Potential Health Hazards of Consuming Lutjanus Goreensis from Coastal Waters in the Niger Delta Contaminated with Toxic Metals

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ABSTRACT

This study investigates the health risks associated with trace elements in Gorean snapper (*Lutjanus goreensis*) from Buguma Creek, Southern Nigeria. Fish samples were collected monthly from May to August 2023, and muscle tissues were analyzed for potential health risks posed by elevated levels of hazardous metals. The concentrations of various heavy metals (Fe, Zn, Pb, Cd, Cu, and As) in Gorean Snapper collected from different locations (Station 1, Station 2, and Station 3) were measured in milligrams per kilogram (mg/Kg) of fish tissue. Results revealed varying metal concentrations across stations, with notable differences in Fe, Zn, Pb, Cd, Cu, and As levels. The Estimated Daily Intake (EDI) values for Cadmium (Cd) were relatively low for both adults and children across all three stations. However, Lead (Pb) and Arsenic (As) exhibited low EDI values, while Zinc (Zn) showed significantly higher values, especially at Station 3. The Hazard Quotient (HQ) and Hazard Index (HI) results indicated potential health risks associated with Zinc exposure, particularly at Station 3, for both adults and children. Carcinogenic Risk (CR) analysis revealed potential health risks associated with long-term exposure to Cadmium for adults. The CR values for Lead and Arsenic fell within acceptable ranges. This study raises concerns about potential health risks associated with the consumption of *L. goreensis* from Buguma and recommends the continuous monitoring of heavy metal concentrations, public awareness programs, further research, collaboration among stakeholders, and the implementation of best practices in aquaculture and fisheries management to reduce heavy metal concentrations in fish.

Keywords: Health Risks, Metal Concentration, Gorean Snapper, Bungoma.

INTRODUCTION

The Niger Delta region of Nigeria, renowned for its vast oil and gas reserves, has witnessed extensive exploration and exploitation activities in the past decades (Ite *et al*., 2013). However, alongside its resource wealth, the region has grappled with a multitude of challenges, stemming from activities such as sabotage, crude oil theft, artisanal refining, and operational spills, which have adversely affected both terrestrial and aquatic ecosystems (Lindén and Plsson, 2013; United Nations Environment Programme, (2011). Among the regions of particular concern within the Niger Delta are the intertidal mangrove swamps, with Buguma

Creek standing out as a prominent example (Gundlach, 2018).

Buguma Creek features a shoreline connecting to the ocean and an intricate network of interconnected creeks, rivers, and extensive mangrove swamps. The inhabitants of Buguma primarily rely on fishing for sustenance and economic livelihood (Amachree, 2018). Seafood, including a wide variety of marine delicacies, plays a pivotal role in the local diet (Elkribi-Boukhris *et al.*, 2022). However, a primary environmental concern in this area relates to the presence of hazardous metals due to crude oil pollution in coastal waters (Pegg and Zabbey, 2013).

The rural communities in the Niger Delta have experienced substantial industrial expansion, commercial activities, and population growth, leading to increased waste production. Inadequate waste disposal practices have resulted in pollution of the air, land, and water resources. Industries and abattoirs in the region often discharge untreated or inadequately treated wastewater and effluents from artisanal crude oil refining into water bodies, contributing to water pollution. Of particular concern are heavy metals present in some of this untreated wastewater, posing risks to aquatic life, human health, and the overall ecological equilibrium. These heavy metals are particularly worrisome due to their non-degradable, toxic, and persistent nature, as they can disrupt aquatic ecosystems.

The Buguma people, deeply interconnected with their environment, are vulnerable to heavy metal poisoning through the food web. Their reliance on the river for fishing, agriculture, and various commercial activities means that they are at risk through both direct consumption of water containing metals and the ingestion of river-caught fish. The pollution and its toxicological effects have led to the underutilization of the river. In response to these challenges, this study aims to identify and address the existing shortcomings to optimize the use of Buguma Creek. While previous research in the Niger Delta has identified high levels of toxic metal contamination in various environments, including rivers, creeks, dumpsites, automotive repair shops, agricultural farms, and urban areas, there is a notable absence of data on the health and ecological risks associated with heavy metals in water, sediment, and shellfish within Buguma Creek (Ihuoma *et al.*, 2020; Joseph *et al.*, 2022; Offiong *et al.*, 2022; Ubong *et al.*, 2023). Thus, this research seeks to fill this knowledge gap.

It is of utmost importance to investigate the potential health and ecological concerns associated with toxic metals in water and sediment, as well as the toxicity of certain fish species known to accumulate these metals in their tissues, which may pose risks to human health.

MATERIAL AND METHODS

Description of the Study Area

Study Area

Buguma Creek is located in Asari-Toru Local Government in Rivers State. Three sampling stations were strategically established within the Creek, each with unique characteristics. Station 1, Amanyanabo Okolo (Maryhood Bridge; Latitude 4°44’19.0932"N; Longitude 6°52’3.8568"E), positioned downstream, primarily serves as a major landing site for artisanal bunkering products, with additional activities such as mangrove firewood collection. Station 2, Amanyanabo Okolo (trans-Kalabari by/Buguma North; Latitude 4°44’40.9488"N; Longitude 6°51’56.7036"E), located downstream, focuses on fishing and mangrove firewood cutting. Station 3, Ido Canal; Latitude 4°44’40.722"N; Longitude 6°51’25.7544"E, situated upstream, engages in activities like sand mining, fishing, and periwinkle collection. These stations were carefully chosen to provide a comprehensive understanding of different areas and activities within the Creek for thorough data collection and analysis.

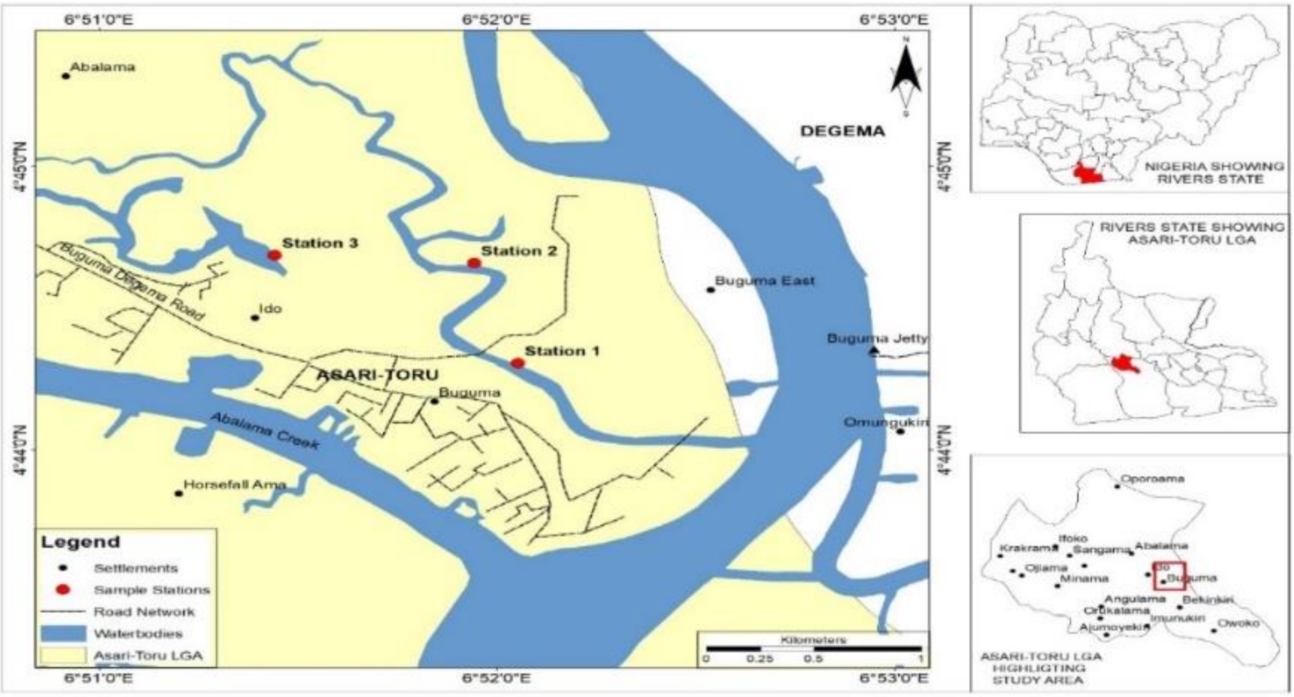

Figure 1. A map of the study Stations; Station 1=Amanyanabo Okolo, Station 2=Amanyanabo Okolo and Station 3=Ido Canal).

Sampling and Digestion of Fish Samples

Gorean snapper (*Lutjanus goreensis*) 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 before being transported to the laboratory. The lengths (24 cm) and weight (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. The analyzed fish sample is a species that is ingested predominantly throughout the year from the impoundment.

Following the process of chilling 5 fish samples per station, one gram of each 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 following the methodology specified in APHA (2005). 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.

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 APHA (2005) manual. The instrument was configured and operated in strict adherence to the manufacturer's specifications.

Human Health Risk Indices Assessment

Estimated daily intake

The heavy metal levels were computed 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 (Luo *et al*., 2012). 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). Chris *et al*. (2023) developed the method, which is represented in Equation 1, for determining the EDI of metals in the consumable tissues of Gorean snapper (*L. goreensis*) in this study.

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

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 Oguguah *et al*., 2017; 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 Oguguah *et al*., 2017 and applies to edible tissues of shellfish; Cm signifies the metal concentration in edible tissues of Gorean snapper (*L. goreensis*) 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 (USEPA), 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 2.

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

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

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, following the USEPA's (2006) 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 (Equation 3) .

$$HQ = CDE/RfD \qquad (3)$$

The Hazard Index (HI)

The hazard index (HI) represents the sum of all potential dangers associated with pollutant absorption. Equation 4, which is a sum of non-carcinogenic effects, is used to calculate it:

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

Where, HI = Hazard index for a specific exposure pathway. The US EPA classifies non-carcinogenic effects (HI <1) as acceptable risk and does not require any policy action from a human health standpoint (USEPA, 2005). 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 US EPA.

Carcinogenic risk assessment (CR)

CR is the lifetime cancer risk probability associated with the ingestion or inhalation of Gorean snapper (*L. goreensis*) 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 USEPA (2012) 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 (Zhang *et al*., 2016).

The cancer risk of the present study was calculated using the expression:

$$CR = CDE*CSF \qquad (5)$$

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. Accordance to the USEPA (2017), metal concentrations are considered detrimental to human health when the cancer risk (CR) ranges exceed 10^{-6} or 10^{-4} (Rahaman *et al.*, 2021).

RESULTS

Table 1 presents the concentrations of various heavy metals (Fe, Zn, Pb, Cd, Cu, and As) in Gorean Snapper (*Lutjanus goreensis*) collected from different locations (Station 1, Station 2, and Station 3). The values are expressed in milligrams per kilogram (mg/Kg) of fish tissue. The highest Fe concentration was in station 2 (20.17±3.24) while the least was in station 3 (17.56±3.19). Zinc (Zn) concentration was highest in Station 3 (132.33±11.91) and lowest in Station 1 (101.34±4.29). however, Lead (Pb) recorded highest at Stations 1 and 2 (0.008±0.004) and the lowest at Station 2 (0.007±0.003). Cadmium (Cd) concentration was highest in Stations 1 and 2 (0.013±0.01) and lowest in Station 2 (0.012±0.00). Copper (Cu) was highest in Station 2: 0.85±0.04 and least in Station 1: 0.81±0.03. However, Arsenic (As) was similar across the stations (0.002±0.00). The concentrations of metals in the three stations were recorded in a similar, decreasing order: Zn>Cu>Pb>Cd >Fe>As. Fe concentrations in Station 2 had a significantly higher ($P < 0.05$) value than in Station 1 and 2, while Station 3 is not significantly different ($P > 0.05$) from Station 1. Similar Zn had significantly different values ($P < 0.05$) across the stations while Pb, Cd, Cu and As showed no statistical significance ($P > 0.05$).

Table 1: Mean concemtrtaions of metals in Gorean snapper (*L. goreensis*)

L. goreensis						
Locations	**Fe (mg/Kg)**	**Zn (mg/Kg)**	**Pb (mg/Kg)**	**Cd (mg/Kg)**	**Cu (mg/Kg)**	**As (mg/Kg)**
Station 1	17.75±0.37^{b}	101.34±4.29 ^{b}	0.008±0.004^{a}	0.013±0.01^{a}	0.81±0.03 ^{a}	0.002±0.00 ^{a}
Station 2	20.17±3.24^{a}	113.26±5.99 ^{ab}	0.007±0.003^{a}	0.012±0.00^{a}	0.85±0.04 ^{a}	0.002±0.00 ^{a}
Station 3	17.56±3.19^{b}	132.33±11.91^{a}	0.008±0.004^{a}	0.013±0.01^{a}	0.82±0.04 ^{a}	0.002±0.00 ^{a}

Estimated Daily Intake (EDI) of *L. goreensis*

Table 2 displays the Estimated Daily Intake (EDI) of heavy metals in (fish) *L. goreensis* for adults and children from the three different sample stations. The EDI represents the amount of a particular contaminant that an individual is estimated to ingest daily through the consumption of the fish. The EDI value for Cadmium (Cd) value was not significantly different ($p > 0.05$) for adults and children between all three stations. The EDI values for Cd are relatively low for both adults and children across all three stations.

However, Lead (Pb) and Arsenic (As) values did not differ significantly in EDI values for adults and children between all three stations. The EDI values for Pb and As are relatively low for both adults and children across all three stations. Meanwhile, Zinc (Zn) values varied significantly in EDI values for both adults and children between all three stations, with Station 3 having the highest EDI values. The EDI values for Zn are relatively high for both adults and children at all three stations.

When considering Iron (Fe) and Copper (Cu), is there a notable difference in EDI (Estimated Daily Intake) values for both adults and children across all three stations? Station 2 appears to have the highest EDI values. Additionally, the EDI values for Fe and Cu are relatively high for both adults and children at all three stations.

The table suggests that consuming *L. goreensis* fish from all three stations may result in a relatively high EDI for Zn, Fe and Cu, while the EDI values for Cd, Pb and As are relatively low. There is a significant variation in EDI values for these contaminants across different stations, which implies that some stations may have relatively higher contaminant levels in the fish.

Table 2: Estimated Daily Intake (EDI) of *L. goreensis*

	Station 1		**Station 2**		**Station 3**	
Heavy Metal	**Adults**	**Children**	**Adults**	**Children**	**Adults**	**Children**
Cd	0.001587	0.001482	0.001465	0.001368	0.001587	0.001482
Pb	0.000977	0.000912	0.000855	0.000798	0.000977	0.000912
Zn	28.87496	134.7498	32.27134	150.5996	37.70499	175.9566
Fe	5.057534	23.60183	5.747068	26.81965	5.003397	23.34919
As	0.000244	0.000228	0.000244	0.000228	0.000244	0.000228
Cu	0.230795	1.077041	0.242192	1.130228	0.233644	1.090338

Hazard quotient (HQ) and Hazard index (HI) of the contaminated *Lutjanus goreensis*

Table 3 shows the results of the Hazard Quotient (HQ) and Hazard Index (HI) of heavy metals in contaminated fish (*L. goreensis*) for adults and children groups at the three sampled stations. For the adults group, the HQ value of Cd varied between 1.46536E-06 in station 2 and 1.58748E-06 in stations 1 and 3. However, the HQ value for Pb varies between 3.41918E-06 in station 2 and 3.90763E-06 in stations 1 and 3. For Zn, the highest HQ values were (11.31149589) in Station 3, followed by (9.68140274) in Station 2 and the least (8.662487671) in Station 1 respectively. The highest value (0.057470685) of Fe was recorded in station 2 followed by 0.050033973 in station 3, while the lease values (0.050575342) were reported in station 1. As showed similar values of 7.32681E-08 between all three stations. The HQ value for Copper (Cu) varied between 0.009231781 in station 1 and 0.009687671 in station 2.

For the children group, the HQ value of Cd varied between 1.36767E-06 in station 2 and 1.48164E-06 in stations 1 and 3. But, the HQ value for Pb varies between 3.19123E-06 in station 2 and 3.64712E-06 in stations 1 and 3. In Zn, the highest HQ values were 52.78698082 in Station 3, followed by 45.17987945 in Station 2 and the least 40.42494247 in Station 1. However, for Fe, the highest HQ value (0.26819653) was recorded in station 2 followed by 0.236018265 in station 1, while the lease values (0.233491872) were reported in station 3. The As HQ values were similar (6.83836E-08) between the three stations while that of Copper (Cu) varied between 0.043081644 in station 1 and 0.045209132 in station 2. The children have the highest HI values (53.06409141) recorded at Station 3 while that of adults (11.37088118) was at Station 3. Therefore, the children group have the highest HI values at Station 3.

Table 3: Hazard quotient (HQ) and Hazard index (HI) of the contaminated *L. goreensis*

	Station 1		**Station 2**		**Station 3**	
Heavy Metal	**Adults**	**Children**	**Adults**	**Children**	**Adults**	**Children**
Cd	1.58748E-06	1.48164E-06	1.46536E-06	1.36767E-06	1.58748E-06	1.48164E-06
Pb	3.90763E-06	3.64712E-06	3.41918E-06	3.19123E-06	3.90763E-06	3.64712E-06
Zn	8.662487671	40.42494247	9.68140274	45.17987945	11.31149589	52.78698082
Fe	0.050575342	0.236018265	0.057470685	0.26819653	0.050033973	0.233491872
As	7.32681E-08	6.83836E-08	7.32681E-08	6.83836E-08	7.32681E-08	6.83836E-08
Cu	0.009231781	0.043081644	0.009687671	0.045209132	0.009345753	0.043613516
HI	**8.722300363**	**40.70404757**	**9.748566054**	**45.49328974**	**11.37088118**	**53.06409141**

Carcinogenic risk to both age groups

Table 4 shows the carcinogenic risk for adults and children group from exposure to Cd, As and Pb in the *L. goreensis* samples from three different stations. The Cd, As and Pb carcinogenic risk (CR) was calculated due to the availability of the cancer-causing power slope factor for those metals. In the adults group, the CR values for Cd (5.56837E-07) were highest in station 2 and the lowest values of 6.03242E-07 were in stations 1 and 3. Similarly, the CR values for Pb range between 2.9063E-08 in station 2 and 3.32149E-08 in stations 1 and 3. However, the CR values of 1.09902E-07 were recorded for As at the three stations. The CR values for these metals in the Adult group fall within this acceptable range of 10^{-6} to 10^{-4}.

For the children group, the CR values for Cd (5.19715E-07) were highest in station 2 and the lowest values of 5.63023E-07 were in stations 1 and 3. Similarly, the CR values for Pb range between 2.71255E-08 in station 2 and 3.10005E-08 in stations 1 and 3. However, the CR values As (1.02575E-07) were recorded was the three stations. The CR values were within this acceptable range of 10^{-6} to 10^{-4} which indicates a negligible health risk.

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

	Station 1		**Station 2**		**Station 3**	
Heavy Metal	**Adults**	**Children**	**Adults**	**Children**	**Adults**	**Children**
Cd	6.03242E-07	5.63023E-07	5.56837E-07	5.19715E-07	6.03242E-07	5.63023E-07
Pb	3.32149E-08	3.10005E-08	2.9063E-08	2.71255E-08	3.32149E-08	3.10005E-08
As	1.09902E-07	1.02575E-07	1.09902E-07	1.02575E-07	1.09902E-07	1.02575E-07

DISCUSSION

Estimated Daily Intake (EDI) of heavy metals in *Lutjanus goreensis*

EDI values for Cadmium (Cd) are consistently low for both adults and children across all three stations, indicating a relatively low risk of daily exposure to Cd through fish consumption for both age groups. Similarly, EDI values for Lead (Pb) and Arsenic (As) are relatively low for both adults and children at all three stations, signifying minimal daily health risks associated with Pb and As exposure through fish consumption for both age groups. This was similar to reports from other works in the Niger Delta, (Chris *et al*

., 2023; Anyanwu and Chris, 2023; Davies and Anyanwu, (2023). The Estimated Daily Intake (EDI) of heavy metals in *L. goreensis* from the three different sample stations raises concerns for both human and aquatic life.

The EDI values for Zinc (Zn) exhibit significant variability among stations and are relatively high for both adults and children at all three stations. This suggests that the consumption of *L. goreensis* may lead to a relatively high daily intake of Zn, which could have health implications, particularly if these elevated levels persist over time. Notably, Station 2 stands out with the highest EDI values for Iron (Fe) and Copper (Cu), highlighting significant variations among stations. EDI values for Fe and Cu are relatively high for both adults and children at all three stations, suggesting that elevated levels of these metals may have health implications for individuals who regularly consume fish from these areas (Rakib *et al*., 2021).

Zinc (Zn) is an essential trace mineral that plays a role in immune function, wound healing, growth, and development (Lin *et al*., 2017). Silva *et al*. (2019) suggest that excessive intake of Zn can interfere with the absorption of other minerals, such as copper, iron, and calcium. However, high levels of Zn can also cause nausea, vomiting, diarrhoea, abdominal cramps, headaches, and reduced immune function (Mouli *et al*., 2019). Therefore, consuming *L. goreensis* with high Zn content may pose a risk of zinc toxicity, especially for children who have lower tolerable upper intake levels (ULs) than adults.

Iron (Fe) is an important component of haemoglobin, the protein that carries oxygen in the blood (Theil *et al* ., 2009). According to Elstrott *et al*. (2020), iron deficiency can lead to anaemia, which causes fatigue, weakness, and increased susceptibility to infections. However, too much iron can also be harmful, as it can accumulate in the liver, heart, and other organs and cause damage (Skalnaya and Skalny, 2018). Excess iron can cause nausea, vomiting, diarrhoea, stomach pain, liver failure, and even death in severe cases (Awuchi *et al*., 2020). Therefore, consuming *L. goreensis* with high Fe content may increase the risk of iron overload, especially for people who have hemochromatosis or other conditions that affect iron metabolism.

Copper (Cu) is another essential trace mineral that is involved in energy production, iron metabolism, antioxidant defence, and nervous system function (Mezzaroba *et al*., 2019). Copper deficiency can cause anaemia, neutropenia, osteoporosis, and neurological problems (Altarelli *et al*., 2019). However, Pohanka, (2019) suggested that excess copper can also be toxic, as it can accumulate in the liver and brain and cause damage. High levels of copper can cause nausea, vomiting, diarrhoea, abdominal pain, liver failure, and neurological symptoms such as tremors, depression, and psychosis (Obasi and Akudinobi, 2020). Therefore, consuming *L. goreensis* with high Cu content may increase the risk of copper toxicity, especially for people who have Wilson's disease or other conditions that affect copper metabolism.

The consumption of *L. goreensis* from the three different sample stations may have health implications for both human and aquatic life due to the varying levels of heavy metals in the fish (Jomova *et al*., 2022). While some of these metals are essential for normal physiological functions, their excess or deficiency can cause adverse effects on various organs and systems (Zoroddu *et al*., 2019). Therefore, it is important to monitor the quality of water and fish in these areas and to limit the intake of fish that contain high amounts of potentially harmful metals.

Hazard Quotient (HQ) and Hazard Index (HI) of heavy metals in contaminated *Lutjanus goreensis*

The results regarding the Hazard Quotient (HQ of heavy metals in contaminated *Lutjanus goreensis* have implications for both human and aquatic life health. The HQ values for Cd are consistently above 1 for all three stations. This indicates a potential health hazard from Cd exposure through fish consumption for adults at all stations. Similar to Cd, the HQ values for Pb are above 1 for all three stations, suggesting a potential health risk associated with Pb exposure for adults. Cadmium (Cd) is a toxic metal that can accumulate in the kidneys and cause kidney damage, bone loss, and hypertension (Fatima *et al*., 2019). However, Cd can also affect the nervous system, the reproductive system, and the immune system. Cd exposure can increase the risk of cancer (Rehman *et al*., 2018), especially lung and prostate cancer. Therefore, consuming *L. goreensis* with high Cd content may pose a serious health hazard for both adults and children who regularly eat fish from these areas.

The highest HQ value for Zn is in Station 3, and it is also above 1. Stations 2 and 3 show HQ values exceeding 1, indicating a potential health risk for adults due to Zn exposure through fish consumption. Zinc (Zn) is an essential trace mineral that plays a role in immune function, wound healing, growth, and development (Lin *et al*., 2017). However, excessive intake of Zn can interfere with the absorption of other minerals, such as copper, iron, and calcium (Silva *et al*., 2019). High levels of Zn can also cause nausea, vomiting, diarrhoea, abdominal cramps, headaches, and reduced immune function (Mouli *et al*., 2019). Therefore, consuming *Lutjanus goreensis* with high Zn content may pose a risk of zinc toxicity, especially for children who have lower tolerable upper intake levels (ULs) than adults.

While there is variation in Fe HQ values among stations, all values are below 1, suggesting a relatively low health risk associated with Fe exposure for adults (Huang *et al*., 2008). The HQ values for As are consistent and very low, indicating a minimal health risk for adults (Alidadi *et al*., 2019). While the HQ values for Cu are consistently below 1, suggesting a relatively low health risk for adults (Li *et al*., 2020).

The highest HQ values for adults are observed at Station 3, indicating a potential cumulative health risk resulting from exposure to multiple contaminants. Likewise, for children, HQ values for Cd consistently exceed 1 at all three stations, implying a potential health hazard associated with Cd exposure through fish consumption (Emam *et al*., 2021). In the case of Pb, children's HQ values surpass 1 at all three stations, signifying potential health risks linked to Pb exposure. Lead (Pb) is another toxic metal that can affect various organs and systems, such as the brain, the blood, the bones, and the kidneys (Collin *et al*., 2022). According to Ramírez Ortega *et al*. (2021), Pb exposure can cause neurological problems, such as cognitive impairment, behavioural disorders, and learning difficulties. Pb can also cause anaemia, hypertension, kidney failure, and reproductive problems (Leal *et al*., 2023). Pb exposure can increase the risk of cancer, especially stomach and lung cancer. Therefore, consuming *L. goreensis* with high Pb content may pose a significant health risk for both adults and children who frequently consume fish from these areas.

The most elevated HQ value for Zn is found at Station 3, where it also exceeds 1, while Stations 2 and 3 display HQ values above 1, suggesting potential health risks for children due to Zn exposure through fish consumption (Rehman *et al*., 2018). Similar to adults, children's HQ values for Fe remain below 1, indicating a relatively low health risk associated with Fe exposure. HQ values for As consistently remain low, signifying minimal health risk for children (Fatima *et al*., 2019). HQ values for Cu consistently fall below 1, suggesting a relatively low health risk for children.

The HI values for children are the highest at Station 3, indicating a potential cumulative health risk from exposure to multiple contaminants, similar to adults. The results suggest that consuming contaminated *L. goreensis* fish may pose a potential health risk, especially for Cd, Pb, and Zn exposure for both adults and children. The HI values for both age groups also indicate a potential cumulative health risk from exposure to multiple contaminants (Christensen *et al*., 2014).

The results suggest that consuming contaminated *L. goreensis* fish may pose a potential health risk for both human and aquatic life due to the varying levels of heavy metals in the fish. According to Jomova *et al*. (2022), some of these metals are essential for normal physiological functions, but their excess or deficiency can cause adverse effects on various organs and systems. Therefore, it is important to monitor the quality of water and fish in these areas and to limit the intake of fish that contain high amounts of potentially harmful metals.

Carcinogenic risk (CR) in *L. goreensis* fish from three different stations.

The results imply that consumption of *L. goreensis* fish from three stations may pose a potential health risk for both adults and children due to the increased carcinogenic risk from long-term exposure to Cadmium (Cd). The consistently elevated carcinogenic risk values for Cd are of particular concern, indicating a significant risk of cancer development (Ke et al., 2015). However, the carcinogenic risk values for Lead (Pb) and Arsenic (As) are below the level of concern, suggesting that exposure to these contaminants through fish consumption does not pose a significant risk of cancer development for both adults and children. The carcinogenic risk (CR) of heavy metals in *L. goreensis* fish has implications for both human and aquatic life health.

The CR values for Cd, Pb, and As fall within the acceptable range of 10^-6 to 10^-4, indicating a relatively low carcinogenic risk for adults at all three stations. However, it is essential to continue monitoring and controlling heavy metal contamination to maintain these low risks and ensure the long-term health of both human and aquatic life.

To assess the potential health hazards associated with specific contaminants, the USEPA has established cancer risk (CR) ranges. According to USEPA (2017), when the cancer risk (CR) ranges are greater than 10^-6 or 10^-4, it indicates that the concentrations of the said metals can be regarded as hazardous to health. This means that CR values in this study falling within these ranges suggest a potential risk to human health due to long-term exposure to the specified contaminants.

Raknuzzaman *et al*. (2016) suggested that CR values within this range indicate a negligible or low health risk associated with long-term exposure to these specific contaminants through the consumption of the analyzed fish. This is reassuring for both adults and children. However, when CR values are within the range set by USEPA, it suggests that the concentrations of these metals in the fish samples are below levels that would typically be considered hazardous to health (Wang *et al*., 2020). This compliance with safety standards is essential for protecting the health of consumers.

The CR values falling within the range of 10^-6 to 10^-4 indicate that the concentrations of Cd, Pb, and As in the *L. goreensis* fish samples are not currently regarded as hazardous to health. This is a positive outcome, but ongoing vigilance is required to ensure that these levels remain within safe limits. Therefore, the results are encouraging, however, it’s important to continue monitoring and controlling heavy metal contamination in fish to maintain these low risks over time.

Arsenic (As) is a carcinogenic metal that can cause various types of cancer, such as skin, lung, bladder, and liver cancer (Zhou and Xi, 2018). As can also affect the skin, the nervous system, the cardiovascular system, and the respiratory system. As exposure can cause skin lesions, peripheral neuropathy, hypertension, and pulmonary diseases (Khairul *et al*., 2017). Therefore, consuming *L. goreensis* with high As content may pose a carcinogenic risk for both adults and children who regularly eat fish from these areas.

Cadmium (Cd) is another carcinogenic metal that can cause cancer of the kidney, the prostate, the lung, and the pancreas (Genchi *et al*., 2020). Ebrahimi *et al*. (2020) reported that Cd can also accumulate in the kidneys and cause kidney damage, bone loss, and hypertension. However, Genchi *et al*. (2020) also suggested that Cd can also affect the nervous system, the reproductive system, and the immune system. Therefore, consuming *Lutjanus goreensis* with high Cd content may pose a carcinogenic risk for both adults and children who frequently consume fish from these areas.

Lead (Pb) is a third carcinogenic metal that can cause cancer of the stomach, the lungs, the brain, and the kidney (Zhou and Xi, 2018). Pb can also affect various organs and systems, such as the brain, the blood, the bones, and the kidneys (Collin *et al*., 2022). Assi *et al*, (2016) reported that Pb exposure can cause neurological problems, such as cognitive impairment, behavioural disorders, and learning difficulties. According to Khairul *et al*. (2017), Pb can also cause anaemia, hypertension, kidney failure, and reproductive problems. Therefore, consuming *Lutjanus goreensis* with high Pb content may pose a carcinogenic risk for both adults and children who often eat fish from these areas.

The results indicate that the carcinogenic risk associated with exposure to As, Cd, and Pb through the consumption of contaminated *Lutjanus goreensis* fish is relatively low for both adults and children at all three stations. These findings are reassuring in terms of cancer risk, as the CR values fall within the acceptable range. However, it is important to monitor and control heavy metal contamination to maintain these low risks and ensure the long-term health of both human and aquatic life. Therefore, the risk of developing cancer from exposure to these specific heavy metals in the analyzed fish samples appears to be low for both adults and children.

CONCLUSION

A study on the Estimated Daily Intake (EDI) of heavy metals in *Lutjanus goreensis* from three sample stations has raised concerns about potential health risks for human and aquatic life. While certain heavy metals, like Cadmium, Lead, and Arsenic, have relatively low EDI values, Zinc, Iron, and Copper show significant variability and higher EDI values, indicating potential health implications. Zinc exposure may have long-term health implications, especially for vulnerable populations like children. Iron and Copper values also highlight the need for careful monitoring. The Hazard Quotient and Hazard Index results highlight potential health risks associated with Zinc exposure, particularly for adults and children. The Carcinogenic Risk analysis indicates a potential health risk associated with long-term exposure to Cadmium, especially for adults, raising concerns about cancer development.

RECOMMENDATIONS

Continuous monitoring of heavy metal concentrations in *Lutjanus goreensis* and the surrounding aquatic environment, public awareness and education programs targeting communities, further research exploring the dynamics of heavy metal accumulation in *L. goreensis*, collaboration among governmental agencies, research institutions, and local communities, and implementation of best practices in aquaculture and fisheries management to reduce heavy metal concentrations in fish is recommended.

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