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ASSESSMENT OF BIO–CONCENTRATED HEAVY METALS IN COMMONLY CONSUMED FISH IN SAPELE DELTA STATE

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Abstract

Heavy metal contamination in aquatic environments poses significant risks to both ecosystems and human health. Fish, as a major protein source, can accumulate toxic metals, making it essential to monitor their safety for consumption. This study assesses the concentration of six heavy metals, lead (Pb), chromium (Cr), nickel (Ni), cadmium (Cd), mercury (Hg), and barium (Ba) in the liver, kidney, and tissue of three selected fish species (*Oreochromis niloticus*, *Puntius brevis*, and *Electrophorus electricus*) from Sapele Markets, Delta State, Nigeria. The analyses focused on six heavy metals: lead (Pb), chromium (Cr), nickel (Ni), cadmium (Cd), mercury (Hg), and barium (Ba) in the liver, kidney, and tissue of the fish..For all the sampled fish species ,most metals were below WHO limits, except for cadmium, which has already reached a level of great concern. Barium, chromium, and mercury were negligible across all species. Additionally, the length-weight relationship indicated negative allometric growth pattern in the three fish species, with condition factors (k) less than 1, suggesting the fish were in poor health. Stomach content analyses revealed that *O. niloticus* is herbivorous, *P. brevis* is carnivorous, and *E. electricus* is a bottom feeder. These findings suggest that while most heavy metal concentrations are within safe limits, the slightly elevated cadmium levels in *O. niloticus* tissue pose a potential health risk, emphasizing the need for regular monitoring and intervention to safeguard public health.

Keywords; Fish product consumption safety, Food and Eco-safety, Human health,, Heavy metals pollution,

Introduction

Fish have long been an essential resource for humans, not only as a food source but also for its economic, subsistence, and cultural importance. Throughout history, fish have been reverend, often featured in religious rituals, symbols, and depicted in art and literature. In many societies, fish holds a deep cultural significance that spans generations. In Nigeria, fish pruducts are reported to contribute up to 40% of the total dietary protein intake (Nwani *et al*. (2019), making it a vital component of the diet. It is one of the primary protein sources in many developing countries, where it is often preferred over other meats like goat and chicken due to its perceived health benefits (Adeyemi *et al*., 2020). In Nigeria, fish is enjoyed both fresh and smoked, forming a cherished delicacy that cuts across socio-economic, religious, and age groups (Ibrahim *et al*., 2017).

Compared to other protein sources, fish offer numerous health advantages. It is rich in high-quality protein, essential amino acids, omega-3 fatty acids, and a variety of vitamins and minerals that are crucial for human health. These nutrients play a vital role in promoting cardiovascular health, supporting cognitive development, and ensuring overall well-being (FAO, 2020). Fish products and forms are also, easily digestible and provide an excellent source of amino acids, making them key dietary components in maintaining nutritional balance. These benefits make fish highly valued food source in many regions, especially in developing nations where nutritional deficiencies are more common.

Fish, however, are not just important for their nutritional value; they also play a critical role in the aquatic ecosystem. They act as bio-indicators of environmental health, particularly concerning heavy metals contamination. Due to their position in the aquatic food web, fish can bioaccumulate heavy metals in their tissues, making them important indicators of water quality and pollution levels (Türkmen *et al*., 2019). Fish have been recognized as effective bio-accumulators of both organic and inorganic pollutants, making them valuable subjects in environmental monitoring studies (Olu *et al*., 2019).

Heavy metals are among the most serious pollutants in aquatic ecosystems due to their toxicity, even at low concentrations, and their ability to enter food chains and accumulate in living organisms (Ali *et al*., 2019). Metals such as mercury (Hg), cadmium (Cd), and lead (Pb) hazardous, as they provide no beneficial function to living organisms and can be toxic even in trace amounts (Zhang *et al*., 2018). The natural aquatic environment is often contaminated with these heavy metals as a result of domestic, industrial, and other human activities. These pollutants can severely disrupt the ecological balance of aquatic environments and pose a threat to the diversity of species that inhabit them (Ibrahim *et al*., 2017).

The issue of heavy metals contamination in aquatic environments has become a significant global concern for both environmental and public health. Fish contaminated with heavy metals can pose serious health risks to consumers through bioaccumulation, leading to conditions such as neurotoxicity, kidney dysfunction, and various forms of cancer (Hailu *et al*., 2020). The Niger Delta region of Nigeria, in particular, is prone to heightened risks due to increasing industrialization and the lack of stringent environmental regulations (Ugochukwu *et al*., 2020). These industrial activities have led to increased heavy metal contamination in local water bodies, which threatens both the environment and public health.

Despite the growing concern, there is a notable lack of recent data on heavy metals concentrations in fish obtained from key markets in the region, such as the Sapele main market in Sapele Local Government Area. This gap in data makes it difficult to fully assess the risk posed by consuming locally sourced fish. As a result, this study aims to analyze the levels of heavy metals in commonly consumed fish species from this region to evaluate the environmental quality and ensure food safety. The findings of this research are expected to raise awareness among local consumers about the safety of fish consumption and the potential health risks associated with heavy metal bioaccumulation. Additionally, this study will contribute valuable information to the existing body of knowledge on aquatic ecosystems in the Niger Delta and their susceptibility to pollution, emphasizing the need for regular monitoring and intervention to protect both human health and the environment.

Materials and Method

Study Area

The study was conducted in Sapele, a town located in Sapele Local Government Area, Delta State, Nigeria. Sapele is known for its significant fishing activities and has a variety of fish species that are commonly consumed by the local population. The choice of this area is based on its relevance to the research topic and the high consumption rate of fish among the residents.

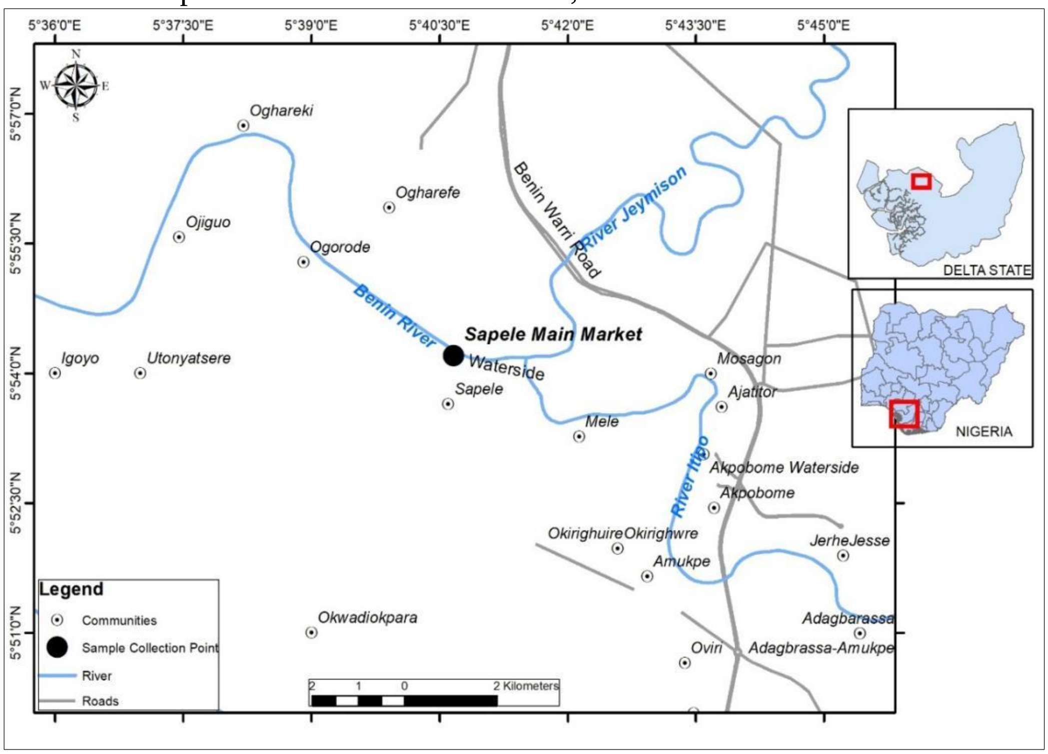

Figure 1: Map of Study Area

Sampling Technique

A purposive sampling technique was used to select the fish species for this study. This method involves selecting samples based on specific criteria; in this case, the popularity and consumption rate of the fish species in the study area. The following steps were taken:

Selection of Fish Species

The fish species commonly consumed in Sapele were identified through a preliminary survey involving local fish vendors and consumers. The fish were identified using dichotomous key and formal identification that are scientifically accepted way to identify species (Idodo-Umeh, 2003).

Collection of Fish Samples:

A total of Thirty (30) live fish samples (10 from each species) were collected from Sapele, Waterside, Fish Market. The samples were transported in plastic container with river water to keep the fish alive and taken to the Biochemistry Laboratory, Delta State University, Abraka, for analyses.

Laboratory Analysis

Stomach Content Analysis

Stomach content of the fish was analyzed using gravimetric method. This involves weighing the total mass of the stomach contents and then calculating the percentage composition of different components based on their known or assumed densities (Amundsen and Sanchez-Hemandez, 2019).

Sample Preparation

The fish samples were cleaned with distilled water to remove any external contaminants. The edible parts (muscles) were filleted wet and homogenized using a food processor. Approximately 2 grams of each homogenized fish samples were digested using a mixture of concentrated nitric acid (HNO_3) and perchloric acid ($HClO_4$) in a ratio of 3:1. The digestion process was carried out in a fume hood at 150°C until a clear solution was obtained.The digested samples were filtered using Whatman No. 4 filter paper and diluted with few drops of HNO_3. (Zheljazkov and Nelson 1996;Shah *et al* 2009).

Heavy Metal Analysis

The concentrations of heavy metals (Lead (Pb), Cadmium (Cd), Mercury (Hg), Arsenic (As), and Nickel (Ni)) in the fish samples were determined using Perkin Elmer Atomic Absorption Spectrophotometry (AAS) AAnalyst 800. This was conducted following these steps:

Calibration

The AAS instrument was calibrated using standard solutions of the heavy metals. Calibration curves were generated for each metal to ensure accurate quantification.

Measurement:

The prepared fish sample solutions were aspirated into the AAS instrument, and the absorbance was measured at specific wavelengths corresponding to each heavy metal.

Specifically, for Cd content, liver sample of the fish were used. A 250 ml conical flask containing precisely 0.5 g of raw liver tissues was filled with 10 ml of aqua regia (1:3: HNO_3: HCl), 5 ml of perchloric acid. The mixture was heated up at 150 ˚C in a digestion block until the acid mixture was reduced to approximately 5 ml. After allowing it to cool, Whatman No. 4 filter paper was used to filter and transferred to a 100 ml volumetric flask. The filtrate was diluted with 1 M HNO_3 and was used for the determination of Cd content using Thermo Jarrell Ash A.A. 12E an instrument designed for an atomization technique which is a graphite atomic absorption spectrophotometer(GFAAS) a model of Perkin Elmer atomic absorption spectrophotometer (AAS) AAnalyst 800 in Andorra.

Also, for Al content, liver samples of fish were use;. following the digestion process as was done with the samples for cadmium. Then the assay was done using the complexometric determination of aluminium as previously described by Dasgupta *et al.* (1995).

The method involves the complexation of Al, with excess EDTA and the selective de-complexation of Al-EDTA complexes with zinc ferrocyanide. The reaction that occurs basically is summarized below.

$$Al^{3+} + EDTA^{4-} \rightarrow Al\text{-}EDTA \quad \text{……….…………….(1)}$$

$$Zn^{2+} + Al\text{-}EDTA \rightarrow ZnEDTA_{2-} + Al \quad \text{…………..(2)}$$

For the standard, a solution containing 40–50 mg of Al was transferred to the

Erlenmeyer flask and diluted to about 100 ml using distilled water. To it was added exactly 50 ml of 0.05 M EDTA solution. For the samples, since it was prepared using acid digestion, the pH was brought to about 3.4 using ammonia solution before 20 ml of acetate buffer was added. This was heated and allowed to boil for 2–3 minutes and allowed to cool. And after the cooling, 0.05 ml of ferricyanide solution and 3–4 drops of 3, 3-dimethylnaphthidine solution were added and the final mixture was titrated against a zinc solution till colour changed to pink.

Data Analysis

The data obtained from the heavy metals analyses were subjected to descriptive statistics using PAST V 4.20. The mean concentrations of each heavy metal in the different fish species were compared with the permissible limits. Data for the heavy metals in different parts of the fish were subjected to Analysis of Variance to check for variation between different parts of the fish. The length-weight relationship was determined and the regression graph was generated using PAST V3.04 for the fish.

Quality Control and Assurance

To ensure the accuracy and reliability of the results, the following quality control measures were implemented:

1. Certified reference materials were used to validate the accuracy of the AAS measurements. 2. Each fish sample was analyzed in triplicate to ensure reproducibility of the results. 3. Reagent blanks were included in the analysis to account for any potential contamination from the reagents and glassware.

Ethical Considerations

Ethical considerations for this study included obtaining necessary permissions from relevant authorities to collect fish samples from the markets. Additionally, all laboratory procedures were conducted following standard safety protocols to protect the researchers and ensure the integrity of the samples.

Result

Table 1 showed the concentrations of the heavy metals (Pb, Cr, Ni, Cd, Hg, Ba) in the liver, kidney, and tissue of three fish species (*O. niloticus, P. brevis, E. electricus*) from the. Pb, Ni, Cd, and Ba levels vary across organs, with Ni and Ba higher in the kidney and liver, while Cd is higher in the tissue. Cr and Hg levels are below detectable limits (< 0.001 ppm) in all fish samples. Overall, heavy metals distribution varies between species and organs.

Table 1: Mean concentrations of heavy metals in selected fish from Sapele market, Delta State, Nigeria

fish	**Organs**	**Pb**	**Cr**	**Ni**	**Cd**	**Hg**	**Ba**
O. *Niloticus*	Liver	0.071	< 0.001	0.117	0.029	< 0.001	< 0.001
	Kidney	0.073	< 0.001	0.127	0.043	< 0.001	< 0.001
	Tissue	0.089	< 0.001	0.119	0.033	< 0.001	< 0.001
P. *Brevis*	Liver	0.059	< 0.001	0.133	0.039	< 0.001	< 0.001
	Kidney	0.088	< 0.001	0.144	0.027	< 0.001	< 0.001

	Tissue	0.091	< 0.001	0.141	0.051	< 0.001	< 0.001
E. electricus	Liver	0.085	< 0.001	0.131	0.046	< 0.001	< 0.001
	Kidney	0.095	< 0.001	0.134	0.026	< 0.001	< 0.001
	Tissue	0.099	< 0.001	0.137	0.025	< 0.001	< 0.001

Table 2 presents descriptive statistics for heavy metal concentrations (Pb, Cr, Ni, Cd, Hg, Ba) in commonly consumed fish species (*O. niloticus, P. brevis, E. electricus*), analyzing kidney, liver, and tissue samples. The statistics include minimum, maximum, standard deviation (SD), and mean values compared to WHO/FAO standards. For Pb and Ni, the recorded concentrations are generally below the WHO/FAO limits, with slight variations in each fish species and organ. Cd is generally at the level of concern. Standard deviations indicate minor variability across samples, and the mean values show overall consistency with safety standards.

Table 2: Descriptive statistics for heavy metals concentration (ppm) for commonly consumed fish in Sapele

Fish species	**Heavy metals(ppm)**	**Organs**	**Min**	**Max**	**SD**	**Mean**	**WHO/FAO Standards**
O. niloticus	Pb	Kidney	0.71	0.09	0.10	0.08	0.50
	Ni	Liver	0.12	0.13	0.01	0.12	0.5-0.6
	Cd	Tissue	0.02	0.04	0.01	0.11	0.5
P. brevis	Pb	Kidney	0.06	0.09	0.02	0.08	0.50
	Ni	Liver	0.13	0.14	0.01	0.14	1.00
	Cd	Tissue	0.03	0.05	0.01	0.04	0.10
E. Electricus	Pb	Kidney	0.09	0.10	0.01	0.09	0.50
	Ni	Liver	0.13	0.14	0.01	0.13	1.00
	Cd	Tissue	0.03	0.05	0.01	0.03	0.10

Data expressed in mg/kg WHO/FAO, (World Health Organisation 2017 /Food and Agricultural Organisation 2020)

Table 3 detailed the ecological features of *O. niloticus, P. brevis, and E. electricus* obtainedfrom Sapele main market. It outlines their feeding habits, stomach contents, biotype complexes, number of samples, and average measurements. *O. niloticus* is herbivorous with full stomachs, pelagic biotype, and averages 163 cm in length and 24 g in weight. *P. brevis*, a carnivore, also has full stomachs, inhabits swampy areas, and averages 50 cm in length and 18 g in weight. *E. electricus*, a bottom feeder with full stomachs, is benthic and averages 79 cm in length and 19 g in weight. Each species had 10 samples analyzed, showing clear differences in feeding habits and ecological niches, reflecting their distinct roles in their respective environments.

Table 3:Ecological Features of Fish Studied from Sapele main market

Scientific Name	Feeding Habits	Stomach Content	Biotype Complex	No of Samples	Mean Length (cm)	Mean Weight (g)
O. niloticus	Herbivorous	4/4 Full stomach	Pelagic	10	24	163
P. brevis	Carnivores	4/4 Full stomach	Swamp	10	18	50
E. electricus	Bottom Feeders	4/4 Full stomach	Benthic	10	19	79

Table 4 shows the length-weight relationship and condition factor for *O. niloticus*, *P. brevis*, *and E. electricus*. For *O. niloticus*, the intercept (a), slope (b), the correlation coefficient (r) and the condition factor (K) were 0.26 0.24 ,0.86 and 0.74 respectively. *P. brevis* has an intercept of 0.91, a slope of 0.21, a correlation coefficient of 0.35, and a condition factor of 0.97. *E. electricus* shows an intercept of 0.75, a slope of 0.30, a correlation coefficient of 0.80, and a condition factor of 0.96. These values reflect differences in growth patterns and overall health among the fish species.

Table 4: Length-weight relationship and condition factor of the sampled fish

Fish Species	**a**	**b**	**r**	**k**
O. niloticus	0.86	0.24	0.26	0.74
P. brevis	0.91	0.21	0.35	0.97
E. electricus	0.75	0.30	0.80	0.96

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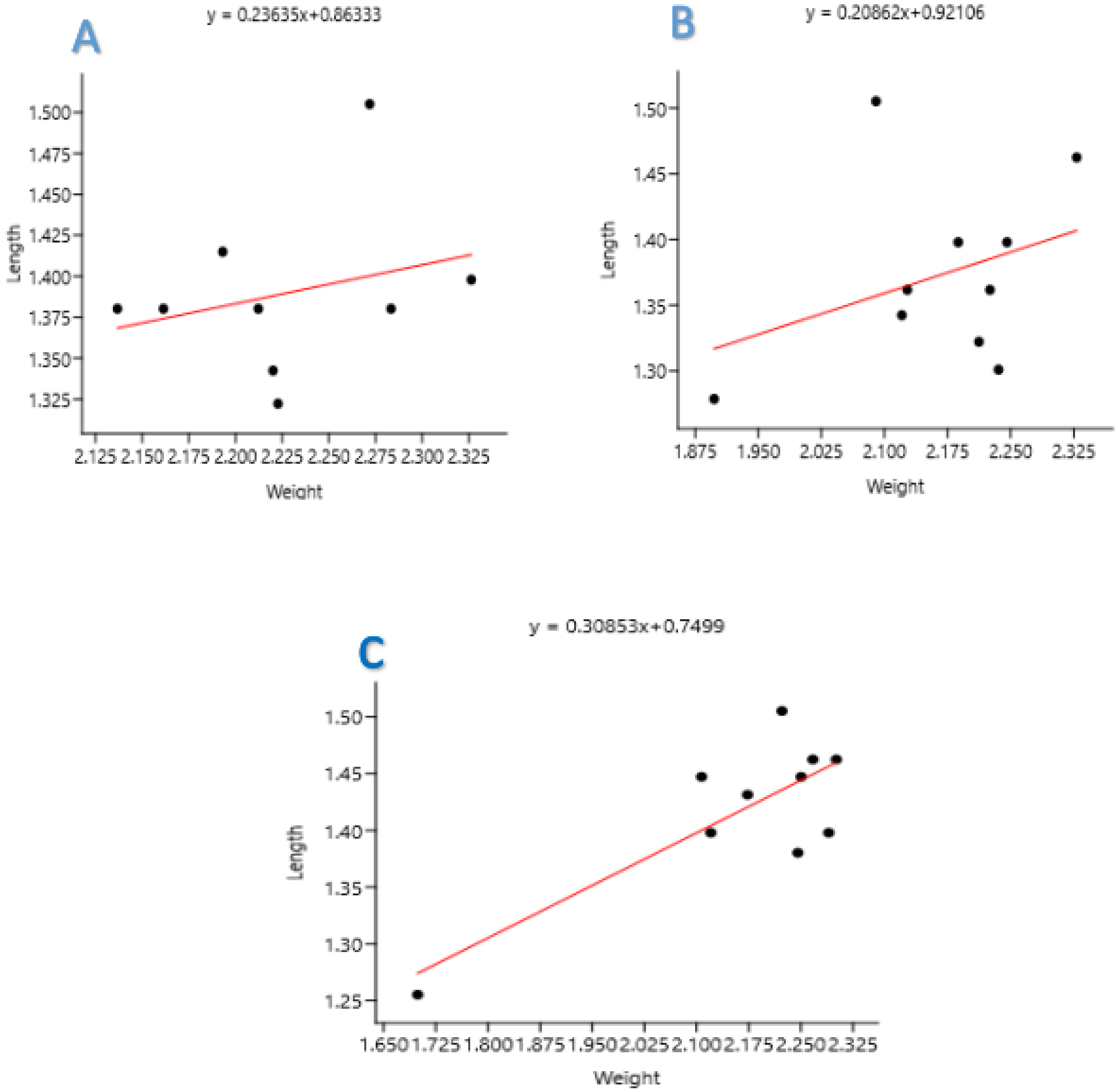

Figure 2: (A) Length-weight relationship graph for *Oreochromis niloticus.* (B) Length-weight relationship graph for *Puntius brevis*(C) Length-weight relationship graph for *Puntius brevis*

Figure 2: (A) Length-weight relationship graph for *Oreochromis niloticus.* (B) Length-weight relationship graph for *Puntius brevis*(C) Length-weight relationship graph for *Puntius brevis*

Discussion

The consumption of fish form an essential part of the diets in many communities, particularly in riverine areas such as Sapele, , Delta State. However, the bioaccumulation of heavy metals in fish pose significant health risks to consumers. This study investigated the concentrations of heavy metals in three commonly consumed fish species (*O. niloticus*, *P. E. brevis*, and *electricus*) obtained from Sapele Main market.

Lead toxicity affects multiple organ systems, including the nervous system (leading to cognitive and behavioral deficits, especially in children), cardiovascular system (e.g., hypertension), and kidneys (USEPA, 2019). The study's findings showed that *O. niloticus* had Pb concentrations in the kidney below the WHO limits, as well as Ni and Cd levels in the liver and tissue, all of which were within safe thresholds. The bioaccumulation pattern in this study followed the order: Pb > Ni > Cd (Table 2). This result aligns with the findings of Abbas *et al*. (2024) in their study on heavy metal accumulation in fish species from Lake Geriyo.

Cadmium (Cd) exposure occurs mainly through contaminated food (especially shellfish, liver, and kidneys of animals), tobacco smoking, and industrial emissions (Ssempebwa, 2020). Cd toxicity affects the kidneys and bones, leading to renal dysfunction and osteoporosis. Although Cd concentrations in this study were within WHO limits, they were approaching concerning levels(Table 2). These findings were consistent with the reports of Ekpo *et al*. (2018) and Abbas *et al*. (2024), who also found elevated Cd concentrations in fish tissue. The bioaccumulation of Cd was likely due to environmental factors, including industrial discharges and agricultural runoff prevalent in the Niger Delta region (Udiba *et al*., 2016), posing a potential risk to human health. Nickel exposure can cause respiratory problems, skin irritation, gastrointestinal issues, and potentially cancer (ATSDR, 2016). The study found high Ni concentrations in the liver of the studied fish species, with notable differences compared to other metals (Table 2). This bioaccumulation in the livers may be related to the fish's feeding habits.

Human activities, such as mining and industrial processes, have increased environmental Ba levels. Exposure to Ba can lead to gastrointestinal, muscular, and cardiovascular issues (WHO, 2016). This study found Ba concentrations in the sampled fish to be below detectable limits.

Chromium(Cr) exposure occurs through industrial processes, inhalation of dust, and contaminated food and water. Hexavalent chromium (Cr (VI) is carcinogenic, particularly associated with lung cancer, and can cause skin and respiratory issues (National Toxicology Program, 2008). However, Cr concentrations were below detectable limits in this study, suggesting minimal contamination.

The findings of this study aligned with other research conducted in Nigeria and globally. For instance, Similarly,Ndimele and Owodeinde (2021) observesed high levels of heavy metal concentrations in the muscle of *B.soporator* in the wet season were Pb 2.21±0.33mg/kg and Cd 0.16±0.05mg/kg while the concentration levels for the dry season ere Pb 1.72± 0.07mg/kg Cd 0.19±0.03mg/kg were Pb exceeded the maximum permissible limits in the tissue of of B. soporator Whereas this study reported high level of Pb concentration in the kidney of *O. niloticus* (0.71mg/kg) and *E.eletricus* (0.09mg/kg). Igbinedion and Oguzie (2016) worked on heavy metals concentration in fish from Osse River and reported mean concentration range values for Cr 0.066-0.2467mg/kg;Cu 6.15-18.32mg/kg, ;Ni 12.41-27.75 mg/kg and V 0.2133-0.3500mg/kg Where Ni and Cr for the fish exceeded the recommended limits set by FAO fo0r fish and fishery products.Which was contrary to this present study were nickel concentration in the liver were below maximum limits in the studied fish. Adengua *et al* (2022) also reported elevated levels of Pb (10.88±3.70 to 12.01±o.42mg/kg)Cd 0.94±0.66 to 1.16±0.10mg/kg) were greater than FAO allowable limits in Bonny Estuary. which may be attributed tot industrial activities and poor wastes management in the Niger Delta region. The presence of heavy metals in fish pose serious risks due to their non-biodegradable nature which could potentially, lead to significant human health issues if left unchecked.

The mean concentration of heavy metals in *O. niloticus* follows the order Cd < Ni < Pb in the kidney, tissues, and liver, while in *P. brevis* and *E. electricus*, the order is Cd < Pb < Ni. This trend is similar to findings by Afshan *et al*. (2014), who reported Pb as the highest metal concentration in the liver and tissue of *Cyprinus carpio*. Industrial pollution, improper wastes disposal, and agricultural runoff may be implicated for this lead contamination levels.

The study also found that all three fish species exhibited negative allometric growth, with condition factors (k) below 1, indicating poor health. This may be due to environmental stress or inadequate food resources, which could also affected their ability to metabolize heavy metals (Ekanem *et al*., 2017). Negative allometric growth is consistent with findings in other studies, where fish exposed to high pollutant levels showed reduced growth rates and poor health (Olusola *et al*., 2019). This raises concerns about the sustainability and health of fish populations in Sapele;s water bodies, with broader ecological implications.

Conclusion

This study has evaluated selected toxic metals concentration bioaccumulated in sampled fish from Sapele environment, Delta State, Nigeria, with the view to improving public awareness on the consumption safety of these fish and by extention, all fish from Sapele water bodies. Lead (Pb), nickel (Ni), cadmium (Cd), and barium (Ba) were found at varying levels across the different fish organs, with Ni concentration higher in the liver and kidney, while Cd was predominantly found in the tissue. However, chromium (Cr) and mercury (Hg) were below detectable limits (< 0.001 ppm) in all fish sampled; suggesting minimal contamination of these metals in the sampled species. The descriptive statistics for heavy metal concentrations show that lead and nickel levels in the studied fish species were generally below the WHO/FAO permissible limits. However, cadmium levels approach the level of concern, especially in *P. brevis*, where mean Cd concentrations are nearing the safety threshold of 0.05 mg/kg. The variability in metals distribution across different organs and fish species was relatively low, as indicated by the small standard deviation values. Ecological analysis further suggested that the feeding habits and habitat types of these fish species influence the bioaccumulation of heavy metals. However, the differences in their biotypes may explain the variation in metal accumulation patterns. In overall, while the concentrations of Pb, Ni, and Ba remained within safe limits, the elevated levels of cadmium in some fish samples suggested a potential health risk for consumers. Therefore,continued monitoring and stricter regulation of heavy metal contamination in aquatic environments is hereby recommended to ensure the safety of seafood from the region.

Recommendations

Awareness programs should be initiated to educate the local population on the potential risks of heavy metals. contamination in fish, even at low levels, and the importance of maintaining clean and sustainable aquatic environments. Also, further studies should be conducted to assess the potential bioaccumulation of other pollutants, such as pesticides and other organic compounds, in fish from the Sapele area. This would provide a more comprehensive understanding of the environmental health of the region

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