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Seasonal Dynamics of Heavy Metal Contamination in Oil-Impacted Surface Waters of Bayelsa State, Nigeria

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ABSTRACT

This study investigated the seasonal dynamics of heavy metal concentrations in surface waters of Bayelsa State, Nigeria, across three oil-impacted sites—River Niger (Ayamasa), Kolo Creek (Ibelebiri), and Taylor Creek (Ikarama)—and one control site, River Niger (Okumbiri). Surface water samples were collected midstream using acid-washed polyethylene bottles. Heavy metals (Fe, Mn, Cu, Zn, Cd, Cr, Pb, Ni) were quantified using Atomic Absorption Spectrophotometry (AAS). Concentrations ranged between Fe: 0.233–4.043 mg/L, Mn: 0.022–0.432 mg/L, Cu: 0.002–0.419 mg/L, Zn: 0.003–1.917 mg/L, Cd: 0.009–0.228 mg/L, Cr: 0.023–1.199 mg/L, Pb: 0.037–0.695 mg/L, and Ni: 0.009–0.197 mg/L across sites and seasons. Data analysis was performed using Analysis of Variance (ANOVA) in SPSS, with Duncan's multiple range test applied to distinguish mean differences. Pearson's correlation coefficients were computed with Paleontological Statistics (PAST) software. Results revealed significantly elevated concentrations of most metals in oil-impacted sites compared to the control, with Kolo Creek (Ibelebiri) consistently recording the highest levels. Seasonal variation was evident, with higher concentrations during the dry season due to reduced dilution capacity, while wet season values reflected dispersal by rainfall and river discharge. Strong correlations among metals (e.g., Fe–Pb, Cu–Zn, Cr–Pb) suggested common anthropogenic sources linked to petroleum activities. These findings underscore the combined influence of crude oil operations and hydrological cycles on heavy metal pollution, highlighting the urgent need for continuous monitoring and regulatory interventions to safeguard aquatic ecosystems and public health in the Niger Delta.

Keywords: Heavy Metal Contamination, Crude Oil Impact, Seasonal Variation, Correlation Analysis.

INTRODUCTION

Water is vital to the survival of both living and non-living entities. Despite the importance of water, many human activities have caused this essential resource to become so contaminated. Due to their toxicity and persistence, heavy metals are among the most hazardous contaminants found in our natural environment. In recent years, their poisoning of rivers, lakes, fish, and sediments has become a significant environmental problem. The Niger Delta region is plagued by the problem of crude oil contamination. The discovery and extraction of crude oil have resulted in a growing pollution of the water bodies in the Niger Delta (Ordinioha & Brisibe, 2013).

Water pollution, which is mostly caused by industrialization, is the accumulation of pollutants in water bodies. For the past few decades, the Niger Delta has gained popularity as a location for the exploitation of crude oil. Due to this unsupervised activity, it has become a hotspot with high concentrations of heavy metals in various kinds of environmental media. Heavy metals (HMs) in both subsurface and surface water bodies are among the most harmful effects of crude oil. High levels of heavy metals, including Fe, Zn, Cu, Pb, and Hg, were found in Nigerian crude oil (Chinedu & Chukwuemeka 2018). One of the primary causes of the degradation in aquatic and terrestrial ecosystems is the unregulated release of wastewater into the environment by petroleum firms. According to Singh et al. (2022), the food chain tends to raise the toxicological potential and danger in humans by consuming fish that have accumulated heavy metals in their water. Enzymes and biological pathways can be inhibited by heavy metals. According to Singh et al. (2022), the toxicity of heavy metal pollution can cause neurological disorders, heart disease, kidney disease, respiratory illnesses, and blockage of the electron transport chain. Environmental heavy metal monitoring is quickly becoming a crucial component of pollution research.

It is commonly known that contaminated surface and groundwater can serve as a conduit for the spread of illness, and as industrialization has increased, groundwater depletion has been speedily rising (Khodapanah et al., 2009). According to Emmanuel et al. (2016), one of the primary causes of the aquatic environment's deterioration and the rise in the concentration of heavy metals in water bodies is the unregulated release of wastewater out into the environment by petroleum corporations. Petroleum processing negatively affected waterways in Nigeria's Niger Delta, according to Owamah's (2013) research, which also found a rise in the concentration of heavy metals.

Despite substantial documentation of heavy metal contamination in oil-producing regions (Uzoekwe & Oghosanine, 2011; Ordinioha & Brisibe, 2013; Adesiyan et al., 2018; Edori et al., 2019), there remains a limited understanding of how seasonal variations influence the distribution and concentration of these metals across diverse aquatic ecosystems in the Niger Delta. Most existing studies have been site-specific and often focus on single-season assessments or isolated pollutants (Emmanuel et al., 2016; Iyama et al., 2023), failing to capture broader comparative analyses across multiple impacted and control communities. This study addresses that gap by evaluating seasonal fluctuations in heavy metal levels across four distinct locations, thereby offering a more comprehensive perspective on petroleum-induced ecological degradation.

METHODS

Study Design

The present study was designed to investigate the seasonal dynamics of heavy metal pollution in aquatic ecosystems impacted by crude oil activities in Bayelsa State, Nigeria. A seasonal stratified ecological sampling approach was employed to ensure both spatial and temporal representation of the study sites. This design allowed for systematic comparisons between oil-impacted water bodies and a control site, thereby strengthening the reliability of observed differences.

Three oil-affected aquatic systems—River Niger (Ayamasa axis), Kolo Creek (Ibelebiri axis), and Taylor Creek (Ikarama axis)—were selected based on their proximity to crude oil exploration and spill-prone areas. In contrast, River Niger (Okumbiri axis) served as the control site, chosen specifically because it has no documented history of oil spills or petroleum-related activities. This control provided a baseline against which contamination levels in impacted sites could be evaluated.

To capture seasonal variability, sampling was conducted during two distinct hydrological periods: February 2024 (dry season) and September 2024 (wet season). This stratified design thus provided a robust framework for assessing the combined effects of crude oil activity and seasonal hydrology on aquatic ecosystems, offering insights critical for environmental monitoring and management in the Niger Delta.

Study Area

The research was conducted across four aquatic ecosystems in Bayelsa State, Niger Delta, Nigeria: River Niger (Ayamasa axis), Kolo Creek (Ibelebiri axis), Taylor Creek (Ikarama axis), and River Niger (Okumbiri axis, serving as the control site). These sites were strategically selected to represent both oil-impacted environments and a non-impacted reference system, thereby enabling comparative analysis of contamination patterns.

Bayelsa State covers approximately 10,773 km² and lies between latitude 4°15′ N to 5°23′ N and longitude 5°15′ E to 6°45′ E (Kadafa, 2012). Ecologically, the region is diverse, comprising mangrove forests, freshwater swamps, lowland rainforests, and derived savannah zones (NDDC, 2006). It is crisscrossed by numerous rivers and creeks that ultimately discharge into the Atlantic Ocean, making its aquatic systems highly dynamic and vulnerable to anthropogenic pressures.

The climate is characterized by a prolonged rainy season (February–November), with peak rainfall in July and September, and a short dry season (December–February). This hydrological rhythm plays a critical role in shaping water quality, influencing both the dilution and concentration of pollutants. The seasonal variability provided an ideal framework for assessing how heavy metal contamination fluctuates under different environmental conditions.

Data Collection of Surface Water Samples

Acid-washed polyethylene bottles were used to collect surface water samples for heavy metal analysis in the four studied water bodies. After reaching midstream into each river, the researcher submerged the bottle into the water, let it fill, and promptly acidified the sample with nitric acid to stop the absorption of metals. The subsequent sample was taken at a distance of 200 meters. In each of the four study locations—Ayamasa (River Niger), Ibelebiri (Kolo Creek), Ikarama (Taylor Creek), and Okumbiri (Control)—the process was repeated. It is crucial to remember that every chemical and reagent employed in this study is of analytical grade. Furthermore, test tubes, funnels, and conical flasks used for gathering and storing water samples were sterilized for approximately an hour at 160°C in a hot air oven. Before being sterilized at 160°C for an hour in a hot air oven, all pipettes and other heat-resistant glassware were wrapped in aluminum foil to prevent recontamination during handling and storage. All of the equipment was cleaned with water, and the samples were then securely taken to the laboratory for analysis.

Laboratory Analysis of Surface Water Samples

The quantification of heavy metals in digested surface water samples was conducted using an Atomic Absorption Spectrophotometer (AAS), specifically the Analyst 400 model. This analytical technique was selected for its sensitivity and reliability in detecting trace metal concentrations in aqueous matrices.

Prior to analysis, the AAS system was configured with acetylene gas, nitrous oxide, and a compressor. The compressor was activated to expel any residual liquid from the liquid trap, in accordance with the procedures outlined by the Association of Official Analytical Chemists (AOAC, 1990). The AAS control unit and extractor were subsequently powered on. To ensure optimal performance, the burner inlet was cleaned using an arrangement card, while the nebulizer and associated tubing were purified with a cleaning wire.

The analytical software interface was launched on the connected computer system. A hollow cathode lamp corresponding to the target analyte was inserted into the lamp holder and activated. The cathode beam was meticulously aligned with the designated target zone on the layout card to maximize light throughput, thereby initiating the spectrophotometric system (Haraguchi et al., 1991).

Each digested water sample was transferred into a 10 mL graduated chamber containing deionized water, adjusted to a predetermined aspiration rate (AOAC, 1990). An analytical blank and a series of calibration standards with known concentrations of the target metals were prepared. These solutions were atomized sequentially, and their absorbance values were recorded to establish calibration curves.

Following the calibration phase, the sample solutions were atomized, and their absorbance was measured under identical conditions. Calibration graphs were constructed for each metal based on the standard absorbance data. The concentrations of heavy metals in the unknown samples were extrapolated from these graphs, ensuring quantitative accuracy.

Methods of Data Analysis

To evaluate the heavy metal concentration of surface water samples, laboratory results were subjected to statistical analysis using the Analysis of Variance (ANOVA) method. This approach enabled the identification of significant differences among sample groups. To further distinguish the means, the Duncan Multiple Range Test was applied within the Statistical Package for the Social Sciences (SPSS).

Alphabetical groupings (a, b, c, d) were used to indicate statistically significant variations between categories, providing clarity in the interpretation of results. In order to calculate the Pearson's correlation coefficient (r), correlation matrices were created independently for the dry and wet seasons using paleontological software. Strong linear correlations are indicated by values near +1 or -1, whereas weak or no correlation is suggested by values near zero. The degree of correlation offers information about the sources, pathways, and seasonality of pollutants.

RESULTS

Table 1: Mean ± standard error of heavy metal mean concentration (mg/L) in water (dry season)

Parameters Mg/L	Ayamasa (River Niger)	Ibelebiri (Kolo Creek)	Ikarama (Taylor Creek)	Okumbiri (River Niger)
Fe	2.939±0.052^{b}	4.0427±0.139^{a}	1.653±0.094^{c}	0.417±0.045^{d}
Mn	0.130±0.032^{b}	0.432±0.026^{a}	0.089±0.004^{bc}	0.049±0.017^{c}
Cu	0.164±0.012^{c}	0.419±0.055^{a}	0.225±0.013^{b}	0.015±0.004^{d}
Zn	1.273±0.066^{c}	1.917±0.023^{a}	1.402±0.013^{b}	0.011±0.002^{d}
Cd	0.106±0.029^{b}	0.228±0.042^{a}	0.099±0.012^{b}	0.022±0.007^{b}
Cr	0.343±0.037^{b}	1.199±0.051^{a}	0.249±0.028^{b}	0.023±0.009^{c}
Pb	0.315±0.005^{b}	0.695±0.100^{a}	0.236±0.022^{b}	0.080±0.007^{c}
Ni	0.106±0.041^{b}	0.197±0.003^{a}	0.107±0.002^{b}	0.015±0.002^{c}

Source: Analysis by Author (2024). Means followed by different letters in a row are significantly different from one another

Table 2: During the dry season, Pearson's correlation coefficients demonstrated very strong positive associations among several heavy metals. Notably, iron (Fe) exhibited a high correlation with lead (Pb) (r = 0.965) and manganese (Mn) (r = 0.937), suggesting a consistent and possibly synergistic mobilization mechanism, likely influenced by oil-related industrial activities or geogenic interactions. Likewise, a nearly perfect connection (r = 0.972) between copper (Cu) and zinc (Zn) suggested possible leaching from mechanical or corrosion-prone sources. While chromium (Cr) showed significant correlations with both Fe (r = 0.909) and Pb (r = 0.916), cadmium (Cd) showed strong correlations with Zn (r = 0.895) and Pb (r = 0.846). These strong intermetallic connections suggest a relatively homogeneous contamination profile, with several metals most likely originating from similar anthropogenic sources and displaying similar environmental transport patterns during low-flow circumstances that are typical of the dry season.

Table 2: Correlation of Heavy Metal Concentrations at Surface water Dry Season

	Fe	**Mn**	**Cu**	**Zn**	**Cd**	**Cr**	**Pb**	**Ni**
Fe	1							
Mn	0.93706	1						
Cu	0.77622	0.7972	1					
Zn	0.8042	0.86713	0.97203	1				
Cd	0.81818	0.86014	0.88112	0.8951	1			
Cr	0.90909	0.86713	0.74825	0.77622	0.8042	1		
Pb	0.96503	0.93007	0.77622	0.83217	0.84615	0.91608	1	
Ni	0.81119	0.76224	0.86713	0.81119	0.86713	0.88112	0.81119	1

Table 3: Mean ± standard error of heavy metal mean concentration (mg/L) in water (Wet season)

Parameters Mg/L	**Ayamasa (River Niger)**	**Ibelebiri (Kolo Creek)**	**Ikarama (Taylor Creek)**	**Okumbiri (River Niger)**
Fe	1.300±0.015^{b}	2.063±0.061^{a}	1.065±0.048^{c}	0.233±0.037^{d}
Mn	0.079±0.012^{b}	0.136±0.016^{a}	0.096±0.002^{b}	0.022±0.002^{c}
Cu	0.113±0.024^{b}	0.258±0.021^{a}	0.127±0.0166^{b}	0.002±0.001^{c}
Zn	0.771±0.030^{b}	1.467±0.034^{a}	0.586±0.049^{c}	0.003±0.001^{d}
Cd	0.047±0.022^{ab}	0.084±0.011^{a}	0.041±0.023^{ab}	0.009±0.002^{b}
Cr	0.156±0.019^{b}	0.897±0.078^{a}	0.169±0.023^{b}	0.050±0.021^{b}
Pb	0.195±0.042^{b}	0.421±0.025^{a}	0.169±0.029^{b}	0.037±0.002^{c}
Ni	0.075±0.043^{bc}	0.169±0.019^{a}	0.089±0.008^{b}	0.009±0.002^{c}

Source: Analysis by Author (2024). Means followed by different letters in a row are significantly different from one another

Table 4: Correlation of Heavy Metal Concentrations at Surface Water Wet Season

	Fe	**Mn**	**Cu**	**Zn**	**Cd**	**Cr**	**Pb**	**Ni**
Fe	1							
Mn	0.83217	1						
Cu	0.76923	0.84615	1					
Zn	0.97023	0.7951	0.76007	1				
Cd	0.68531	0.77622	0.67832	0.74956	1			
Cr	0.82517	0.90909	0.92308	0.77408	0.67133	1		
Pb	0.8951	0.82517	0.8951	0.89667	0.60839	0.88811	1	
Ni	0.82517	0.87413	0.76224	0.86865	0.81818	0.7972	0.81818	1

Table 4: In the wet season, strong correlations persisted, although with slightly reduced magnitudes for some pairs. The Fe–Zn correlation remained high (r = 0.970), reinforcing the consistency of their co-occurrence across hydrological regimes. The Cu–Cr (r = 0.923) and Pb–Zn (r = 0.897) correlations remained substantial, suggesting stable associations despite increased dilution. Interestingly, Cd demonstrated comparatively lower correlations with Pb (r = 0.608) and Cu (r = 0.678), implying potential variation in its mobility or source contributions during the wet season. The persistence of strong Fe–Pb, Cr–Mn, and Ni–Zn correlations underline the sustained presence of common pollution sources, even amidst seasonal hydrological fluctuations.

DISCUSSIONS

Iron concentrations across crude oil–impacted waterbodies River Niger (Ayamasa axis), Kolo Creek (Ibelebiri axis), and Taylor Creek (Ikarama axis) revealed a clear distinction between the control location, River Niger (Okumbiri axis). Ayamasa recorded mean values of 2.939 mg/L (dry season) and 1.300 mg/L (wet season), while Ibelebiri showed the highest levels at 4.042 mg/L (dry) and 2.063 mg/L (wet). Ikarama followed with 1.653 mg/L (dry) and 1.065 mg/L (wet). In contrast, the control site at Okumbiri had much lower values of 0.417 mg/L (dry) and 0.233 mg/L (wet). This consistent disparity strongly indicated that crude oil activities contributed to elevated iron levels in the affected locations. Comparable findings have been reported in previous studies. Uzoekwe and Oghosanine (2011) as well as Owamah (2013) documented significant iron enrichment in effluent discharged from petrochemical refineries and in nearby water bodies compared to control zones. Their results aligned with this present investigation, reinforcing the conclusion that refinery effluents can substantially raise iron concentrations in aquatic systems. Further consistency emerges when compared with Edori et al. (2019), who reported iron levels ranging from 0.008 to 5.910 mg/L in the Elelenwo River, Rivers State. Their exceptionally high readings were attributed to the timing of sample collection, which coincided with the peak of a crude oil spill. This highlights how environmental events such as spills can dramatically influence heavy metal concentrations.

This study revealed marked geographical differences in manganese (Mn) concentrations across the four sampled sites during both the dry and rainy seasons. Kolo Creek (Ibelebiri) stood out with the highest Mn levels, recording 0.432 mg/L (dry season) and 0.136 mg/L (rainy season)—substantially greater than any other location. River Niger (Ayamasa) followed, with concentrations of 0.130 mg/L and 0.079 mg/L, while Taylor Creek (Ikarama) showed 0.089 mg/L and 0.096 mg/L, values that were statistically indistinguishable from the control site in the dry season. The lowest concentrations were observed at River Niger (Okumbiri), a site with no history of crude oil activity, where Mn levels dropped to 0.049 mg/L and 0.022 mg/L. When compared to previous findings, the results present an interesting contrast; for instance, Eyankware et al. (2023) reported Mn concentrations in the Okerenkoko, Peterou-Gbene, and Billie Rivers ranging from 0.0015 ± 0.0017 mg/L to 0.684 ± 0.008 mg/L. The current study's values were marginally lower. Conversely, Ekpete et al. (2019) documented a broader Mn range of 0.349 ± 0.062–2.891 ± 1.033 mg/L, which aligned more closely with the concentrations observed in this study.

The average copper (Cu) concentrations recorded across the study water bodies ranged between 0.015 and 0.419 mg/L in the dry season and 0.002 and 0.002–0.258 mg/L in the wet season. These values were noticeably lower than earlier regional estimates. For example, Ekpete et al. (2019) reported much higher concentrations in the Silver River, Southern Ijaw Local Government Area of Bayelsa State, ranging from 2.171 to 3.691 mg/L. More recent work by Iyama et al. (2023) documented mean Cu levels of 0.159 mg/L in the Uwanga River and 0.204 mg/L in the Worokuma River, both within Bayelsa State. The dry and wet season variation observed in this study is particularly revealing. The lower concentrations during the wet season (0.002–0.258 mg/L) can be linked to dilution effects from heavy rainfall and increased river discharge, which disperse and reduce the accumulation of metals in surface waters. In contrast, the higher concentrations in the dry season (0.015–0.419 mg/L) reflected reduced water volume, allowing metals to concentrate more readily. By situating these results alongside earlier studies, it becomes clear that while copper levels in the present investigation were lower than some regional reports, the dry and wet season rhythm of dilution and concentration remains a consistent driver of variability in metal pollution.

Crude oil–impacted locations River Niger (Ayamasa), Kolo Creek (Ibelebiri), and Taylor Creek (Ikarama), zinc concentrations were consistently elevated compared to the control site, River Niger (Okumbiri). For instance, Ayamasa recorded mean Zn values of 1.273 mg/L in the dry season and 0.771 mg/L in the rainy season, while the control group showed much lower levels of 0.011 mg/L and 0.003 mg/L, respectively. Similarly, the control location at Okumbiri had lower zinc values than both Ibelebiri and Ikarama, reinforcing the influence of crude oil activities on metal enrichment in these environments. When compared with previous research, this present study recorded slightly lower values. Amolo et al. (2022), working in the Imiringi, Emeyal, and Otabagi areas of Bayelsa State, reported mean zinc concentrations ranging between 1.344 and 2.461 mg/L. The contrast suggests that while zinc contamination remains a persistent issue in oil-affected regions, local variations in pollution intensity, hydrological conditions, and timing of sampling can significantly influence the recorded levels.

Cadmium concentrations in the study locations revealed a clear distinction between crude oil–impacted sites and the control. Ayamasa recorded mean values of 0.106 mg/L (dry season) and 0.047 mg/L (wet season), while Ibelebiri and Ikarama showed 0.228 mg/L and 0.084 mg/L, and 0.099 mg/L and 0.041 mg/L, respectively. In contrast, the control site at Okumbiri had much lower levels of 0.022 mg/L (dry) and 0.009 mg/L (wet). This disparity highlights the influence of crude oil activities on cadmium enrichment in aquatic environments. When compared with previous studies, the cadmium levels observed in this study were relatively higher than those reported by Iyama et al. (2023), who found concentrations ranging between 0.112 and 0.114 mg/L in the Santa Barbara River, Bayelsa State. However, both sets of findings remain significantly lower than the values documented by Ekpete et al. (2019) in the Southern Ijaw's Silver River, where cadmium levels reached as high as 2.410 mg/L (range: 0.714–2.410 mg/L). Interestingly, their study noted that no oil spill was present at the time, pointing instead to other anthropogenic sources for the elevated cadmium levels. This observation also aligned with another study conducted by Ogunfowokan et al. (2010), who reported cadmium contamination in reservoirs at Ede, Opa, and Asejire in Osun State, Nigeria. Their findings highlighted that cadmium can accumulate not only through crude oil pollution but also via bioaccumulation in aquatic species and other human activities. Similarly, Emmanuel et al. (2016) detected heavy metals in water bodies near the Eleme refinery, attributing the contamination to wastewater discharge from refinery operations.

Chromium concentrations varied across the study sites, with Ibelebiri (Kolo Creek) consistently recording the highest values in both dry and wet seasons, while River Niger (Okumbiri), the control site, showed the lowest levels. During the dry season, mean chromium concentrations ranged between 0.023 and 1.199 mg/L, whereas in the rainy season, values ranged between 0.050 and 0.897 mg/L. This variation reflects the influence of rainfall and hydrological changes, with dilution during the wet seasons moderating concentrations, though still maintaining elevated levels compared to the control. When compared with previous research, the values observed in this present study were somewhat higher than those reported by Iyama et al. (2023). Their study documented chromium levels of 0.222 mg/L in the Worokuma River and 0.410 mg/L in the Uwanga River, both located in Bayelsa State. The contrast highlights how local conditions—such as proximity to crude oil operations, effluent discharges, and seasonal hydrology—can significantly shape chromium concentrations in aquatic systems.

Lead concentrations varied across the study sites, with River Niger (Ayamasa) recording 0.315 mg/L, Kolo Creek (Ibelebiri) showing the highest level at 0.695 mg/L, Taylor Creek (Ikarama) at 0.236 mg/L, and the control site, River Niger (Okumbiri), at a much lower 0.080 mg/L. This clear disparity highlighted the impact of crude oil activities, as the control location consistently exhibited the lowest values. Compared to previous studies, the Pb levels observed in this study were higher than those reported by Iyama et al. (2023), who found concentrations of 0.011 mg/L in the Uwanga River and 0.049 mg/L in the Shellikiri River, both in Bayelsa State. However, the values remain lower than those documented by Ekpete et al. (2019), who reported lead concentrations as high as 3.813 mg/L in the Silver River, Bayelsa State. In their study, crude oil leaks were identified as the primary source of contamination, underscoring the strong link between oil-related activities and elevated heavy metal levels. Evidence from related studies further strengthens the link between industrial activities and elevated lead concentrations in aquatic environments. In the Eleme region of Rivers State, Emmanuel et al. (2016) reported that surface water contained higher lead levels (0.0031±0.0006 ppm) compared to subterranean water. This disparity was attributed to wastewater discharge from the Eleme refinery, which directly impacted surface water quality.

Nickel concentrations in the study sites revealed a clear pattern of contamination linked to crude oil activities. Mean values ranged from 0.015 to 0.197 mg/L during the dry season and 0.009 to 0.169 mg/L during the rainy season, with the control location consistently showing lower levels than crude oil–impacted areas. This disparity underscores the influence of oil-related operations on heavy metal enrichment in aquatic environments. The findings aligned closely with previous research in the region. Emmanuel et al. (2016) reported that surface waters around the Eleme refinery contained higher nickel concentrations than control sites, attributing the elevated levels to refinery effluent discharge. Similarly, Owamah (2013) documented significant nickel contamination in surface waters near oil-polluted areas of the Niger Delta.

CONCLUSION

This investigation highlighted the pressing environmental and public health implications of heavy metal contamination in aquatic bodies impacted by crude oil-related activities in Bayelsa State, Nigeria. The consistent detection of elevated levels of metals such as iron, manganese, copper, zinc, cadmium, chromium, lead, and nickel, especially during the dry season, reflects the intensified impact of petroleum-related activities on aquatic ecosystems. Kolo Creek (Ibelebiri axis), in particular, demonstrated significantly higher contamination levels, highlighting its vulnerability and the potential risks posed to surrounding ecosystems. The strong correlations between metal concentrations suggest common pollution sources, most likely linked to crude oil exploitation and industrial discharge.

These findings call for urgent, multi-level interventions, robust environmental monitoring frameworks, strict enforcement of pollution control policies, and community-driven remediation efforts. Protecting water resources from further degradation is not only essential for ecosystem preservation but also vital for safeguarding the health and livelihoods of residents in the Niger Delta region.

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