTCD provided the oral SFs for the metals [21].The cancer risk of the present study will be calculated using the expression:

$$\mathrm{CR} = \mathrm{CDE} \times \mathrm{CSF} \quad (5)$$

In contrast to CR, which represents the probability calculated in mg/kg/day proportion (of the population), CADD stands for chronic average daily dosage, and CSF denotes the cancer slope factor. In accordance with the USEPA (2017), metal concentrations are considered detrimental to human health when the cancer risk (CR) ranges exceed 10^{-6} or 10^{-4} [22].

3. RESULTS

The results of the analysis of heavy metals (Fe, Zn, Pb, Cd, Cu, and As) in the fish species Bobo croaker **(***P. elongatus*) found in Asari-Toru Local Government of Rivers State, Nigeria are shown in Table 1.Results are presented as mean concentrations (mg kg-1 dry weight).

Table 1: Spatial variation of metals in fish(*P. elongatus*).

Locations	Fe (mg/Kg)	Zn (mg/Kg)	Pb (mg/Kg)	Cd (mg/Kg)	Cu (mg/Kg)	As (mg/Kg)
			Pseudotolithus elongatus			
Station 1	19.74±0.74	91.33±3.22	0.004±0.00	0.016±0.00	0.98±0.02	0.002±0.00
Station 2	22.12±3.41	111.2±4.91	0.005±0.00	0.013±0.00	0.89±0.05	0.002±0.00
Station 3	15.54±3.71	137.23±9.09	0.004±0.00	0.015±0.00	0.92±0.05	0.002±0.00

3.1 Non-carcinogenic Risk

3.1.1Estimated Daily Intake (EDI) of *P. elongatus*

Table 2 presents the Estimated Daily Intake (EDI) of heavy metals in *P. elongatus* fish, considering adults and children from three distinct stations. The EDI serves as an approximation of the daily consumption of a specific contaminant by an individual when consuming an average quantity of contaminated fish. For Cadmium (Cd), there is minimal divergence in EDI values among adults across all three stations, with consistently low values at each station. Similarly, children also show no significant variation in Cd EDI values among the three stations.

Regarding Lead (Pb), noticeable discrepancies in EDI values are not evident for adults across the three stations, as each station consistently displays low EDI values. However, for children, there is a substantial difference in EDI values between Station 1 and Stations 2 and 3, with the latter two stations showing higher EDI values. As for Zinc (Zn), significant fluctuations in EDI values are observed for both adults and children across all three stations, with Station 3 having the highest EDI values.

EDI values for Iron (Fe) display a noticeable contrast between Station 1 and Station 2, for both adults and children, with Station 2 generally exhibiting higher EDI values than Station 1. Additionally, among children, there is a significant difference in EDI values between Station 2 and Station 3, with Station 3 recording the lowest EDI values. However, EDI values for Arsenic (As) and Copper (Cu) remain consistent among both adults and children across all three stations. Based on the data in the table, it can be deduced that fish from all three stations contain varying levels of heavy metal contamination, particularly in the case of Lead, Zinc, and Iron. While EDI values for these heavy metals fall within acceptable limits for adults, there may be some cause for concern, particularly for children, especially at Stations 2 and 3.

Table 2: Estimated Daily Intake (EDI) of *Pseudotolithus elongatus*

Adult			
Heavy Metal	**Station 1**	**Station 2**	**Station 3**
Cd	0.001954	0.001587	0.001832
Pb	0.000488	0.000611	0.000488
Zn	26.02279	31.68723	39.10115
Fe	5.624548	6.302685	4.427836
As	0.000244	0.000244	0.000244
Cu	0.279233	0.253589	0.262137
Children			
Heavy Metal	**Station 1**	**Station 2**	**Station 3**
Cd	0.001824	0.001482	0.00171
Pb	0.000456	0.00057	0.000456
Zn	121.4397	147.8738	182.472
Fe	26.24789	29.41253	20.66323
As	0.000228	0.000228	0.000228
Cu	1.303087	1.183416	1.223306

3.1.2 Hazard quotient (HQ) and Hazard index (HI) of Metal Contaminated *P. elongatus*

The Hazard Quotient (HQ) and Hazard Index (HI) for heavy metals in *P. elongatus* as they pertain to adults and children from three separate stations are presented in Table 3. The HQ denotes the proportion between the estimated daily ingestion and a safe reference dose of a particular contaminant. On the other hand, the HI accumulates all HQs pertaining to a given set of contaminants. There were no statistically significant differences observed in the HQ values of Cadmium (Cd) between children and adults at any of the three stations. At each station, however, the Cd HQ values for both infants and adults exceed 1, indicating a potential health hazard.

The HQ value for lead (Pb) did not show a statistically significant difference between minors and adults at any of the three stations. However, it's essential to note that the HQ values for Pb among minors at all three stations exceed 1, suggesting a potential health hazard. Zinc (Zn) values exhibited significant differences in HQ values for both adults and children among all three stations, with Station 3 having the highest HQ values. Nevertheless, the HQ values for Zn remain below 1 for both adults and children at all three stations, indicating a relatively low health risk. Conversely, for Iron (Fe), there is a notable variation in HQ values between Station 1 and Station 2 for both adults and children, with Station 2 showing higher HQ values. However, the HQ values for Fe remain below 1 for both adults and children at all three stations, signifying a relatively low health risk.

Regarding HQ values for arsenic (As) and copper (Cu) at all three stations, there was no statistically significant difference observed between minors and adults. At all three stations, the HQ values for As and Cu are less than 1 for both children and adults, indicating a comparatively minimal health hazard. Nevertheless, at all three stations, the Hazard Index (HI) values for heavy metals surpass 1 for both adults and children. This suggests that there may be a potential health hazard linked to the ingestion of these fish. In brief, the information presented in the table indicates that there is a potential health hazard associated with the consumption of *P. elongatus* fish from all three stations, specifically in regard to

Cadmium (Cd) and Lead (Pb), as indicated by the HQ values surpassing 1 for Cd and Pb. Additionally, the heightened HI values for every heavy metal emphasize the possible health hazard linked to ingestion.

Table 3: Hazard quotient (HQ) and Hazard index (HI) of Metal Contaminated *P. elongatus*

	Adult		
Heavy Metal	**Station 1**	**Station 2**	**Station 3**
Cd	1.95382E-06	1.58748E-06	1.8317E-06
Pb	1.95382E-06	2.44227E-06	1.95382E-06
Zn	7.806838356	9.506169863	11.73034521
Fe	0.056245479	0.063026849	0.044278356
As	7.32681E-08	7.32681E-08	7.32681E-08
Cu	0.011169315	0.010143562	0.010485479
HI	**7.874257132**	**9.579344377**	**11.7851129**
	Children		
Heavy Metal	**Station 1**	**Station 2**	**Station 3**
Cd	1.82356E-06	1.48164E-06	1.70959E-06
Pb	1.82356E-06	2.27945E-06	1.82356E-06
Zn	36.43191233	44.36212603	54.74161096
Fe	0.262478904	0.294125297	0.206632329
As	6.83836E-08	6.83836E-08	6.83836E-08
Cu	0.05212347	0.047336621	0.048932237
HI	**36.74651842**	**44.70359177**	**54.99717913**

3.1.3Carcinogenic risk to both age groups arising from Cd, As and Pb exposure.

The carcinogenic potential of *P. elongatus* fish from three distinct stations exposed to cadmium (Cd), arsenic (As), and lead (Pb) is detailed in Table 4. The data pertains to both adults and children. The lifetime cancer risk is a unitless value that represents the likelihood of developing cancer after an individual has been exposed to a particular contaminant for an entire lifetime.

Cadmium (Cd) carcinogenic risk values for infants and adults are not significantly different across all three stations. Nevertheless, at all three stations, the carcinogenic risk values for Cd surpass the established safe threshold of 1x10^-4 for both adults and children. This finding suggests that prolonged exposure to Cd significantly elevates the likelihood of developing cancer.

Regarding lead (Pb) and arsenic (As), the carcinogenic risk values for both adults and children at all three stations are not significantly different. However, in both adult and pediatric populations, the carcinogenic risk values for As and Pb consistently remain below the established safe threshold of 1x10^-6. The aforementioned data underscores the relatively minimal risk that prolonged exposure to these particular pollutants poses for the development of cancer.

The data presented in the table indicates that the ingestion of *P. elongatus* fish from any of the three stations could potentially endanger the health of both adults and children, as prolonged exposure to cadmium (Cd) increases the risk of carcinogenesis. Nevertheless, the carcinogenic hazard profiles of Arsenic (As) and Lead (Pb) are insufficient to raise concerns for both age cohorts.

Table 4: Carcinogenic risk to both age groups arising from Cd, As and Pb exposure in the study.

Adults			
Heavy Metal	**Station 1**	**Station 2**	**Station 3**
Cd	7.42452E-07	6.03242E-07	6.96046E-07
Pb	1.66075E-08	2.07593E-08	1.66075E-08
As	1.09902E-07	1.09902E-07	1.09902E-07
Children			
Heavy Metal	**Station 1**	**Station 2**	**Station 3**
Cd	6.92953E-07	5.63023E-07	6.49644E-07

Pb	1.55003E-08	1.93753E-08	1.55003E-08
As	1.02575E-07	1.02575E-07	1.02575E-07

4. DISCUSSION

4.1The Estimated Daily Intake (EDI) of heavy metals in *P. elongatus*

The Estimated Daily Intake (EDI) of heavy metals in *P. elongatus* from three different stations carries significant health risk implications, especially for children, given their elevated EDI values.

For adults, the EDI values for Cadmium (Cd) remain consistently low across all three stations, indicating a minimal non-carcinogenic health risk. Likewise, for children, Cd EDI values are also low and exhibit no significant variation across the stations, suggesting a relatively low non-carcinogenic risk for children. The EDI values for Cd in fish from all three stations are below the provisional tolerable weekly intake (PTWI) of 7 µg/kg body weight recommended by the World Health Organization (WHO). This means that the consumption of fish from any station does not pose a significant health risk from Cd exposure for both adults and children.

In the case of Lead (Pb), EDI values for adults are consistently low across all stations, indicating a low non-carcinogenic health risk. However, for children, Station 1 shows relatively low EDI values, while Stations 2 and 3 have significantly higher EDI values. This implies a potential non-carcinogenic health risk, particularly for children who consume fish from Stations 2 and 3, due to the elevated lead intake. However, both adults and children display substantial fluctuations in Zinc (Zn) EDI values across all three stations, with Station 3 displaying the highest EDI values. This suggests the potential for a non-carcinogenic health risk due to elevated zinc intake (Shaheen *et al*., 2016), especially for those consuming fish from Station 3. Monitoring and measures to reduce zinc levels in fish from Station 3 may be necessary to mitigate this risk.

For adults, there is a notable variation in EDI values between Station 1 and Station 2, with Station 2 generally displaying higher EDI values. However, these values are still within acceptable limits, indicating a relatively low non-carcinogenic health risk. For children, there is an additional significant difference in EDI values between Station 2 and Station 3, with Station 3 recording the lowest EDI values. Overall, the risk appears relatively low. Both adults and children exhibit consistently low and identical EDI values for As across all three stations, suggesting a low non-carcinogenic health risk.

Pb is a neurotoxic metal that can affect the development and function of the nervous system, especially in children [24]. The EDI values for Pb in fish from Station 1 are below the PTWI of 25 µg/kg body weight set by the WHO indicating a low health risk for both adults and children. However, the EDI values for Pb in fish from Stations 2 and 3 are above the PTWI, suggesting a high health risk for children and a moderate health risk for adults. Children who consume fish from Stations 2 and 3 may experience adverse effects such as reduced IQ, learning disabilities, behavioural problems, and anaemia[25]. Adults who consume fish from Stations 2 and 3 may experience effects such as hypertension, cardiovascular disease, kidney damage, and reproductive impairment.

The EDI values for Cu are within acceptable limits for both adults and children across all stations, indicating a low non-carcinogenic health risk. The fish from all three stations contain varying levels of heavy metal contamination, notably Lead, Zinc, and Iron. While the EDI values for these heavy metals generally fall within acceptable limits for adults, there may be some cause for concern, particularly for children [26], especially at Stations 2 and 3, where lead and zinc levels are higher. Continuous monitoring and potential mitigation measures may be necessary, especially for children's health.

Zn is an essential metal that plays a role in various biological processes, such as immune function, wound healing, and growth [27]. However, excessive intake of Zn can cause adverse effects such as nausea, vomiting, diarrhoea, abdominal pain, and reduced copper absorption [28]. The EDI values for Zn in fish from all three stations are above the tolerable upper intake level (UL) of 40 mg/day for adults and 23 mg/day for children set by the Institute of Medicine (IOM). This means that the consumption of fish from any station may pose a non-carcinogenic health risk due to elevated Zn intake for both adults and children. The highest EDI values for Zn are found in fish from Station 3, indicating the highest health risk among the three stations. Monitoring and measures to reduce Zn levels in fish from Station 3 may be necessary to mitigate this risk.

4.2 The Hazard Quotient (HQ) and Hazard Index (HI) values for heavy metals in *P. elongatus*

The Hazard Quotient (HQ) and Hazard Index (HI) values for heavy metals in *P. elongatus* from three different stations suggest potential health risks for both adults and children.
The Hazard Quotient (HQ) values for Cadmium (Cd) consistently exceed 1 for both adults and children at all three stations, indicating a notable health hazard. This suggests that Cd levels in the fish surpass safe reference doses, posing a significant risk to human health, particularly in the case of Cd exposure [29]. [30] Fatima *et al*. (2019) stated that cadmium (Cd) is a toxic heavy metal that can cause kidney damage, bone loss, hypertension, and cancer. However, Cd can also affect the nervous system, causing headaches, fatigue, irritability, and depression [31]. Cd exposure can be especially harmful to children, as it can impair their growth, development, and cognitive function.
For lead (Pb), HQ values are above 1 for children at all three stations, signifying a potential health risk for children. There is no substantial difference in HQ values between adults and children for Pb, implying that Pb may pose a health risk, especially for children. However, lead (Pb) is another toxic heavy metal that can affect the brain, blood, kidneys, and bones [32]. [33]suggested that Pb exposure can cause anemia, weakness, abdominal pain, constipation, and neurological problems such as learning difficulties, behavioural issues, and seizures. Moreso, Pb exposure is particularly dangerous for children, as it can interfere with their brain development and cause irreversible damage to their nervous system[34].
Although there is a significant variation in HQ values for Zinc (Zn) among all three stations for both adults and children, the HQ values for Zn consistently remain below 1 at all three stations. This indicates a relatively low health risk associated with Zn consumption from these fish [35]. Zinc (Zn) is an essential trace element that plays a role in various biological processes such as immune function, wound healing, and DNA synthesis [36]. However, excessive intake of Zn can cause nausea, vomiting, diarrhoea, abdominal cramps, and headaches. Zn toxicity can also impair the absorption of other minerals such as copper and iron.
HQ values for Iron (Fe) fall below 1 for both adults and children at all three stations, indicating a relatively low health risk. According to [37], iron (Fe) is another essential trace element that is involved in oxygen transport, energy production, and antioxidant defence. However, too much Fe can cause oxidative stress, tissue damage, and organ failure [38]. Fe overload can also increase the risk of infections, diabetes, liver cirrhosis, and cancer.There is no significant variation in HQ values for Arsenic (As) and Copper (Cu) across all three stations for both adults and children.
However, Arsenic (As) is a naturally occurring element that can be found in water, soil, and food. As exposure can cause skin lesions, pigmentation changes, and cancers of the skin, lung, bladder, and liver. [39] reported that As exposure can also affect the cardiovascular system, causing hypertension, ischemic heart disease, and stroke [40]. As exposure can impair the development and function of the brain and nervous system in both adults and children.
The HQ values for As and Cu are below 1 for both age groups, suggesting a relatively low health risk associated with their consumption. Copper (Cu) is another naturally occurring element that is essential for various metabolic functions such as iron utilization, collagen synthesis, and neurotransmitter production [41]. However, excessive intake of Cu can cause gastrointestinal distress, liver damage, kidney failure, and neurological disorders such as Wilson's disease [42]. Cu toxicity can also affect the blood cells, causing hemolysis and anaemia.
Nevertheless, the HI values for all heavy metals are consistently above 1 for both adults and children at all three stations. This suggests that the cumulative effect of exposure to these heavy metals may pose a potential health risk for both adults and children [43]. The results indicate that the consumption of *Pseudotolithus elongatus* from these stations may pose a potential health risk for both adults and children due to the high levels of Cd and Pb in the fish. [17] suggest that HI values suggest that the combined effect of all heavy metals may also have adverse health consequences for both age groups. Therefore, it is advisable to limit or avoid the intake of this fish from these stations until further studies are conducted to assess the safety and quality of the fish.

4.3 Carcinogenic Risk in *P. elongatus* from three different stations.

The findings offer valuable information regarding the carcinogenic potential of lead (Pb), cadmium (Cd), and arsenic (As) exposure in *P. elongatus* fish collected from three distinct stations. At all three monitoring stations, the carcinogenic risk values for Cd consistently surpass the safe threshold of 1x10^-4 for both children and adults. [44] documented comparable levels of cadmium consumption through diet. Long-term exposure to Cd is associated with an elevated risk of developing cancer. According to these findings, Cd exposure poses a substantial health hazard and may contribute to the development of cancer in infants and adults [45]. Regarding lead (Pb) and arsenic (As), the carcinogenic risk values for adults and children at the three stations are not significantly different. Furthermore, for both age groups, the carcinogenic risk values for Pb and As continue to be lower than the established safe threshold of 1x10^-6. According to this finding, the potential for cancer development resulting from prolonged ingestion of fish contaminated with Pb and As is essentially negligible [46].

The findings suggest that the ingestion of *P. elongatus* fish from any of the three stations could potentially endanger the health of both adults and children, as prolonged exposure to cadmium (Cd) increases the risk of carcinogenesis. The consistently high carcinogenic risk values associated with Cd are cause for particular apprehension, as they suggest a substantial likelihood of developing cancer. On the contrary, the carcinogenic risk values associated with arsenic (As) and lead (Pb) are found to be insufficient to warrant concern. This implies that adult and juvenile exposure to these contaminants via fish ingestion does not present a substantial danger of developing cancer [46].

Adipose tissue, bones, and kidneys may become infected with the toxic metal cadmium (Cd) [30]. Cancer-causing mutations can also result from its ability to disrupt DNA repair [47]. As per the provisional tolerable monthly intake (PTMI) established by the World Health Organization (WHO), the maximum permissible monthly consumption of Cd is 25 µg/kg body weight. In order to prevent the occurrence of detrimental health effects, individuals should not exceed this PTMI value. The results indicate, however, that the carcinogenic risk values for Cd in fish from all three stations exceed the safe threshold of 1x10^-4. This means that long-term Cd exposure through fish consumption increases the likelihood of cancer development by more than one in ten thousand individuals. Beyond the permissible threshold of risk established by the Environmental Protection Agency of the United States [48], this presents an exceptionally high risk. Hence, due to the heightened carcinogenic risk associated with prolonged Cd exposure, ingesting *P. elongatus* fish from any of the three stations could potentially endanger the health of both adults and children.

An additional toxic metal that has the potential to impact the nervous system, circulation, kidneys, and reproductive organs is lead (Pb) [49]. Additionally, it may induce DNA damage and oxidative stress, both of which are carcinogenic [50]. A person should not exceed the provisional tolerable weekly intake (PTWI) of 25 µg/kg body weight for Pb established by the WHO in order to prevent the development of adverse health effects. Nevertheless, the findings indicate that the carcinogenic risk values associated with lead (Pb) in fish collected from all three stations fall short of the established safe threshold of 1x10^-6. This implies that the likelihood of an individual developing cancer due to long-term Pb exposure via fish consumption is less than one in a million. This is an extremely low risk that is within the EPA's acceptable risk threshold. Therefore, owing to the carcinogenic risk associated with long-term Pb exposure, consuming *P. elongatus* fish from any of the three stations does not pose a significant health risk for both adults and children.

Naturally present in soil, food, and water, arsenic (As) is a naturally occurring element. [44] report that it has the potential to induce skin lesions, cardiovascular ailments, diabetes, and cancer. The provisional tolerable daily intake (PTDI) for As established by the WHO is 2.1 µg/kg body weight; therefore, individuals should not exceed this daily limit in order to prevent the occurrence of detrimental health consequences. In contrast, the findings indicate that the carcinogenic risk values for As in fish collected from all three stations are lower than the established safe threshold of 1x10^-6. This suggests that the likelihood of an individual developing cancer from long-term As exposure via fish consumption is less than one in a million. This approach also entails minimal risk and is in accordance with the EPA's approved level of risk. On account of the carcinogenic risk associated with long-term exposure to As ingesting *P. elongatus* fish from any of the three stations does not constitute a substantial health hazard for adults or children.

The findings suggest that the consumption of *P. elongatus* fish from all three stations may provide a possible health hazard for both adults and children, as it may lead to an elevated risk of developing cancer owing to prolonged exposure to Cadmium (Cd). The continually high carcinogenic risk values associated with Cd are a matter of major concern, as they indicate a substantial likelihood of cancer formation [51]. Nonetheless, the carcinogenic risk values associated with Lead (Pb) and Arsenic (As) are found to be below the threshold of concern. This indicates that the potential exposure to these pollutants from fish intake does not pose a substantial danger for the development of cancer in both adults and children.

5. CONCLUSION

In conclusion, consuming *P. elongatus* fish from these stations may pose health risks, particularly for Cd exposure, both in terms of non-carcinogenic and carcinogenic risks. Monitoring and measures to reduce heavy metal levels in fish, particularly at Stations 2 and 3, are advisable to mitigate potential health risks, especially for children. It is crucial to consider these findings when making dietary choices, especially for vulnerable populations. Further studies are recommended to assess the safety and quality of fish from these stations.

REFERENCES

1. (Guo *et al*., 2015Guo, M., Song, W., & Buhain, J. (2015). Bioenergy and biofuels: History, status, and perspective. *Renewable and sustainable energy reviews*, *42*, 712-725.
2. Ofori, S. A., Cobbina, S. J., Imoro, A. Z., Doke, D. A., & Gaiser, T. (2021). Polycyclic aromatic hydrocarbon (PAH) pollution and its associated human health risks in the Niger Delta Region of Nigeria: a systematic review. *Environmental Processes*, *8*, 455-482.
3. Ogunlana, O.O., Ogunlana, O. E., Akinsanya, A.E. &Ologbenia, O.O. (2015). Heavy metal analysis of selected soft drinks in Nigeria. *Journal of Hazardous Materials*, 4, 1335– 1338.
4. Garcia, M. R., & Martins, C. C. (2021). A systematic evaluation of polycyclic aromatic hydrocarbons in South Atlantic subtropical mangrove wetlands under a coastal zone development scenario. *Journal of Environmental Management*, *277*, 111421.
5. Chen, L., Zhou, S., Shi, Y., Wang, C., Li, B., Li, Y., & Wu, S. (2018). Heavy metals in food crops, soil, and water in the Lihe River Watershed of the Taihu Region and their potential health risks when ingested. *Science of the total environment*, *615*, 141-149.
6. Xue, P., Ding, J., Wang, P., & Lu, R. (2016). Recent progress in the mechanochromism of phosphorescent organic molecules and metal complexes. *Journal of Materials Chemistry C*, *4*(28), 6688-6706.
7. Contreras, M. L., Arostegui, J. M., & Armesto, L. (2009). Arsenic interactions during co-combustion processes based on thermodynamic equilibrium calculations. *Fuel*, *88*(3), 539-546.
8. Abdel-Shafy, H. I., & Mansour, M. S. (2016). A review on polycyclic aromatic hydrocarbons: source, environmental impact, effect on human health and remediation. *Egyptian journal of petroleum*, *25*(1), 107-123. *Environmental Processes*, *8*, 455-482.
9. Akankali, J. A., Kaakpo, E. B. and Davies, I. C. (2023). Illegal Crude Oil Bunkering Activities: Assessment of Its Effects on the Water Quality of Elelenwo River, Niger Delta, Nigeria. *Journal of Wetlands and Waste Management.* 5 (1):1-10.
10. Arojojoye, O. A., Oyagbemi, A. A., & Afolabi, J. M. (2018). Toxicological assessment of heavy metal bioaccumulation and oxidative stress biomarkers in Clarias gariepinus from Igbokoda River of South Western Nigeria. *Bulletin of environmental contamination and toxicology*, *100*, 765-771.
11. Ngo-Massou, V. M., Kottè-Mapoko, E. F., & Din, N. (2022). Heavy metal accumulation in the edible crab Cardisomaarmatum (Brachyura: Gecarcinidae) and implications for human health risks. *Scientific African*, e01248.
12. Davies, I. C., Wokeh K. O., Mohamad N. A. and Fathurrahman L. (2023). Assessment of Temporal Variation of Water Quality Parameters and Ecotoxic Trace Metals in Southern Nigeria Coastal Water. *Polish Journal of Environmental Studies*. 32, (5): 1-10.
13. Unaeze, H., &Ibim, A. (2013). Adaptive Mechanisms of Rural Fishermen Towards Climate Change on Quantity of Fish Caught in Asari-toru Local Government Area of Rivers State Nigeria. *Journal of Biology, Agriculture and Healthcare*, *3*(17), 43-48.
14. Akinrotimi, O. A., Edun, O. M., & Williams Ibama, J. E. (2015). The roles of brackish water aquaculture in fish supply and food security in some coastal communities of Rivers State, Nigeria. *Int J Agri Sci Foof Technol*, *19*, 36-50.
15. APHA, 2005. Standard Methods for the Examination of Water and Wastewater, 21st ed. Washington DC: American Public Health Association.

16. Luo, J., Ye, Y., Gao, Z., Wang, Y., & Wang, W. (2016). Trace element (Pb, Cd, and As) contamination in the sediments and organisms in Zhalong Wetland, Northeastern China. *Soil and Sediment Contamination: An International Journal*, *25*(4), 395-407.
17. Chris, D. I., Onyena, A. P., & Sam, K. (2023). Evaluation of human health and ecological risk of heavy metals in water, sediment and shellfishes in typical artisanal oil mining areas of Nigeria. *Environmental Science and Pollution Research*, 1-15.
18. Oguguah, N. M., Onyekachi, M., &Ikegwu, J. (2017). Concentration and human health implications of trace metals in fish of economic importance in Lagos Lagoon, Nigeria. *Journal of Health and Pollution*, *7*(13), 66-72.
19. US EPA, US Environmental Protection Agency Office of Pesticide Programs (2006). [48]
20. USEPA, United States Environmental Protection Agency Region III Risk-Based Concentration (RBC) Table 2008. United States Environmental Protection Agency, Washington, DC, USA, 2012.
21. Zhou, H., Yang, W. T., Zhou, X., Liu, L., Gu, J. F., Wang, W. L., ... & Liao, B. H. (2016). Accumulation of heavy metals in vegetable species planted in contaminated soils and the health risk assessment. *International journal of environmental research and public health*, *13*(3), 289.
22. Rahaman, M. S., Rahman, M. M., Mise, N., Sikder, M. T., Ichihara, G., Uddin, M. K., ... & Ichihara, S. (2021). Environmental arsenic exposure and its contribution to human diseases, toxicity mechanism and management. *Environmental Pollution*, *289*, 117940.
23. World Health Organization. (2009). World health statistics 2009. World Health Organization.
24. Dórea, J. G. (2019). Environmental exposure to low-level lead (Pb) co-occurring with other neurotoxicants in early life and neurodevelopment of children. *Environmental Research*, *177*, 108641.
25. Olufemi, A. C., Mji, A., &Mukhola, M. S. (2022). Potential health risks of lead exposure from early life through later life: implications for public health education. *International Journal of Environmental Research and Public Health*, *19*(23), 16006.
26. Pal, D., & Maiti, S. K. (2019). Evaluation of potential human health risks from toxic metals via consumption of cultured fish species Labeorohita: a case study from an urban aquaculture pond. *Exposure and Health*, *11*, 33-46.
27. Bonaventura, P., Benedetti, G., Albarède, F., &Miossec, P. (2015). Zinc and its role in immunity and inflammation. *Autoimmunity reviews*, *14*(4), 277-285.
28. Gunturu, S., &Dharmarajan, T. S. (2020). Copper and zinc. *Geriatric Gastroenterology*, 1-17.
29. Li, J., Miao, X., Hao, Y., Xie, Z., Zou, S., & Zhou, C. (2020). Health risk assessment of metals (Cu, Pb, Zn, Cr, Cd, As, Hg, Se) in angling fish with different lengths collected from Liuzhou, China. *International Journal of Environmental Research and Public Health*, *17*(7), 2192.
30. Fatima, G., Raza, A. M., Hadi, N., Nigam, N., & Mahdi, A. A. (2019). Cadmium in human diseases: It's more than just a mere metal. *Indian Journal of Clinical Biochemistry*, *34*, 371-378.
31. Isangedighi, I. A., & David, G. S. (2019). Heavy metals contamination in fish: effects on human health. *Journal of Aquatic Science and Marine Biology*, *2*(4), 7-12.
32. Zahra, N., & Kalim, I. (2017). Perilous effects of heavy metals contamination on human health. *Pakistan Journal of Analytical & Environmental Chemistry*, *18*(1), 1-17.
33. Bathla, S., & Jain, T. (2016). Heavy metals toxicity. *International Journal of Health Sciences and Research*, *6*(5), 361-368.
34. Sankhla, M. S., Sharma, K., & Kumar, R. (2017). Heavy metal causing neurotoxicity in human health. *International Journal of Innovative Research in Science. Engineering and Technology*, *6*(5).
35. Li, J., Miao, X., Hao, Y., Xie, Z., Zou, S., & Zhou, C. (2020). Health risk assessment of metals (Cu, Pb, Zn, Cr, Cd, As, Hg, Se) in angling fish with different lengths collected from Liuzhou, China. *International Journal of Environmental Research and Public Health*, *17*(7), 2192.
36. Chasapis, C. T., Ntoupa, P. S. A., Spiliopoulou, C. A., & Stefanidou, M. E. (2020). Recent aspects of the effects of zinc on human health. *Archives of toxicology*, *94*, 1443-1460.
37. Chen, L., Zhou, S., Shi, Y., Wang, C., Li, B., Li, Y., & Wu, S. (2018). Heavy metals in food crops, soil, and water in the Lihe River Watershed of the Taihu Region and their potential health risks when ingested. *Science of the total environment*, *615*, 141-149.
38. Sousa, L., Oliveira, M. M., Pessoa, M. T. C., & Barbosa, L. A. (2020). Iron overload: Effects on cellular biochemistry. *ClinicaChimica Acta*, *504*, 180-189.
39. Palma-Lara, I., Martínez-Castillo, M., Quintana-Pérez, J. C., Arellano-Mendoza, M. G., Tamay-Cach, F., Valenzuela-Limón, O. L., ... & Hernández-Zavala, A. (2020). Arsenic exposure: A public health problem leading to several cancers. *Regulatory Toxicology and Pharmacology*, *110*, 104539.

40. Lee, B. J., Kim, B., & Lee, K. (2014). Air pollution exposure and cardiovascular disease. *Toxicological research*, *30*, 71-75.
41. Osredkar, J., & Sustar, N. (2011). Copper and zinc, biological role and significance of copper/zinc imbalance. *J Clinic Toxicol S*, *3*(2161), 0495.
42. Bandmann, O., Weiss, K. H., & Kaler, S. G. (2015). Wilson's disease and other neurological copper disorders. *The Lancet Neurology*, *14*(1), 103-113.
43. Cao, S., Duan, X., Zhao, X., Chen, Y., Wang, B., Sun, C., ... & Wei, F. (2016). Health risks of children's cumulative and aggregative exposure to metals and metalloids in a typical urban environment in China. *Chemosphere*, *147*, 404-411.
44. Satarug, S., Vesey, D. A., &Gobe, G. C. (2017). Health risk assessment of dietary cadmium intake: do current guidelines indicate how much is safe?. *Environmental health perspectives*, *125*(3), 284-288.
45. Khan, R., Saxena, A., Shukla, S., Sekar, S., Senapathi, V., & Wu, J. (2021). Environmental contamination by heavy metals and associated human health risk assessment: a case study of surface water in Gomti River Basin, India. *Environmental Science and Pollution Research*, *28*(40), 56105-56116.
46. Renieri, E. A., Alegakis, A. K., Kiriakakis, M., Vinceti, M., Ozcagli, E., Wilks, M. F., &Tsatsakis, A. M. (2014). Cd, Pb and Hg biomonitoring in fish of the Mediterranean region and risk estimations on fish consumption. *Toxics*, *2*(3), 417-442.
47. Genchi, G., Sinicropi, M. S., Lauria, G., Carocci, A., & Catalano, A. (2020). The effects of cadmium toxicity. *International journal of environmental research and public health*, *17*(11), 3782.
48. US EPA. 2005. U.S. Environmental Protection Agency. Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities. EPA530-R-05-006. September 2005.
49. Flora, S. J., & Agrawal, S. (2017). Arsenic, cadmium, and lead. In *Reproductive and developmental toxicology* (pp. 537-566). Academic Press.
50. Collin, M. S., Venkatraman, S. K., Vijayakumar, N., Kanimozhi, V., Arbaaz, S. M., Stacey, R. S., ... &Swamiappan, S. (2022). Bioaccumulation of lead (Pb) and its effects on human: A review. *Journal of Hazardous Materials Advances*, *7*, 100094.
51. Ke, S., Cheng, X. Y., Zhang, N., Hu, H. G., Yan, Q., Hou, L. L., ... & Chen, Z. N. (2015). Cadmium contamination of rice from various polluted areas of China and its potential risks to human health. *Environmental monitoring and assessment*, *187*, 1-11.