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Seasonal Variations Of Heavy Metal Concentrations In The African River Prawn (Macrobrachium Vollenhovenii) From The River-Nun, Niger Delta, Nigeria.

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Abstract: Seasonal variations of selected heavy metals in the fresh water prawn *Macrobrachium vollenhovenii from* River-Nun was investigated. This was done in order to gauge the amount of heavy metals accumulated in the prawn in order to address safety concerns about the consumption of prawn from this river system and establish the health status of the river body. Triplicate sub surface water samples were collected from three (3) sampling points from the water body once monthly for twelve (12) months. Also, prawn samples were collected monthly from three (3) fish landing points in the river catchment area for 12 months. Prawn samples were identified using standard keys. Water and Prawn samples were analyzed for the heavy metals lead (Pb), Cadmium (Cd), Mercury (Hg), Chromium (Cr) and Zinc (Zn) using standard techniques. Means and standard deviations for all metal characteristics in water and prawn were calculated. Analysis of Variance (ANOVA) was employed to measure for similarities and variability in heavy metal characteristics in prawn and water for the river system. Turkey HSD Post HOC test was employed to separate means where variability occurred. This was done at the 95% confidence limit (P=0.05). Student T-test was also employed to check for variability between seasons in the measured parameters. This was aided by the use of the SPSS® statistical tool kit. Result of the study indicate that wet season values of the heavy metals in water were greater than values obtain in the dry season. Except for the metals Hg and Zn, all heavy metal characteristics of the river are consistently higher than the recommended permissible value for heavy metals in water. Bioaccumulation factor (BAF) was higher that the threshold value (BAF>1) for all metals. Based on the findings, the study concludes that the consumption of the studied prawn species is contaminated with elevated levels of toxic metals which is associated with higher degree of potential health risks.

Keywords: Seasonal, Heavy Metals, *Macrobrachium Vollenhovenii*, River-Nun, Niger Delta

1.0 Introduction

The contamination of aquatic ecosystems by heavy metals is a global environmental issue that has garnered significant attention due to its potential risks to human health and threat to biodiversity. Heavy metals, including cadmium (Cd), lead (Pb), mercury (Hg), and arsenic (As), are natural constituents of the Earth's crust. However, their anthropogenic introduction into aquatic environments through industrial, agricultural, and domestic activities has raised considerable concerns [1]. These metals are non-biodegradable, tend to bio-accumulate, and can magnify along trophic levels, leading to adverse effects on aquatic organisms and humans who consume them ([2]. Among aquatic organisms, river prawns and fish species serve as vital components of aquatic ecosystems and are also significant sources of protein for human populations, particularly in regions reliant on fisheries for subsistence and income [3]. The bioaccumulation of heavy metals in these species poses a threat to food safety and public health, as these metals can accumulate in the tissues of fish and prawns, often exceeding permissible levels set by regulatory agencies such

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as the World Health Organization [4]. In regions where communities depend heavily on rivers for fishing and aquaculture, such as in developing countries, monitoring and managing heavy metal pollution is critical.

As River-Nun situated in the Niger Delta is exposed perennially to the risk of hydrocarbon pollution, there is an urgent need to monitor the heavy metal characteristics of its water and prawns. This will serve to address safety concerns about the consumption of prawns from the river and gauge the threat to human health.

2.0 Materials and Method

2.1 Description of Study area (River-nun (Amassoma)

The study area is in River-Nun spanning study stations ranging from Amassoma to Ogobiri Axis. The river was purposively selected because the species (*Macrobrachium vollenhovenii*) are known to be caught by fishers in the Amassoma axis. Amassoma is located within latitude 4° 58' 15" N and longitude 6° 06' 32.94" E. It lies within the flood plains of the western flanks of the Wilberforce Island in Southern Ijaw Local Government Area of Bayelsa State. Several fish landing areas were identified and used for collection of both physicochemical and prawn samples. The exact coordinates of the sampling points are shown in Table 1

Table 1: Coordinates of Sample Stations in River-nun at Amassoma, Bayelsa State

S/N	STATIONS	LATITUDE	LONGITUDE	ALTITUDE(M)
1	Station 1	N4^{0}55'46.165''	E6^{0}14'14.46''	1.5
2	Station 2	N4^{0}55'36.287''	E6^{0}6'22.56''	1.0
3	Station 3	N4^{0}55'41.41''	E6^{0}6'22.53''	1.5

2.2 Collection of Samples

2.2.1 Collection of water samples

Water samples were collected monthly in triplicates plastic bottles from each of the three stations at Amassoma respectively for 12 months (November 2023 to October, 2024)

A total of One Hundred and Eight Samples (108) were collected to analyze for the heavy metals Pb, Cd, Hg, Cr, and Zn in River-Nun. All samples were stored in an ice chest (<40^{0}c) before transferring to the laboratory of the Department of Biological Sciences, Niger Delta University.

2.2.2 Collection of Prawn Samples

Fresh live specimens of *Macrobrachium vollenhovenii* were obtained from local fishers monthly for twelve calendar months at River-Nun from November 2023 to October, 2024 covering wet and dry seasons. Specimens were kept in an ice chest and preserved in 10% formalin and taken to the Department of Biological Sciences Laboratory at the Niger Delta University. Samples were identified using Keys provided by Chace [5] and Augustine [6].

2.3 Sample Analysis

2.3.1. Water quality of samples

In the laboratory, the water samples were filtered using a 45 mm Whatman filter paper. The filtrates were then digested with a mixture of 10ml of concentrated nitric acid and 2ml of concentrated Perchloric acid respectively. The content was then digested slowly by heating it in a water bath. The samples were the allowed to cool and then put in a conical flask. Analysis for five (5) heavy metals; Pb, Cd, Hg, Cr and Zn conducted using the flame atomic absorption spectrophotometry with Buck scientific model 200A Spectrophotometer equipped with a high sensitivity nebulizer using their different wave lengths.

2.3.2 Analysis of Samples and Quality Assurance

All the samples, along with the sample blanks (only deionized water) and standards, were aspirated into a flame atomic absorption spectrophotometer (AAS) (model: Varian AA240FS & AA280 Z, Varian Inc., Palo Alto, CA, USA). A calibration curve was executed for concentration versus. absorbance. Through the least square method and using the fitting of a straight line, the data were statistically analyzed. While calculating the concentration of various elements, necessary corrections were made considering the blank samples. Replicate samples, blank samples and certified reference materials (CRM) were used for the accuracy of the experiment.

Plate 1: *Macrobrachium vollenhovenii* from River-Nun, Bayelsa State

2.4 Statistical Analysis

Means and standard deviations for all metal characteristics in water and prawn were calculated. Analysis of Variance (ANOVA) was employed to measure for similarities and variability in heavy metal characteristics in prawn and water for the river system. Turkey HSD Post HOC test was employed to separate means where variability occurs. This was done at the 95% confidence limit (P=0.05). Student T-test was employed to check for variability between seasons in the river system for the measured parameters.

The Bioaccumulation Factors (BAFs) was determined by dividing the concentration of each heavy metal in the water by the concentration of heavy metals accumulated in the prawn using the formula for calculation according to the United States Environmental Protection Agency [7]:

$$BAF = \frac{Cm}{Csd}$$

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Note: BAF= Bioaccumulation Factor; Cm= heavy metal accumulated shrimps;

Csd = heavy metal accumulated in water. When BAF> 1, then aquatic biota has a bio-accumulator potential

3.0 Result and Discussion

3.1 Result

The result of this study is displayed in Tables 1 to 4.

Table 1 show the seasonal values of heavy metals in water of River-nun.

Table 1: Mean Seasonal heavy metals in water in River-nun

S/N	Heavy metals (mg/kg)	Dry season	Wet season
1	Pb (Lead)	2±0.62.76^{a}	6.97 ± 2.90^{b}
2	Cadmium (Cd)	2.04 ± 0.54^{a}	2.92 ± 1.02^{b}
3	Mercury (Hg)	0.08 ± 0.13^{a}	0.08 ± 0.107^{a}
4	Chromium (Cr)	0.06 ± 0.06^{a}	0.087 ± 0.106^{a}
5	Zinc (Zn)	27.59 ± 10.62^{a}	43.76 ± 6.48^{b}

Means ± Standard deviation. Means with same letter superscript (a, b) on the same row are not significantly different (P>0.05)

Table 2 show the seasonal values of heavy metals in *Macrobrachium vollenhovenii* of River-Nun.

Table 2: Seasonal heavy metals in *Macrobrachium vollenhovenii* in River-nun

S/N	Heavy metals (mg/kg)	Dry season	Wet season
1	Pb (Lead)	3.32 ± 0.77^{a}	8.39 ± 3.14^{b}
2	Cadmium (Cd)	2.44 ± 0.42^{a}	3.18 ± 1.03^{b}
3	Mercury (Hg)	0.23 ± 0.26^{a}	0.12 ± 0.16^{b}
4	Chromium (Cr)	0.17 ± 0.18^{a}	0.173 ± 0.21^{a}
5	Zinc (Zn)	31.43 ± 10.82^{a}	48.40 ± 6.12^{b}

Means ± Standard deviation. Means with same letter superscript (a, b) on the same row are not significantly different (P>0.05)

Table 3 show the comparison of values of heavy metals in water of River-nun and in tissues of *Macrobrachium vollenhovenii* in River-nun during the study period.

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Table 3: Total Heavy metals in Water and *Macrobrachium vollenhovenii* in River-nun

S/N	Heavy metals (mg/kg)	Water	*Macrobrachium vollenhovenii*
1	Pb (Lead)	5.16 ± 3.12^{a}	6.28 ± 3.50^{a}
2	Cadmium (Cd)	2.55 ± 0.95^{a}	2.87 ± 0.90^{a}
3	Mercury (Hg)	0.085 ± 0.11^{a}	0.171 ± 0.21^{b}
4	Chromium (Cr)	0.077 ± 0.09^{a}	0.17 ± 0.20^{b}
5	Zinc (Zn)	37.02 ± 11.61^{a}	41.33 ± 11.85^{a}

Means ± Standard deviation. Means with same letter superscript (a, b) on the same row are not significantly different (P>0.05).

3.2 Discussion of Result

3.2.1. Heavy metals in water

3.2.1.1 Lead (Pb)

The result for the seasonal variation of heavy metals in River-Nun shows differences in heavy metal characteristics. The result for seasonal values of heavy metals in water of River-nun shows that Pb values ranged from 2.0 ± 0.62 mg/kg in the dry season to 6.97 ± 2.90 mg/kg in the wet season. Wet season values were significantly different (P<0.05) and higher than dry season values. These values are all higher than the international permissible value for Pb in water bodies, which is 0.01 mg/L according to the World Health Organization [4]. This result is consistent with the findings of Milivojević et al. [8], who reported Pb concentrations in river water that exceeded WHO limits, particularly during the rainy season due to increased runoff from agricultural and urban sources.

Other studies that support the findings of this study include Lopes et al. [9] who reported Pb levels exceeding permissible thresholds in both water and aquatic organisms from the Brazilian coastal lagoons, reinforcing the global concern about anthropogenic Pb pollution in freshwater systems.

One reason for this high concentration of Pb may be due to the presence of refuse dumpsites close to riverbanks in the river and the indiscriminate disposal of household and market waste directly into the water body. This assumption agrees with the findings of Kumar et al. [10], who observed that water bodies near urban slums and market areas in India had significantly higher Pb concentrations due to poor waste management practices. Lead usually enters surface and groundwater through various pathways, including municipal sewage, mining runoff, corrosion of plumbing systems, leaching of paints, and the burning of fossil fuels. Additionally, Pb present in contaminated soil may diffuse through the soil solution into nearby water bodies (Hardman et al, [11]), thereby explaining the elevated levels observed in this study. The proximity of River-Nun to populated towns, increased vehicular traffic, and water-based transportation systems may also account for the elevated levels of lead.

3.2.1.2 Cadmium (Cd)

In River-Nun, Cadmium (Cd) concentration in water ranged from 2.04 ± 0.54 mg/kg in the dry season to 2.92 ± 1.02 mg/kg in the wet season. Wet season values were significantly higher (P<0.05) than dry season values. All the observed Cd concentrations in water across seasons and locations were far above the World Health Organization's permissible limit of 0.003 mg/L for drinking water (WHO, [4]), indicating potential ecological and public health risks.

The high Cd levels recorded in this study may be attributed to various anthropogenic activities such as metal plating, battery production, industrial wastewater discharge, and agricultural runoff. According to Choi et al [12], cadmium is a sulfur-seeking metal that tends to accumulate in sedimentary environments with low oxygen levels, particularly in systems experiencing high organic matter decomposition. The river-Nun, characterized by high waste input and organic decay, provide ideal conditions for cadmium retention in sediments and subsequent release into overlying water.

The findings of this study are consistent with the work of Rajeshkumar et al. [13], who reported seasonal variations in cadmium concentration in fish and water samples from Meiliang Bay of Taihu Lake in China, with higher concentrations during the rainy season due to runoff and sediment disturbance. Similarly, Chopra and Pathak [14] recorded cadmium levels exceeding permissible limits in the Ganga river, especially in areas with dense human settlements and industrial activity. also reported comparable high Cd concentrations in the surface water of River Owan, Nigeria, linking them to agricultural and urban runoff. These findings reinforce the seasonal trends observed in this study, where wet season values were consistently higher across the river.

Additional support comes from Ibrahim et al. [15], who identified elevated Cd levels in Jakara river, Nigeria, and associated them with urban pollution and domestic waste disposal. Alinnor and Obiji [16] also recorded cadmium levels surpassing regulatory limits in rivers around the Niger Delta, corroborating the widespread presence of this contaminant in Nigerian freshwater systems due to poor waste management and unregulated effluent discharge.

Conversely, the results of this study contrast with those of Gijo and Alagoa [17], who found cadmium concentrations below 1.0 mg/kg in sediments from the River-Nun estuary near Akassa, possibly due to lower urban activity and pollution pressure in that location. Similarly, Amirrah et al. [18] observed low Cd concentrations in fish and water from Malaysian aquatic ecosystems, with values within WHO and FAO safety limits. These discrepancies may be due to differences in environmental policies, industrial density, hydrology, and pollution sources across the various study areas. The elevated Cd levels reported in this study highlight the urgent need for continuous environmental monitoring, stricter waste management policies, and public education on the sources and risks of cadmium pollution in the Niger Delta region.

3.2.1.3 Mercury (Hg)

Mercury (Hg) recorded the same mean value of 0.08 ± 0.13 mg/kg in the dry season and 0.08 ± 0.107 mg/kg in the wet season in River-Nun. There was no significant difference ($P>0.05$) in the seasonal values of mercury concentration in River-Nun. While these values were within the WHO permissible limit of 1.0 mg/kg in fish tissues, they exceeded the WHO guideline of 0.001 mg/L for mercury in drinking water, indicating potential ecological risk [4].

The relatively low seasonal variation observed in this study may be attributed to the stable geochemical behavior of mercury, particularly its strong association with sediments and organic matter. Mercury in aquatic environments exists primarily in two forms: inorganic mercury and methylmercury. Although mercury can be taken up directly by aquatic organisms in its inorganic form, its most toxic and bioavailable form is methylmercury, which is produced by microbial methylation in sediments [19]. The methylated form is easily absorbed through gills and digestive tracts and subsequently accumulates in the tissues of fish and other aquatic organisms.

Mercury bio-accumulates strongly in aquatic food chains and can concentrate in mussels, crustaceans, and fish up to 10^5 to 10^6 times higher than levels in surrounding water ([20], [21]). These findings are consistent with the low but persistent mercury levels observed in this study, which may experience greater sediment disturbance and bacterial activity that enhance methylation during the wet season. Huang and Ghio [22] also reported significant bioaccumulation of mercury and other trace metals in benthic species due to their feeding habits and prolonged sediment interaction, a pattern consistent with the habitat conditions observed in the sampled areas.

Conversely, some studies have reported lower or non-detectable levels of mercury in similar environments. For instance, Gijo and Alagoa [17] found mercury concentrations below 0.05 mg/kg in the sediment of the River-Nun estuary near Akassa, attributing the low values to limited industrial activity in the region. This contrasts with the relatively higher values observed in this study, possibly due to greater anthropogenic pressure and higher bacterial activity in the more urbanized segments of River-Nun.

3.2.1.4 Chromium (Cr)

Chromium (Cr) values in water samples from River-Nun ranged from 0.06 ± 0.06 mg/kg in the dry season to 0.087 ± 0.106 mg/kg in the wet season. Although the wet season values were slightly higher, the difference was not statistically significant (P>0.05). Importantly, all measured values were below the WHO permissible limit of 0.1 mg/L for drinking water, indicating no immediate health risk in relation to this parameter [4].

Chromium is a trace heavy metal that occasionally occurs in surface and groundwater at low concentrations. Its presence in aquatic environments can be attributed to both natural and anthropogenic sources such as the discharge from steel and pulp mills, erosion of natural deposits, improper waste disposal, and leaching from paints and tanning industries ([23], [24]). The relatively low levels of Cr recorded in this study may be linked to the fact that chromium, particularly in its trivalent form (Cr(III)), is a metal of low biogeochemical mobility, especially in oxygen-rich surface waters where it tends to form stable insoluble compounds that settle in sediments [25].

This study's findings are consistent with those of Dirisu and Olomukoro [26], who reported low levels of Cr in Agbede Wetlands in southern Nigeria, attributing the concentrations to minimal industrial discharge in the area and the natural buffering capacity of the wetland ecosystem.

3.2.1.5 Zinc (Zn)

In River-Nun, the concentration of zinc (Zn) in water ranged from 27.59 ± 10.62 mg/kg in the dry season to 43.76 ± 6.48 mg/kg in the wet season. The difference between seasons was statistically significant (P<0.05), with wet season values being notably higher. These values are below the maximum permissible limit of 100 mg/kg in aquatic organisms set by the World Health Organization and FAO (WHO, [4]; FAO, [27]), but they exceed the WHO's safe limit for zinc in drinking water, which is 3.0 mg/L.

Zinc is one of the most frequently detected trace metals in freshwater environments due to the relatively high solubility of its compounds. It is considered an essential trace element for aquatic organisms, playing crucial physiological and biochemical roles. For example, zinc is a component of the enzyme carbonic anhydrase, which catalyzes the conversion of carbon dioxide to carbonic acid in the blood, facilitating gas exchange and acid–base balance in fish [28]. Because of its importance in metabolic processes, aquatic organisms possess internal mechanisms to regulate and transport zinc for the synthesis of vital enzymes and proteins [23]. However, excessive zinc concentrations in water may lead to toxic effects, including impaired osmoregulation, oxidative stress, and gill damage, particularly when concentrations exceed the species-specific tolerance levels.

The findings of this study are consistent with those of Abdel-Khalek et al. [29], who observed elevated zinc concentrations in the muscles and livers of Nile tilapia from the Nile river. Their study also reported higher values during the wet season, which was attributed to increased surface runoff, erosion, and the flushing of contaminated sediments into the water. Similarly, Al-Yousuf et al. [30] found high zinc concentrations in various tissues of *Lethrinus lentjan* fish from the Arabian Gulf, indicating the natural tendency of zinc to bioaccumulate in aquatic fauna in both polluted and semi-polluted environments.

3.2.2. Heavy metals in prawn tissues

The analysis of heavy metal concentrations in the tissues of *Macrobrachium vollenhovenii* revealed seasonal and spatial variations between seasons in River-Nun. The bioaccumulation pattern indicated that the prawn species had absorbed varying levels of Pb, Cd, Hg, Cr, and Zn, with higher concentrations generally recorded during the wet season due to increased surface runoff, sediment resuspension, and higher pollutant influx.

3.2.2.1 Lead (Pb)

Lead (Pb) levels in prawn tissues ranged from 3.32 ± 0.77 mg/kg (dry season) to 8.39 ± 3.14 mg/kg (wet season) in River-Nun. These values exceeded the FAO/WHO permissible limit of 1.5 mg/kg for Pb in seafood, indicating a potential health hazard [31]. These findings are consistent with Mziray and Kimirei [3], who reported elevated Pb in prawns along the Zanzibar coast, and with Rajeshkumar et al. [13], who also observed significantly high Pb levels in prawns during the wet season. In contrast, Dirisu [32]

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recorded Pb concentrations in *Caridina africana* that were well below WHO limits, likely due to lower industrial activity in that region.

3.2.2.2 Cadmium (Cd)

Cadmium (Cd) concentrations in prawn tissues ranged from 2.44 ± 0.42 mg/kg (dry) to 3.18 ± 1.03 mg/kg (wet) in River-Nun These concentrations exceed the 2.0 mg/kg permissible limit, suggesting a moderate to high contamination level [33]. Similar bioaccumulation patterns have been reported by Ahmad et al. [34] and Adebayo et al. [35], who linked high Cd levels to runoff from industrial and agricultural sources. However, values reported by Nwani et al. [36] in vannamei shrimp were far lower (0.011 ± 0.004 mg/kg), emphasizing regional variation based on pollution intensity.

3.2.2.3 Mercury (Hg)

Mercury (Hg) showed a reverse seasonal trend compared to other metals. In River-Nun, concentrations dropped from 0.23 ± 0.26 mg/kg in the dry season to 0.12 ± 0.16 mg/kg in the wet season, Although these values were within the WHO permissible limit of 1.0 mg/kg, the higher dry-season concentrations may be due to reduced dilution or reabsorption of mercury from sediments during low-flow conditions [37]. Similar seasonal patterns were observed by Iqbal et al. [38], who found higher Hg in prawns during drier months, unlike Gijo and Alagoa [17], who reported consistently low Hg concentrations across seasons.

3.2.2.4 Chromium (Cr)

Chromium (Cr) concentrations in prawn tissues were generally low but still notable. Concentrations ranged from 0.17 ± 0.18 mg/kg to 0.173 ± 0.21 mg/kg. The values exceeded the internationally accepted safety limit of 0.003 mg/kg for Cr in aquatic organisms. These results align with those of Kumar et al. [10], who noted Cr accumulation in prawns due to industrial runoff. However, Dirisu [32] reported lower Cr levels in crustaceans from Agbede wetlands, suggesting less contamination in those ecosystems.

3.2.2.5 Zinc (Zn)

Zinc (Zn) was the most abundant metal in prawn tissues, reflecting its essential biological role. Concentrations ranged from 31.43 ± 10.82 mg/kg to 48.40 ± 6.12 mg/kg in River-nun were well below the maximum permissible level of 100 mg/kg for Zn in aquatic organisms [4]. These findings are consistent with Lopes et al. [9] and Abdel-Khalek et al. [29], who noted moderate but safe levels of Zn in crustaceans, while differing from Rashed [39], who reported excessive Zn accumulation in fish from Lake Nasser.

The overall trend of heavy metal accumulation in prawn tissues followed the sequence: Zn > Pb > Cd > Cr > Hg. This aligns with the earlier findings by Gupta et al. [28], who documented similar bioaccumulation hierarchies in freshwater prawn species. The elevated metal levels during the wet season suggest higher input from anthropogenic activities such as agricultural runoff and urban effluents in River-Nun.

3.2.3 Bioaccumulation in Prawn Tissues

The BAF of lead (Pb) in River-nun was 1.217. indicating comparable but slightly elevated Pb bioaccumulation in the urbanized River-Nun. Cadmium (Cd), showed a BAF of 1.12. Mercury (Hg) exhibited the most pronounced BAF of 2.0. Chromium (Cr) also followed this trend, with a high BAF in River-Nun (2.2) reflecting a great chromium uptake in the prawns from River-Nun. For zinc (Zn), the BAF in River-nun was 1.116.

According to Arnot and Gobas [40], a BAF value below 1 indicates that there is no possibility of bioaccumulation, while values between 1 and 5 are classified as "bio-accumulative," and values exceeding 5 are considered "very bio-accumulative." In the present study, none of the heavy metals exhibited very high bioaccumulation (i.e., BAF > 5). All the metals are within the range indicating bioaccumulation (1 < BAF < 5), suggesting that prawns in River-Nun are accumulating measurable and potentially harmful levels of these metals through trophic transfer and environmental exposure.

These findings are in partial disagreement with the results of Monikh et al. [41], who reported higher BAF values for cadmium and lower values for lead, zinc, and copper in *Metapenaeus affinis* collected from the northwest Persian Gulf. The discrepancies could be attributed to species differences, environmental conditions, metal availability, or sediment characteristics across study sites. The relatively moderate BAF values in this study also suggest that although *Macrobrachium vollenhovenii* is not experiencing severe bio-accumulative stress, continued exposure to contaminated water could lead to chronic accumulation over time, posing risks to predators and human consumers alike.

Bioaccumulation factors (BAF) calculated in this study further support these observations, with all metals showing BAF > 1, confirming prawns' potential as bio-indicators of aquatic heavy metal pollution. These findings underline the urgent need for continuous monitoring of aquatic environments and stricter pollution control to prevent potential health risks from the consumption of *Macrobrachium vollenhovenii* and similar aquatic organisms.

4.0 Conclusion

This study examined the seasonal variations of the heavy metals Pb, Cd, Hg, Cr and Zn in the tissues of the fresh water prawn *Macrobrachium vollenhovenii* in River-Nun.

Water samples were collected monthly from November 2023 to October, 2024 and analyzed for the above heavy metals. Prawn samples were also collected from landing points and investigated for the same heavy metal concentrations in their tissues using standard procedures.

The result of the heavy metal analysis in water reveals that the concentration of the metals Pb, Cd, Hg, Cr and Zn were greater than the international permissible limit of these metals in water. Heavy metal values also reveal that the concentrations of heavy metals followed this trend: Zn > Pb > Cd > Cr > Hg.

Except for Hg and Zn, all the heavy metals measured in prawn tissues were higher than the international permissible limit of heavy metals in animal tissues including fish.

Bioaccumulation Factor (BAF) of the prawn samples show values that are greater than 1 (BAF > 1) for all metal samples. This indicate an affinity of the prawn *Macrbrachium vollenhovenii* to readily bio-accumulate heavy metals as the concentration in prawn was always greater than the concentration in water. Seasonally, BAF was always higher in the wet season than in the dry season. This coincidentally aligns with the period of peak recruitment (natality) of *Macrobrachium spp* as identified in previous studies.

This imply a greater risk of heavy metal poisoning if the prawn is consumed particularly in the wet season. It can be concluded based on the finding of this study, that consuming prawn from River-Nun, may pose a serious risk of cancer and other associated diseases to man because of the tendency for bio-magnification as the heavy metals in this prawn exceed tolerable limits.

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Appendices

Table 5: FAO/WHO Permissible limit of Heavy metals in Animal Tissues

S/N	Heavy metals	Permissible Value mg/kg (ppm)
1	Cu	**30 (FAO/WHO, ([4],[27])**
2	Ni	**70-80 (USFDA, ([7])**
3	Fe	**100 (FAO/WHO, ([4], [27])**
4	Co	**-**
5	Mn	**1.0 (FAO/WHO, ([4], [27])**
6	Zn	**100 (FAO/WHO, ([4], [27])**

Adapted from Alagoa and Yabefa, [42]

Table 6: EU and Australian permissible limit for Heavy metals in Aquatic Organisms

S/N	Metal	Value for fish mg/kg or ppm	Value for abalone mg/kg) (Australia)	Value (mg/kg) European Regulation
1	Cd	-	2.0	**0.05**
2	Cu	0.5	2.0	**-**
3	Pb	0.5	2.0	**0.30**
4	Hg	1.0	0.5	**0.5**

Source: EU regulation 1881/2006/. Australian National Seafood (Fish, Mollusc and Crustacean) guideline for heavy metals

Table 4.11: Permissible limit of heavy metal ions in water

S/N	Heavy metal ions	WHO's permissible limit (mg L−1)
1	Se	**0.02**
2	Hg	**0.001**
3	Mn	**0.02**
4	Ag	**0.1**
5	Cd	**0.05**
6	Cr	**0.003**

7	Pb	**0.01**
8	Zn	**3.00**
9	Fe	**0.30**
10	Cu	**0.02**
11	As	**0.01**

Adapted from Sankhla et al [43]