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# Bioaccumulation Of Heavy Metals In *Crysicthes nigrodigitatus* (Silver Catfish) From The Tombia Axis Of River Nun, Bayelsa State, Nigeria: Implications For Aquatic Life And Human Health Risks

***Godwin P. Angaye[1], Apollos P. Ubi[2] & Ebelemi E. Charles[3]**

**[1]Department of Biology, Bayelsa Medical University, Yenagoa, Bayelsa State, Nigeria.**
**[2]Department of Geography and Environmental Science, University of Port-Harcourt, River State**
**[3]Department of Biological Sciences, Niger Delta University, Wilberforce Island, Nigeria**
**Corresponding author: godwin.angaye@bmu.edu.ng; gpangaye@gmail.com Tel: +2348037933229**

**ABSTRACT**
This study investigates the bioaccumulation of heavy metals in *Crysicthes nigrodigitatus* (Silver Catfish) from the Tombia Axis of River Nun, Bayelsa State, Nigeria, and evaluates the associated health risks to humans and aquatic life. Heavy metal contamination in aquatic ecosystems, primarily from anthropogenic activities such as industrial discharges, agricultural runoff, and domestic waste, is a growing concern in the region. Using a combination of field and laboratory analyses, the study quantified the concentrations of key heavy metals Lead (Pb), Cadmium (Cd), Mercury (Hg), Arsenic (As), Copper (Cu), and Zinc (Zn) in different tissues of *C. nigrodigitatus* (muscle, gills, liver, and skin) across various sampling sites and seasons. Atomic Absorption Spectrophotometry (AAS) was employed to detect the presence of these metals in both fish tissues and water samples. Health risk assessments, including the calculation of carcinogenic and non-carcinogenic risks, were conducted using established frameworks like hazard quotient (HQ). The results revealed significantly low bioaccumulation of Pb, Cd, and Hg, in the liver and gills of the fish, with concentrations with the safe permissible limits for safe human consumption. These findings highlight the need for continuous and improved pollution control as well as public health awareness in the region. The research provides a valuable baseline for future monitoring of heavy metal contamination in River Nun and similar aquatic ecosystems in the Niger Delta.
**Keywords**: Bioaccumulation, heavy metals, *Crysicthes nigrodigitatus*, health risk assessment, River Nun, Bayelsa State, Nigeria, pollution, fish consumption.

## 1. INTRODUCTION

Heavy metal pollution is a significant global environmental issue, especially in aquatic ecosystems. Metals such as lead (Pb), cadmium (Cd), mercury (Hg), and arsenic (As) are introduced into water bodies through industrial activities, agricultural runoff, and waste disposal (Angon et al., 2024; Oladimeji et al., 2024). These pollutants persist in the environment, accumulating in water, sediment, and organisms, posing a serious threat to aquatic life and humans who consume contaminated species. Metals can biomagnify through the food chain, leading to higher concentrations in predators, including fish, which pose potential health risks to both ecosystems and human populations (Dey, 2024).

*Chrysicthes nigrodigitatus* (Silver Catfish) is a widely consumed fish species in West Africa, particularly in Nigeria, due to its high nutritional value. Rich in protein, omega-3 fatty acids, and essential minerals like calcium and phosphorus, it serves as a critical dietary component (Tenyang et al., 2020). Economically, it supports local fisheries, providing income for artisanal fishermen and contributing to the region's food security. Fish affordability and availability make them a staple in the diets of many, particularly in coastal communities (Viana et al., 2013).

Bioaccumulation refers to the process by which toxic substances, particularly heavy metals, accumulate in an organism over time. In aquatic organisms, metals like mercury, cadmium, and lead are absorbed from water and sediment and stored in tissues such as muscle, liver, and gills (Ray & Vashishth, 2024). These metals enter the food chain when organisms are consumed by higher trophic levels, leading to increased concentrations in apex predators like fish.

Heavy metals pose significant health risks to humans, primarily through contaminated water and food sources like fish. Long-term exposure to heavy metals such as mercury and cadmium can lead to chronic diseases, including kidney damage, neurological disorders, and cancer (Balali-Mood et al., 2021). In addition, metals like lead can impair cognitive development in children, while arsenic exposure is linked to developmental effects and skin cancer (Mitra et al., 2022). Consumption of contaminated fish is a primary route for human exposure to these toxins, making it a public health concern in regions with heavy metal pollution.

The Tombia Axis of River Nun is an important water source in Bayelsa State, and *Crysicthes nigrodigitatus* serves as a common fish species consumed by local communities. However, industrial, agricultural, and domestic activities could lead to the introduction of toxic metals into the river system, affecting fish species and posing a threat to human health through consumption.

## 2. METHODOLOGY

### 2.1 Study Area

The study will be conducted in the Tombia Axis of River Nun, located in Bayelsa State, Nigeria. River Nun is part of the Niger Delta ecosystem, an area influenced by both natural and anthropogenic activities, such as dredging, agriculture, municipal, and industrial discharge. The Tombia Axis has been identified as a critical zone for aquatic biodiversity, with *Crysicthes nigrodigitatus* (Silver Catfish) being a common species in the region. The river is significant for local communities, where fishing is one of primary livelihood. The study will focus on four randomly selected locations along the Tombia Axis, chosen based on proximity to potential pollution sources such as industrial discharge points and agricultural runoff.

### 2.2 Sampling Method

A random sampling approach was used to select four sites along the Tombia Axis, representing both high and low-risk areas for heavy metal contamination. Fish samples of *C. nigrodigitatus* were collected in triplicate at each site, with 12 fish caught using artisanal methods, ensuring diversity in size, age, and sex. The fish were transported on ice to the laboratory for analysis. Water samples were also collected at each site, with 2 liters taken in triplicate, preserved with nitric acid, and transported under proper conditions for laboratory analysis.

### 2.3 Laboratory Analysis

The laboratory analysis quantified heavy metals (Lead, Cadmium, Mercury, and Arsenic) in both fish tissues and water samples using standard methods. Fish tissues (muscle, liver, gills, and skin) were homogenized, dried, ground, and digested with nitric and perchloric acids for metal analysis. Water samples were filtered, acidified, and analyzed for heavy metals using Atomic Absorption Spectrophotometry (AAS) (APHA, 2017; Mendelsohn et al., 2019).

### 2.4 Health Risk Assessment

Health risks associated with the consumption of heavy metal-contaminated *C. nigrodigitatus* will be assessed using the following procedures: The hazard quotient (HQ) was calculated for each metal by dividing the estimated daily intake (EDI) by the reference dose (RfD). If $HQ > 1$, there is an increased risk for non-carcinogenic effects. The total hazard index (HI) was derived by summing the individual HQs for all metals (WHO, 2011).

### 2.5 Statistical Analysis

Data were analyzed using SPSS (Version 23) to examine heavy metal concentrations across four sites and fish tissues. Descriptive statistics (mean, standard deviation, range) were computed for fish tissues and water samples. ANOVA was used to compare concentrations across sites and tissues, with significance determined at $p < 0.05$, highlighting variations in contamination levels.

## 3. RESULTS AND DISCUSSION

### 3.1 Concentrations of heavy metals in the muscle tissue

Results presented in Table 1 showed that concentrations of lead in the tissues of *Chrysichthys nigrodigitatus* ranged from 0.005 to 0.011 mg/kg, with the highest concentration in LA and the lowest in LC. Cadmium and mercury were below detection limits (<0.001 mg/kg) in all stations. Chromium was detected in LA (0.002 mg/kg), LB (0.005 mg/kg), and LD (0.004 mg/kg), but below detection in LC. Arsenic was only detected in LC (0.003 mg/kg), with other sites recording BDL values. These findings suggest relatively low but varied levels of heavy metals across sites, with some variation based on location and metal type.

Table 1: Results on the concentrations of metals in the tissues of *Chrysichthys nigrodigitatus*

| Locations | Lead (mg/kg) | Cadmium (mg/kg) | Chromium (mg/kg) | Mercury (mg/kg) | Arsenic (mg/kg) |
|---|---|---|---|---|---|
| LA | 0.011±0.004 | BDL | 0.002±0.00 | BDL | BDL |
| LB | 0.009±0.000 | BDL | 0.005±0.00 | BDL | BDL |
| LC | 0.005±0.002 | BDL | BDL | BDL | 0.003±0.000 |
| LD | 0.007±0.003 | BDL | 0.004±0.001 | BDL | BDL |

Statistical assessment revealed slight spatial variation in heavy metal concentrations across stations LA to LD. Lead showed significant differences, with LA recording the highest mean value. Chromium concentrations also varied, with LB having the highest and LC showing undetectable levels. Arsenic was only present in LC, indicating a localized source. Cadmium and mercury were consistently below detection limits, suggesting minimal contamination. However, no strong statistical significance was observed in inter-site variation due to the low overall concentrations and standard deviations, indicating relatively homogeneous contamination levels across the Tombia Axis.

Health risk assessments showed negligible non-carcinogenic risks from heavy metals in fish, with Hazard Quotients (HQ) below 1 due to low lead and arsenic levels and undetectable mercury and cadmium. Carcinogenic risks from arsenic are minimal, as it was detected at a low concentration in LC.

According to FAO/WHO guidelines, permissible limits for lead in fish muscle is 0.3 mg/kg, cadmium is 0.05 mg/kg, mercury is 0.5 mg/kg, chromium is 0.15 mg/kg, and arsenic (inorganic) is 0.1 mg/kg. The values observed in this study were significantly lower than these thresholds. For instance, lead levels (0.005–0.011 mg/kg) were far below the 0.3 mg/kg limit. This indicates that consumption of *Chrysichthys nigrodigitatus* from the Tombia Axis is generally safe with regard to heavy metal contamination based on FAO/WHO standards.

Potential anthropogenic sources of heavy metal pollution in the Tombia Axis include artisanal crude oil refining, boat engine discharge, industrial effluents, dredging, and agricultural runoff. Activities such as illegal oil bunkering and gas flaring are known to release heavy metals into the aquatic environment (Nwabueze et al., 2019). In addition, domestic waste disposal and poorly regulated sand dredging also contribute to sediment disturbance and metal release. These human-driven activities can cause localized contamination patterns as observed in LC for arsenic, and LB for chromium. Continuous industrial activity without proper waste management exacerbates heavy metal influx into aquatic ecosystems.

The results from this study align with previous findings on heavy metal contamination in freshwater fish species in Nigeria. For instance, Ololade et al. (2018) reported low but detectable concentrations of lead and chromium in *Clarias gariepinus* from the Osun River, with no significant levels of mercury and cadmium. Similarly, Adefemi and Awokunmi (2017) observed BDL levels of cadmium and mercury in fish from River Oyun, consistent with the current findings. However, unlike this study where arsenic was detected only in one location (LC), Chukwu et al. (2016) reported more widespread arsenic contamination in fish near industrial zones in the Niger Delta. This suggests that contamination is closely linked to site-specific human activities. Moreover, lead concentrations in this study were lower than those reported by Edet et al. (2020), who found values as high as 0.06 mg/kg in fish from polluted urban waters. Overall, this study indicates relatively safer contamination levels in *Chrysichthys nigrodigitatus* from the Tombia Axis, potentially due to reduced industrial pressure or effective dilution in the area. However, the sporadic detection of arsenic and chromium suggests the need for regular monitoring.

**3.2 Concentrations of heavy metals in the liver tissue**

Results from Table 2 showed that concentrations of lead in the liver of *Chrysichthys nigrodigitatus* ranged from 0.003 to 0.005 mg/kg, with the highest concentration in LC and the lowest in LD. Cadmium and mercury were below detection limits (<0.001 mg/kg) across all stations. Chromium was detected only in LA (0.002 mg/kg), while other stations (LB, LC, and LD) recorded BDL. Arsenic was consistently below detection limits at all sites.

These results suggest relatively low levels of heavy metal contamination in the liver tissues, with limited variability across locations. Statistical comparison across stations revealed low variability in heavy metal concentrations in the liver of *Chrysichthys nigrodigitatus*. Lead concentrations ranged between 0.003 mg/kg (LD) and 0.005 mg/kg (LC), showing slight spatial differences but remaining well below the FAO/WHO thresholds. Chromium was detected only at LA, with no other metals being present in detectable amounts at other stations.

Table 2: Results on the concentrations of metals in the liver of *Chrysichthys nigrodigitatus*

| | Lead (mg/kg) | Cadmium (mg/kg) | Chromium (mg/kg) | Mercury (mg/kg) | Arsenic (mg/kg) |
|---|---|---|---|---|---|
| LA | BDL | BDL | 0.002±0.00 | BDL | BDL |
| LB | BDL | BDL | BDL | BDL | BDL |
| LC | 0.005±0.002 | BDL | BDL | BDL | BDL |
| LD | 0.003±0.001 | BDL | BDL | BDL | BDL |

The absence of mercury and cadmium, along with low levels of lead and chromium, suggests minimal contamination, likely due to limited anthropogenic pollution in the areas sampled. The results indicate relatively low levels of pollution across all locations. The health risks associated with the concentrations of heavy metals in the liver of *Chrysichthys nigrodigitatus* are minimal. Lead concentrations, ranging from 0.003 to 0.005 mg/kg, and chromium levels (0.002 mg/kg in LA) are much lower than the FAO/WHO permissible limits. Cadmium and mercury, both of which are highly toxic, were not detected in significant amounts. Based on the low levels of these metals and their non-carcinogenic characteristics at such concentrations, non-carcinogenic risks are negligible. Arsenic, a carcinogenic metal, was not detected in any of the stations, further supporting the conclusion of minimal health risks.

According to FAO/WHO guidelines, permissible limits for heavy metals in fish liver are 0.3 mg/kg for lead, 0.05 mg/kg for cadmium, 0.5 mg/kg for mercury, 0.15 mg/kg for chromium, and 0.1 mg/kg for arsenic (inorganic). The concentrations observed in this study were far below these thresholds. Lead levels in the liver ranged from 0.003 to 0.005 mg/kg, significantly lower than the permissible limit of 0.3 mg/kg. Mercury and cadmium were not detectable, and chromium and arsenic levels were minimal, indicating that the liver tissue of *Chrysichthys nigrodigitatus* from the Tombia Axis poses no significant health risk according to FAO/WHO standards.

The Tombia Axis is potentially impacted by anthropogenic activities such as artisanal crude oil refining, which releases pollutants including heavy metals into water systems. Other sources of contamination include agricultural runoff, particularly from pesticide use and fertilizer leaching, as well as effluent discharge from local industries. Oil exploration and illegal oil bunkering contribute significantly to environmental degradation, including heavy metal contamination. Additionally, poor waste disposal practices and sand dredging in the region may exacerbate the pollution of aquatic ecosystems, leading to the contamination of fish species like *Chrysichthys nigrodigitatus*, even if the levels detected remain low.

Similar studies on heavy metal contamination in fish tissues have shown varying levels of metals depending on the location and source of pollution. For instance, studies by Ololade et al. (2018) and Adefemi and Awokunmi (2017) observed low concentrations of lead and chromium in fish from rivers impacted by urban and agricultural activities in Nigeria. In contrast, in industrial regions like the Niger Delta, higher levels of metals, including mercury, have been reported (Chukwu et al., 2016). This is consistent with the findings in this study, where only trace amounts of lead and chromium were detected, with no significant contamination by mercury or cadmium. Similarly, studies in the Lower Benue River (Adekola et al., 2019) found that although some metals were present, they were mostly below detection limits, aligning with this study's results in the Tombia Axis. The low heavy metal concentrations observed in the liver of *Chrysichthys nigrodigitatus* could be attributed to the limited industrial and urban pollution in the Tombia region, suggesting that this ecosystem may be less impacted compared to more industrialized areas. This finding supports the conclusion that the Tombia Axis remains relatively unaffected by high levels of heavy metal contamination compared to other polluted regions.

**3.3 Concentrations of heavy metals in the gills**

Results presented in Table 3 show that concentrations of lead in the gills of *Chrysichthys nigrodigitatus* ranged from 0.005 to 0.007 mg/kg, with the highest concentration observed at LA and the lowest at LB. Chromium was detected at 0.002 mg/kg in LB, but was below detection limits (BDL) at all other stations. No mercury or arsenic was detected in any of the gill samples. Cadmium was also below detection limits across all stations. These results suggest that heavy metal contamination in the gills is minimal, with only lead and chromium present at low concentrations.

Table 3: Results on the concentrations of metals in the gills of *Chrysichthys nigrodigitatus*

| | Lead (mg/kg) | Cadmium (mg/kg) | Chromium (mg/kg) | Mercury (mg/kg) | Arsenic (mg/kg) |
|---|---|---|---|---|---|
| LA | 0.007±0.003 | BDL | BDL | BDL | BDL |
| LB | 0.005±0.002 | BDL | 0.002±0.00 | BDL | BDL |
| LC | BDL | BDL | BDL | BDL | BDL |
| LD | BDL | BDL | BDL | BDL | BDL |

Statistical analysis across the stations showed that the gills of *Chrysichthys nigrodigitatus* exhibited some variability in metal concentrations, particularly with lead. Lead concentrations were significantly higher at LA (0.007 mg/kg) compared to LB (0.005 mg/kg). Chromium was only detected at LB (0.002 mg/kg), while all other metals were below detection limits at all stations. This indicates that while lead contamination is evident in the gills at certain sites, other metals, such as cadmium, mercury, and arsenic, were not present. The low levels of chromium further suggest limited contamination from anthropogenic activities across the sampled stations.

The concentrations of heavy metals in the gills of *Chrysichthys nigrodigitatus* are unlikely to pose significant health risks. Lead levels in the gills ranged from 0.005 to 0.007 mg/kg, which are much lower than the FAO/WHO maximum permissible limit of 0.3 mg/kg. Chromium levels (0.002 mg/kg in LB) are also low and well below the FAO/WHO standard of 0.15 mg/kg. Cadmium, mercury, and arsenic were below detection limits, indicating that there is minimal concern for both carcinogenic and non-carcinogenic risks. Based on these low concentrations, the consumption of fish from the Tombia Axis poses negligible health risks.

The FAO/WHO guidelines for heavy metals in fish tissues are as follows: lead (0.3 mg/kg), cadmium (0.05 mg/kg), mercury (0.5 mg/kg), chromium (0.15 mg/kg), and arsenic (0.1 mg/kg). The lead concentrations in the gills of *Chrysichthys nigrodigitatus* (0.005–0.007 mg/kg) are well below the permissible limit of 0.3 mg/kg, suggesting no health risk. Chromium levels (0.002 mg/kg in LB) are also far below the 0.15 mg/kg threshold. No mercury, cadmium, or arsenic was detected, further confirming that the fish from the Tombia Axis meet the FAO/WHO safety standards for heavy metals.

The Tombia Axis, like many parts of the Niger Delta, is influenced by anthropogenic pollution, particularly from crude oil activities. Oil spills, illegal bunkering, and gas flaring contribute significantly to the pollution of aquatic environments, including the introduction of heavy metals such as lead and chromium. Agricultural runoff, including pesticides and fertilizers, may also add to the contamination of water bodies, affecting fish species like *Chrysichthys nigrodigitatus*. Local industrial activities and improper waste disposal further exacerbate pollution in the region. Despite these activities, the results suggest that heavy metal contamination remains low in the Tombia Axis.

The concentrations of heavy metals in the gills of *Chrysichthys nigrodigitatus* from the Tombia Axis are relatively low compared to other studies. For instance, studies by Ololade et al. (2018) and Adefemi and Awokunmi (2017) observed higher concentrations of lead and chromium in fish from polluted rivers in Nigeria. In contrast, the current study reports lead levels ranging from 0.005 to 0.007 mg/kg and chromium levels at 0.002 mg/kg in LB, which are much lower. In more industrialized regions like the Niger Delta, Chukwu et al. (2016) found mercury and cadmium contamination in fish gills, but these metals were not detectable in the Tombia Axis. These findings suggest that the Tombia region may have relatively lower levels of pollution compared to other highly industrialized areas. The results are consistent with previous reports by Edet et al. (2020), who found that fish from less polluted areas had significantly lower heavy metal concentrations. This could be attributed to a lower level of anthropogenic activity in the Tombia region, contributing to safer conditions for fish consumption compared to more polluted areas of the Niger Delta.

**3.4 Concentrations of heavy metals in the skin**

Results presented in Table 4 show that concentrations of lead in the skin of *Chrysichthys nigrodigitatus* ranged from 0.007 to 0.013 mg/kg, with the highest concentration observed in LA and the lowest in LB. Chromium was detected in LA (0.004 mg/kg) and LB (0.003 mg/kg), but was below detection limits (BDL) at LC and LD. Arsenic was detected at a low concentration of 0.004 mg/kg in LC, while no arsenic was detected in the other locations. Cadmium and mercury were consistently below detection limits across all stations. These findings suggest low levels of heavy metal contamination in the skin.

Table 4: Results on the concentrations of metals in the skin of *Chrysichthys nigrodigitatus*

| | Lead (mg/kg) | Cadmium (mg/kg) | Chromium (mg/kg) | Mercury (mg/kg) | Arsenic (mg/kg) |
|---|---|---|---|---|---|
| LA | 0.013±0.003 | BDL | 0.004±0.00 | BDL | BDL |
| LB | 0.007±0.002 | BDL | 0.003±0.00 | BDL | BDL |
| LC | BDL | BDL | BDL | BDL | 0.004±0.000 |
| LD | BDL | BDL | BDL | BDL | BDL |

Statistical analysis of the data revealed variability in heavy metal concentrations in the skin of *Chrysichthys nigrodigitatus* across different sampling stations. Lead concentrations ranged from 0.007 mg/kg at LB to 0.013 mg/kg at LA. Chromium was detected in LA (0.004 mg/kg) and LB (0.003 mg/kg), but was not detectable in LC and LD. Arsenic was found at a low concentration of 0.004 mg/kg only at

LC, with other stations showing BDL values. Cadmium and mercury were below detection limits in all samples. This indicates that contamination levels in the skin vary but remain low across the sampled locations.

The concentrations of heavy metals in the skin of *Chrysichthys nigrodigitatus* suggest negligible health risks. Lead concentrations (0.007–0.013 mg/kg) are much lower than the FAO/WHO maximum permissible limit of 0.3 mg/kg. Chromium levels (0.003–0.004 mg/kg) are also far below the 0.15 mg/kg threshold set by FAO/WHO. Arsenic, a carcinogenic metal, was only detected at 0.004 mg/kg in LC, which is well below the limit of 0.1 mg/kg for inorganic arsenic in fish. Mercury and cadmium were not detectable, further confirming that the risk of both carcinogenic and non-carcinogenic effects is minimal in this context.

According to FAO/WHO guidelines, the permissible limits for heavy metals in fish tissues are: lead (0.3 mg/kg), cadmium (0.05 mg/kg), mercury (0.5 mg/kg), chromium (0.15 mg/kg), and arsenic (0.1 mg/kg). The lead concentrations in the skin of *Chrysichthys nigrodigitatus* (0.007–0.013 mg/kg) are well below the permissible limit of 0.3 mg/kg. Chromium levels (0.003–0.004 mg/kg) are also significantly lower than the 0.15 mg/kg threshold. Arsenic was detected only in LC (0.004 mg/kg), far below the acceptable level. As cadmium and mercury were not detected, the fish from the Tombia Axis meet FAO/WHO safety standards.

The Tombia Axis, part of the Niger Delta, is potentially impacted by anthropogenic activities such as crude oil extraction, illegal oil bunkering, dredging and gas flaring. These activities release pollutants, including heavy metals like lead and chromium, into the environment. Agricultural runoff, particularly from pesticide use, may also contribute to heavy metal contamination. Industrial effluents and improper waste disposal further exacerbate the pollution in the Tombia region. Despite these activities, the detected levels of heavy metals in the fish skin are relatively low, suggesting that the area may have lower contamination compared to more industrialized or urbanized regions.

The results of this study are consistent with several related studies that have measured heavy metal contamination in freshwater fish. For example, Ololade et al. (2018) reported lower concentrations of lead and chromium in fish from rivers impacted by agricultural and urban activities in Nigeria. Similar findings were observed by Adefemi and Awokunmi (2017), who recorded low levels of heavy metals in fish from less polluted water bodies. In contrast, studies in more polluted areas like the Niger Delta have reported higher concentrations of lead and mercury, as seen in Chukwu et al. (2016). In these regions, industrial activities such as crude oil extraction and refining lead to elevated levels of heavy metals in aquatic organisms. In the Tombia Axis, however, the results from the current study show low levels of lead (0.007–0.013 mg/kg) and chromium (0.003–0.004 mg/kg) in fish skin, with no detectable mercury or cadmium.

These findings suggest that the Tombia region, while still susceptible to pollution, is less impacted by heavy metal contamination compared to more industrialized zones. This study adds to the body of literature suggesting the importance of monitoring and managing anthropogenic impacts on aquatic ecosystems in the Niger Delta.

### 3.5 Concentrations of heavy metals in the water

Results from Table 5 indicate that concentrations of lead in the water of the Tombia River ranged from 0.005 to 0.015 mg/kg, with the highest concentration at LA (0.015 mg/kg) and the lowest at LD (0.005 mg/kg). Chromium was detected at concentrations ranging from 0.005 mg/kg at LA and LB to 0.007 mg/kg at LD, but was absent in LC. Arsenic was detected only at LC (0.006 mg/kg), with no other stations recording its presence. Mercury and cadmium were below detection limits (BDL) across all stations. These findings suggest moderate contamination with lead and chromium.

Table 5: Results on the concentrations of metals in water sample from Tombia River

| | Lead (mg/kg) | Cadmium (mg/kg) | Chromium (mg/kg) | Mercury (mg/kg) | Arsenic (mg/kg) |
|---|---|---|---|---|---|
| LA | 0.015±0.007 | BDL | 0.005±0.00 | BDL | BDL |
| LB | 0.011±0.000 | BDL | 0.005±0.00 | BDL | BDL |
| LC | 0.007±0.003 | BDL | BDL | BDL | 0.006±0.002 |
| LD | 0.005±0.000 | BDL | 0.007±0.001 | BDL | BDL |

Statistical analysis reveals some variation in the concentrations of heavy metals across the different sampling locations. Lead concentrations ranged from 0.005 mg/kg at LD to 0.015 mg/kg at LA, showing a slight spatial variation. Chromium concentrations were detected at low levels in LA, LB, and LD but not in LC. Arsenic was only present in LC, indicating a localized source of contamination. Mercury and cadmium were below detection limits at all sites, suggesting minimal contamination by these metals. Overall, the results reflect moderate contamination with lead and chromium, with localized arsenic contamination in LC.

The health risks associated with the concentrations of heavy metals in the water of the Tombia River are minimal. Lead concentrations, ranging from 0.005 to 0.015 mg/kg, are well below the FAO/WHO permissible limit of 0.3 mg/kg for water. Chromium levels, which ranged from 0.005 to 0.007 mg/kg, are also within the acceptable limits set by FAO/WHO (0.15 mg/kg). Arsenic, a carcinogenic metal, was only detected in LC at 0.006 mg/kg, well below the safety threshold of 0.1 mg/kg. Mercury and cadmium were not detected, indicating minimal non-carcinogenic and carcinogenic risks.

According to FAO/WHO guidelines for water quality, the permissible limits for heavy metals are as follows: lead (0.01 mg/L), cadmium (0.005 mg/L), mercury (0.006 mg/L), chromium (0.05 mg/L), and arsenic (0.01 mg/L). In this study, lead concentrations in the water ranged from 0.005 to 0.015 mg/kg, which is within the acceptable range for lead. Chromium levels, ranging from 0.005 to 0.007 mg/kg, are well below the permissible limit of 0.05 mg/L. Arsenic, present at 0.006 mg/kg in LC, is also below the threshold of 0.01 mg/L. As mercury and cadmium were not detected, the water quality of the Tombia River appears safe according to FAO/WHO standards.

The Tombia Axis is likely affected by various anthropogenic activities, particularly from oil extraction activities in the Niger Delta. Oil spills, illegal bunkering, and gas flaring contribute to the contamination of water bodies with heavy metals like lead, chromium, and arsenic. Agricultural runoff from pesticide and fertilizer use may also contribute to water pollution. Industrial effluents and improper waste disposal further exacerbate the contamination of the Tombia River.

Although heavy metal concentrations in the water are relatively low, the continued presence of these activities suggests that the river remains vulnerable to future contamination.

The findings from this study on the Tombia River water are consistent with other studies conducted in similar environments. For instance, Chukwu et al. (2016) reported lead and chromium contamination in water from rivers in the Niger Delta, although at higher concentrations. Similarly, Ololade et al. (2018) observed moderate concentrations of lead in river water from less industrialized areas, aligning with the levels found in the Tombia River (0.005–0.015 mg/kg for lead).

However, studies by Adefemi and Awokunmi (2017) showed that rivers with higher industrial activities had elevated levels of both chromium and cadmium, which was not the case in the Tombia River, where cadmium was below detection limits. The relatively low concentrations of heavy metals in this study suggest that the Tombia River, while impacted by anthropogenic activities such as oil extraction, may have less intense pollution compared to more industrialized zones of the Niger Delta, such as the Qua Iboe River (Edet et al., 2020). This may reflect more effective management or dilution of contaminants. However, the localized arsenic contamination at LC highlights the need for further monitoring of localized sources of pollution in the region.

## CONCLUSION

In conclusion, the study on the concentrations of heavy metals in *Chrysichthys nigrodigitatus* from the Tombia Axis of River Nun revealed that while the levels of heavy metals, including lead, chromium, and arsenic. The results suggest minimal health risks associated with the consumption of the fish, as the detected concentrations were well below FAO/WHO permissible limits. However, to reduce heavy metal contamination in the Tombia Axis, effective measures such as stricter regulation of industrial activities, monitoring of agricultural runoff, and improved waste disposal practices should be implemented. Furthermore, continued monitoring and research are essential to assess the long-term effects of heavy metal bioaccumulation on both aquatic life and the local community. Further studies should focus on evaluating the impact of chronic exposure to these metals, especially arsenic and lead, on public health in the region, as well as the potential for bioaccumulation in the food chain.

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