World Journal of Innovation and Modern Technology E-ISSN 2756-5491 P-ISSN 2682-5910
Vol 8. No. 4 2024 www.iiardjournals.org Online Version

Assessing Seasonal and Spatial Variations of Heavy Metal Concentrations in Microplastics, a case study of Otuoke River, Southern Nigeria

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DOI: 10.56201/wjimt.v8.no4.2024.pg108.121

Abstract

This study assessed the seasonal and spatial variations of heavy metal concentrations in microplastics present in water (MCPW) within the Otuoke River, Southern Nigeria, employing an integrated analytical approach. A dissecting microscope was used to visually identify microplastics, and a Flame Atomic Absorption Spectrophotometer (FAAS) was employed to evaluate heavy metals in accordance with US EPA 3050B procedure. Investigated metals included Cr, Fe, Hg, Mn, Ni, Cu, Pb, and Cd. The findings showed that in every sampling location and season, the amounts of Cd, Pb, and Hg were below detection thresholds. Conversely, during the dry season, elevated concentrations of Cu (41.06 ± 6.67 mg/kg), Mn (133.22 ± 2.71 mg/kg), Ni (33.23 ± 0.72 mg/kg), Cr (15.96 ± 0.67 mg/kg), and Fe (14,072.18 ± 1402.27 mg/kg) were recorded. These concentrations significantly exceeded the permissible limits and chronic hazard rating (CHR) recommendations set by the Federal Environmental Protection Agency (FEPA). Seasonal analysis showed that the concentrations of these metals declined sharply during the wet season. Principal Component Analysis (PCA) showed two major components with 85% of total variance, indicating common sources and intermetallic associations. This study is a pointer to the potential health and ecological risks posed by heavy metal-laden microplastics, indicating the need for stringent pollution control measures. The findings contribute to understanding the interaction between microplastics and toxic metals in river systems, suggesting a platform for environmental management cum policy framework in the Niger Delta regions and other regions with similar contamination profiles.

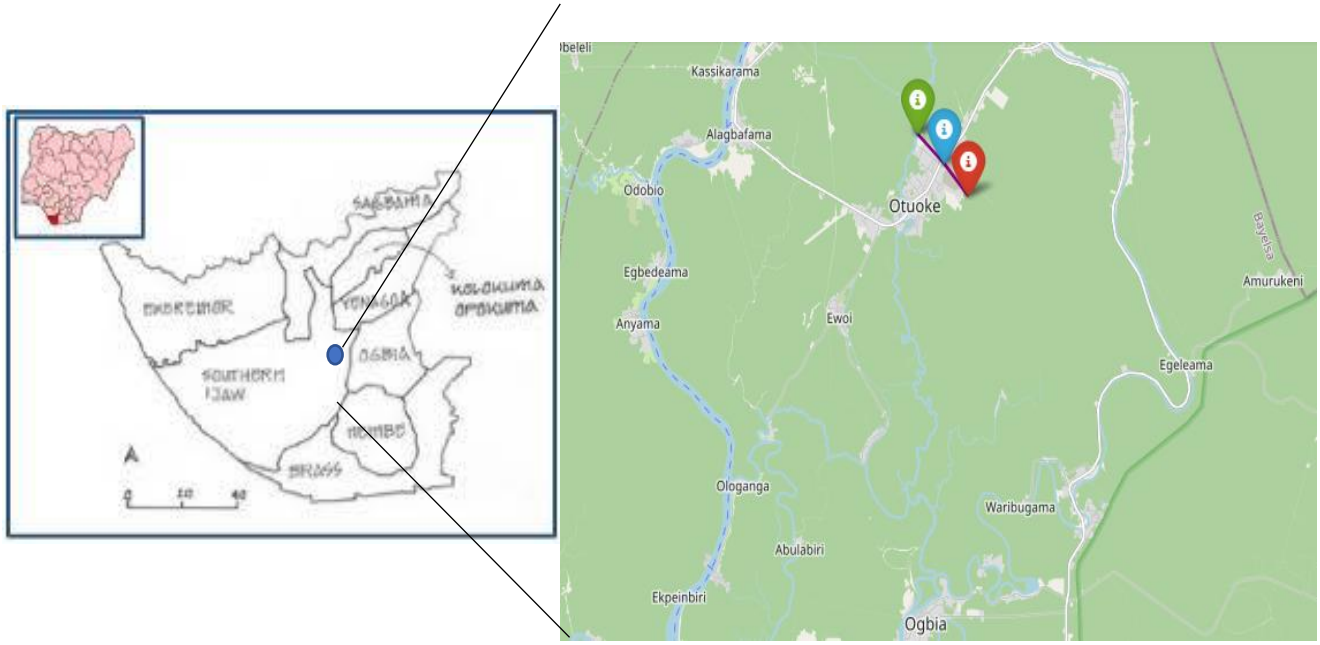
Keywords: *Heavy metal concentrations, microplastics in water, Otuoke River, seasonal variation*

1. Introduction

The widespread use of plastics has led to a global environmental crisis, with the aquatic environment bearing a substantial brunt of this burden. Nigeria, ranked as the ninth-largest contributor to marine plastic pollution globally, continues to grapple with the challenge of plastic waste disposal, despite regulatory efforts and public awareness campaigns (Jambeck et al., 2015). The rising plastic consumption in the country, which grows at an estimated 10.3% annually, has been fueled by investments in the plastic industry and the material's versatility, lightweight, and low cost (Babayemi et al., 2018; Verla et al., 2019). As a result, plastic debris, including microplastics - plastic fragments less than 5 mm in size and has become ubiquitous in Nigerian rivers and coastal waters. Microplastics can originate from larger plastic items broken down by environmental forces or be directly introduced into the environment through sources such as cosmetic products, synthetic textiles, and industrial processes (Thompson, 2015; Wang et al., 2018). Due to their small size, they are easily transported and dispersed, making them a pervasive contaminant in aquatic systems. The Otuoke River, like many other rivers in Southern Nigeria, is under significant environmental stress from anthropogenic activities, including agriculture, effluent discharges, and urbanization, which contribute to both plastic and heavy metal pollution. The convergence of these pollutants poses a dual threat: while microplastics can accumulate toxic chemicals from the environment, the presence of heavy metals can further exacerbate the ecological impact of plastic pollution. Basically, in rivers, these microplastics pose severe ecological risks, not only because of their persistence and propensity for bioaccumulation but also due to their role as vectors for other pollutants, including heavy metals. Heavy metals can adsorb onto the surface of microplastics or integrate into their structure during manufacturing, leading to complex interactions that have the potential to disrupt aquatic life and pose health risks to human populations relying on these water bodies. There is a knowledge gap in the quantification and analysis of heavy metals in association with microplastics or organic contaminants. Consequently, there is an urgent need to comprehensively assess the role of microplastics as carriers of heavy metals in aquatic ecosystems such as the Otuoke River. The objective of this study, therefore, is designed to investigate the seasonal and spatial distribution of heavy metal concentrations in microplastics found in the Otuoke River. The research will cover key sections of the river, including upstream, midstream, and downstream locations, to assess how heavy metal levels vary across different parts of the river. Seasonal variations will also be considered, with sampling conducted during both the dry and wet seasons to capture fluctuations in pollutant concentrations influenced by changes in water flow, precipitation, and human activities.

2. Materials and Methods

2.1 Study Area



Map of Otuoke river showing sampling stations (Source: OpenStreetMap)

The Otuoke River is located in the Southern region of Nigeria, situated at approximately 5°12'59.6" N and 6°19'10.1" E (earlier reported by Isaac, 2024a). The town of Otuoke, which is home to the Federal University of Otuoke, is a socio-political and educational centre situated along the Otuoke River in the Niger Delta region (Tamuno, 2005). traversing diverse landscapes, including agricultural fields, urban settlements, and industrial zones. The river serves as a vital water source for the surrounding communities, but it is subjected to various anthropogenic activities that introduce pollutants such as plastics and heavy metals. In this study, the river was divided into three distinct sections based on their geographical and environmental characteristics: upstream (STA -1), midstream (STA -2), and downstream (STA -3). The upstream section is characterized by less human interference and is mainly surrounded by agricultural land. The midstream section runs through Otuoke town, which experiences significant urban runoff and wastewater discharge. The downstream section, closer to a confluence with a larger water body, is influenced by industrial activities and increased sedimentation.

2.2. Sample Collection

Sampling was carried out during two distinct seasons: the dry season (November to March) and the wet season (April to October) to capture seasonal variations in heavy metal concentrations

associated with microplastics. Three sampling stations were selected along the 3.9 km stretch of the river (Fig. 1): Station 1 (5°11'35.1" N and 6°20'10.4" E), Station 2 (5°12'09.3" N and 6°19'10.2" E) and Station 3 (5°12'19.6" N and 6°19'03.2" E). Three (3) water samples were taken in each of the upstream, midstream, and downstream sections, giving a total of nine (9) samples per season. This sampling distribution was adopted to ensure adequate spatial representation across the river. Collection of samples of microplastics in surface water was carried out following the method described by Isaac (2024); Wang et al. (2017); Qu *et al*., (2018) and Zhu *et al*. (2019) with slight modification to suit the environment of study. Five litres of surface water sample (0–20 cm in depth) was collected using pre-cleaned glass bottles. The samples were filtered through a stainless-steel sieve (mesh size: 500 μm) to remove larger debris and then passed through a 0.45 μm sieve to collect microplastic particles. Three replicates were collected at each station. The residue on the sieve was rinsed with distilled water into a 100 mL glass jar and kept at 4 °C before analysis. The collected particles were stored in clean glass containers and preserved with 4% formalin solution until further analysis.

2.3 Analytical Procedure

The isolated microplastics (MCPW) were further analysed for heavy metal content. MCPW samples were air-dried in the laboratory at room temperature, pulverized independently and then sieved through a 2 mm pore size sieve to remove coarse particles. Pulverized samples were subjected to partial acid digestion following the method - US EPA 3050B (USEPA, 1996) and described by Vedolin et al, 2018. Exactly 2g each of MCPW was put in a 50 mL beaker and then 5 mL of concentrated HNO_3, 3.0 mL of H_2O_2 (30 % V/V) and 10 mL of HCl were added at 90 °C. Samples were digested on a Corning PC-351 model hot plate at medium to low heat until about 5 ml concentrated extract was left (or with sample concentrate tending towards near-dryness). Afterwards, the content of beaker was left to cool for about 30 minutes. Sample solution was filtered and quantitatively transferred into 50 ml standard volumetric flask. Finally, filtered solutions were made up to the 50 ml graduation mark using distilled water. Thereafter, metals (Cd, Cu, Cr, Fe, Mn, Ni, Pb and Hg) levels were determined using the GBC 908PBMT model Flame Atomic Absorption Spectrophotometer (FAAS) following the standard methods outlined by the American Public Health Association (APHA, 2017). Each sample was individually aspirated. The total metal concentrations are reported in units of mg/kg.

2.4. Quality control and quality assessment

The certified reference materials (CRMs) for heavy metals measured using atomic absorption spectroscopy (AAS) Sigma-Aldrich; Fe, Cd, Cr, Pb, Cu, Ni, Mn and Hg standards were used. All samples were analysed in triplicate; blank samples were also analysed. The rate of recovery of each metal as obtained through incorporation of a Matrix Spike (MS). This is generated by adding a known amount (a spike) of analyte to a sample, testing the spiked sample, and determining if we have recovered the amount that we added. The recovery rate of the laboratory analytical method was assessed using two sediment and water samples, to which a spiking solution was added. A Spiking solution is a standard that is chosen for preparing MS; the concentration of the analyte in the spiking solution is usually 60 -100 times higher than the concentration found in the unspiked

sample. Percentage recovery (% R) for metals was calculated to be: Ni- 99.1 %, Pb- 98.9 %, Cu- 95.7 %, Cd- 99.2 %, Cr- 98.8 %

2.5. Data Analysis

Data analysis was performed using statistical software (SPSS) to evaluate the spatial and seasonal variations of heavy metal concentrations in microplastics. Differences in metal concentrations in surface water, location and season were tested by analysis of variance (One-way ANOVA) using SPSS (version 25). Furthermore, descriptive analysis (mean, standard deviation, and range) and the potential sources of heavy metal contamination were inferred using Principal Component Analysis (PCA) and Cluster Analysis (CA).

3. Results and Discussion

3.1 Spatial and temporal concentrations of heavy metal in microplastics in water

Cadmium

The concentrations of cadmium (Cd) in microplastics in water (MCPW) were consistently below the detection limit of 0.001 mg/kg across all sampling locations and seasons, indicating a low level of contamination, aligning with the Federal Environmental Protection Agency (FEPA) permissible level of 0.01 mg/kg for Cu in river water (Table 1). Similar results were reported by Nwankwoala & Ememu (2019) in a study on microplastics in the Bonny River, Nigeria, where Cd was found to be below detection limits. However, Liu *et al.* (2020) observed elevated Cd concentrations in microplastics in the Yangtze River, China, which they attributed to industrial activities and urban runoff. Keskin *et al.* (2022) also reported higher Cd levels in microplastics from Turkish rivers, suggesting localized sources of contamination.

Table 1: Concentrations of heavy metals (Cd, Cu, Pb & Mn) in MCPW during dry and wet seasons in comparison with quality guidelines

MCPW Location	Cd (mg/kg)	Cu (mg/kg)	Pb (mg/kg)	Mn (mg/kg)
		Dry Season		
STA-1	<0.001	41.06 ± 6.67^{c}	<0.001	133.22 ± 2.71^{b}
STA-2	<0.001	37.88 ± 2.80^{c}	<0.001	106.37 ± 4.86^{c}
STA-3	<0.001	10.03 ± 0.95^{c}	<0.001	62.50 ± 2.94^{c}
		Wet Season		
STA-1	<0.001	0.33 ± 0.05^{c}	<0.001	10.98 ± 0.19^{c}
STA-2	<0.001	<0.001^{c}	<0.001	14.48 ± 0.37^{b}
STA-3	<0.001	<0.001^{c}	<0.001	2.98 ± 0.04^{c}
F-value	-	98.298	-	831.520
P-value	-	P < 0.01	-	P <0.01
*FEPA	-	-	0.01	0.05
**CHR	-	0.003	30.24	0.10
***ACUTE	-	0.41	112	NA

*Data are expressed as mean ± SD (Holmes-Sidak Test n = 3). values with superscript, a showed significant (p<0.05) difference when compared spatially within group. Values with superscript b, showed significant (p<0.05) difference when compared temporally between groups, values with superscript c, showed no significant (p>0.05) when compared spatially within group while superscript d, showed no significant difference when compared temporally between groups. **CHR and ***ACUTE are chronic hazard rating and acute hazard rating are metrics for evaluating potential heavy metal hazard in river surface water (Source: USEPA National ambient water quality criteria)*

Table 2: Concentrations of heavy metals (Ni, Cr, Fe & Hg) in MCPW during dry and wet in comparison with quality guidelines

MCPW Location	Ni (mg/kg)	Cr (mg/kg)	Fe (mg/kg)	Hg (mg/kg)
		Dry Season		
STA-1	33.23 ± 0.72[a, b]	15.96 ± 0.67[a]	14,072.18 ± 1402.27[a]	<0.001
STA-2	25.03 ± 2.03[a, b]	<0.001 [b]	7,560.06 ± 139.15 [a]	<0.001
STA-3	12.47 ± 0.51[c, b]	18.06 ± 1.10 [c]	13,932.68 ± 489.70 [a,b]	<0.001
		Wet Season		
STA-1	2.67 ± 0.12 [a,b]	<0.001 [b]	1,113.88 ± 131.09 [b]	<0.001
STA-2	2.38 ± 0.13[a]	<0.001 [b]	2.67 ± 0.12[b]	<0.001
STA-3	0.44 ± 0.03[a]	1.81 ± 0.09	3,384.76 ± 214.71[b]	<0.001
F-value	460.736	1678.461	213.571	-
P-value	P < 0.01	P < 0.01	P < 0.01	-
***FEPA**	-	0.05	1.00	-
****CHR**	0.008	0.05	0.05	0.13
*****ACUTE**	0.074	1.10	0.3	0.7

*Data are expressed as mean ± SD (Holmes-Sidak Test n = 3). values with superscript, a showed significant (p<0.05) difference when compared spatially within group. Values with superscript b, showed significant (p<0.05) difference when compared temporally between groups, values with superscript c, showed no significant (p>0.05) when compared spatially within group while superscript d, showed no significant difference when compared temporally between groups. **CHR and ***ACUTE are chronic hazard rating and acute hazard rating are metrics for evaluating potential heavy metal hazard in river surface water (Source: USEPA National ambient water quality criteria)*

The minimal Cd levels in this study indicate a lower risk of toxicity in the Otuoke River, reducing the potential for bioaccumulation and health risks in aquatic life and communities relying on the river.

Copper

Copper (Cu) levels exhibited significant variability between dry and wet seasons. During the dry season, STA-1 recorded the highest concentration at 41.06 ± 6.67 mg/kg, while STA-3 had the

lowest at 10.03 ± 0.95 mg/kg. In contrast, during the wet season, Cu concentrations drastically declined, with STA-1 showing only 0.33 ± 0.05 mg/kg. the concentration of Cu was statistically significantly ($p < 0.01$) during dry season. More so, during the dry season, the difference in Cu concentration was not significant, Cu concentrations exceeding Chronic Human Risk (CHR) value of 30.24 mg/kg, at all locations. However, all locations (STA -1, STA -2, STA -3) fell below the acute toxicity level (112 mg/kg) during the wet season. Similar high Cu levels in microplastics were reported by Okoro & Agwu (2021) in the Lagos Lagoon, Nigeria, where they linked elevated concentrations to industrial activities and runoff. Brennecke *et al.* (2016) also reported high Cu concentrations in the Mediterranean Sea, linked to shipping and maritime activities. Conversely, Hale *et al.* (2019) found significantly lower Cu concentrations in the Great Lakes, North America, reflecting lower anthropogenic influence. The elevated Cu levels during the dry season in the Otuoke River suggest increased contamination due to reduced water volume and anthropogenic inputs, emphasizing the need for enhanced monitoring during this period.

Lead

Lead (Pb) concentrations remained undetectable (<0.001 mg/kg) at all stations during both seasons, which fell below the FEPA stipulated threshold of 0.01 mg/kg, indicating that Pb levels were not a concern in MCPW across the sampled locations and seasons. This finding is consistent with several studies in Nigeria, such as those conducted in the Lagos Lagoon and Cross River, where Pb levels in microplastics were also found to be below detection thresholds. However, studies in more industrialized regions like the Yangtze River in China have reported significantly higher Pb concentrations due to industrial discharge and vehicular emissions. The lack of Pb contamination in the Otuoke River suggests limited exposure to sources of lead, indicating a lower potential risk of Pb-related health issues for the aquatic ecosystem and surrounding communities.

Manganese

Manganese (Mn) concentrations varied significantly between dry and wet seasons. In the dry season, STA-1 had the highest concentration at 133.22 ± 2.71 mg/kg, while STA-3 had the lowest at 62.50 ± 2.94 mg/kg. During the wet season, Mn concentrations markedly decreased, with STA-1 showing 10.98 ± 0.19 mg/kg and STA-2 showing a slightly higher value of 14.48 ± 0.37 mg/kg. There were statistically significant ($P < 0.01$) spatial and seasonal differences in Mn levels. Data showed that Mn concentrations exceeded acceptable FEPA limit of 0.05 mg/kg for Mn during dry season at all locations and fell below this limit during wet season. Similar studies in the Niger Delta have reported comparable high Mn levels, particularly during dry seasons when water volumes are reduced. Conversely, studies from less industrialized regions in Southeast Asia and Europe show significantly lower Mn concentrations, suggesting that local anthropogenic activities, such as oil exploration and metal refining, may be contributing to Mn pollution in the Otuoke River. High Mn levels can lead to neurological issues in humans and toxicity in aquatic life, making it imperative to implement pollution control measures during the dry season.

Nickel

Nickel (Ni) concentrations were statistically significantly higher during the dry season compared to the wet season, at $P < 0.01$. At STA-1, Ni levels were recorded at 33.23 ± 0.72 mg/kg in the dry season, which dropped to 2.67 ± 0.12 mg/kg in the wet season. The dry season levels were well above the chronic level of 0.008 mg/kg, indicating potential health risks. Results revealed marked differences in Ni concentrations between seasons. However, in both seasons, the difference in Ni Nickel concentration across locations were not statistically significant at $P > 0.05$. Elevated Ni levels in microplastics have also been reported in studies from the Niger Delta, where industrial effluents are prevalent. Similar trends were observed in rivers in India and South America, where Ni contamination is often attributed to mining and metal processing. In contrast, Ni levels in microplastics from remote areas like the Arctic are significantly lower. The high Ni concentrations in the Otuoke River, especially during the dry season, could be linked to the influx of industrial waste and decreased dilution capacity, emphasizing the need for stringent industrial effluent management.

Chromium

Chromium (Cr) levels exhibited low concentrations in the wet season, with STA-3 showing a measurable value of 1.81 ± 0.09 mg/kg, while it was below detection limits in other locations. Conversely, during the dry season, STA-1 recorded 15.96 ± 0.67 mg/kg. The difference in Cr concentrations between the two seasons was statistically significant at P-value of $P < 0.01$. the difference in Cr across locations during dry season was statistically significant at $P < 0.01$ while the reverse was the case during the wet season. Both dry and wet season concentrations exceeded the chronic guideline of 0.05 mg/kg, indicating a potential level of Cr contamination in MCPW. Elevated Cr levels in microplastics have been documented in Nigerian rivers impacted by industrial effluents, such as the Ogun River and River Niger, reflecting similar contamination patterns as seen in the Otuoke River. In contrast, Cr concentrations in microplastics from European rivers and Canadian lakes were found to be below detection limits or at negligible levels, indicating less anthropogenic influence. High Cr levels in the Otuoke River may pose risks such as oxidative stress in aquatic life and carcinogenic effects in humans, necessitating the implementation of pollution abatement strategies.

Iron

Iron (Fe) levels in MCPW were alarmingly high during the dry season, with STA-1 measuring 14,072.18 ± 1402.27 mg/kg, whereas wet season values dropped significantly to 1,113.88 ± 131.09 mg/kg at the same site. Temporally, ANOVA result revealed a statistically significant ($P < 0.01$) difference in Fe concentrations. Spatially, the difference in Fe concentration across locations were not statistically significant ($P > 0.05$). Both dry and wet season concentrations far exceeded the chronic guideline of 0.05 mg/kg, indicating potential Fe contamination. Similar trends have been observed in the Niger Delta, where high Fe levels are attributed to oil and gas exploration activities. Studies from other regions, such as North America and Western Europe, generally report much lower Fe concentrations, reflecting less industrial contamination. The extreme Fe concentrations

in the Otuoke River may indicate localized pollution sources and the potential for bioaccumulation, which could disrupt the river's ecological balance.

Mercury

Mercury (Hg) concentrations remained below the detection limit of <0.001 mg/kg at all sampling locations and seasons. The absence of detectable mercury is in alignment with the environmental standards that prioritize low or no mercury contamination. This result is consistent with findings from Etim *et al.* (2020) in the Imo River, Nigeria. However, Xu *et al.* (2020) reported significantly higher Hg levels in the Pearl River, China, linked to industrial emissions and urban runoff. The absence of detectable Hg in the Otuoke River indicates minimal contamination, reducing the risk of mercury toxicity in the local ecosystem and human populations.

3.1 Potential source of contamination

The source identification was investigated using two (2) tools namely, principal component analysis and cluster analysis as discussed:

3.1.1 Principal component analysis

The Principal Component Analysis (PCA further revealed the effects of seasonal changes and site-specific factors in the MCPW, showing significant patterns in the concentrations of heavy metals. The cumulative variance of 85.4% was explained by the first two principal components (PC1 and PC2), of which PC1 contributed 61.2% and PC2 24.2% (Table 1). This large cumulative percentage suggests that the complexity of the heavy metal distribution in the samples may be succinctly summarized by these constituents. The PCA plot demonstrated the clear seasonal variation in metal concentrations by differentiating samples from the dry and rainy seasons. Fe, Mn, and Ni are the major drivers of PC1, accounting for most of the variance (Fig. 2). The distinct split along the PC1 axis can be explained by the much greater quantities of these metals during the dry season.

Table 3: Total and cumulative variance of heavy metals in PCA analysis of MCPW

Component	Cd	Cu	Pb	Mn	Ni	Cr	Fe	Hg	Eigen value	Total Variance (%)	Cumulative Variance (%)
PC1	0.12	0.34	0.08	0.45	0.28	0.16	0.6	0.12	5.13	64	64
PC2	0.18	0.53	0.15	0.11	0.32	0.49	0.07	0.05	1.66	21	85

High Fe concentrations, especially at STA-1 and STA-3 in the dry season, exceeded 14,000 mg/kg, indicating contributions from nearby geological sources and potential industrial runoff, in line with research from Okoro et al. (2020) in the Niger Delta. The separation along PC1 suggests that seasonal variations in hydrology can have an impact on the mobilization and retention of these

metals. PC2, which accounts for a lesser but significant percentage of the variation, reveals more nuanced differences associated with trace metals like copper (Cu) and chromium (Cr). Cu concentrations were much lower during the rainy season owing to dilution from increased runoff and flow, although being substantially greater during the dry season. This behaviour suggests that localized pollution sources that are less prominent during the wet season are reflected in PC2.
The homogeneity of metal concentrations owing to dilution is highlighted by the clustering of wet season samples with lower PC1 and somewhat negative PC2 scores. The distribution of samples along the two principal components indicates that site-specific variables contribute secondary contributions, while seasonal variability is the dominant factor driving observed changes in heavy metal concentrations. Because of the masking effect of increased water volume and velocity, the close grouping of wet season samples shows a reduced impact of site-specific characteristics during this period. The larger dispersion of dry season sample along PC1, on the other hand, is indicative of site-specific metal accumulation mechanisms that are more prominent under the low-flow circumstances that are typical of the dry season. Overall, PCA does a good job of illustrating how seasonal and localized factors interact to affect the levels of heavy metals in the MCPW.

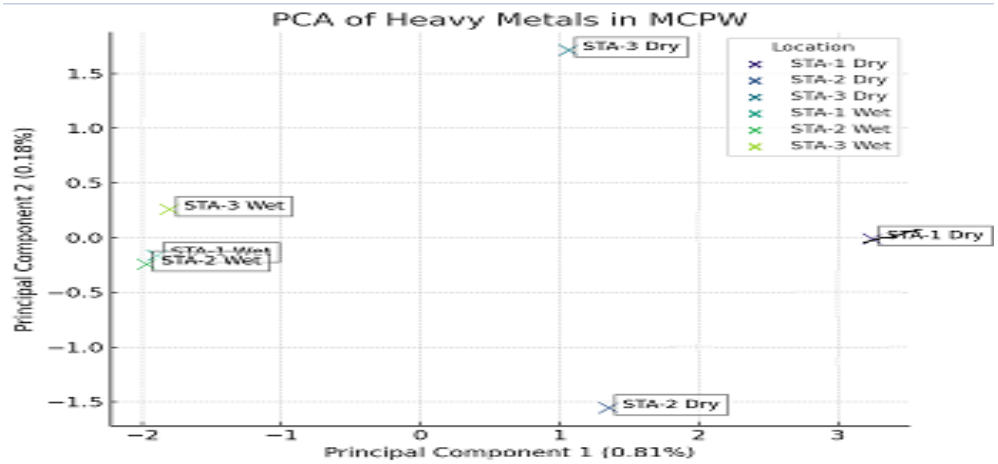


Fig. 2: Principal component loadings of selected metals in MCPW investigated in Otuoke river during at different locations and seasons

3.1.2 Cluster Analysis

Based on the heavy metal profiles of the MCPW samples, the Hierarchical Cluster Analysis (CA) complements the results of the Principal Component Analysis (PCA) by illuminating the similarities and differences across the samples. The two main clusters in the dendrogram produced by the CA, which correspond to the samples collected during the dry and wet seasons, suggests that seasonal variations have a significant impact on the distribution of heavy metals, in agreement with the observation of PCA. The samples collected during the dry season have a clear clustering pattern, suggesting that their heavy metal profiles are comparable and are marked by higher levels of Fe, Mn, and Ni. Common seasonal conditions, such lower water levels and less dilution, which promote metal retention and build-up in the sediment and water column, are probably the cause of this

resemblance. Samples from STA-1 and STA-2 are more closely connected to one another within this cluster, indicating that these two sites may have comparable environmental conditions or pollution sources due to their closeness to industrial activity or particular hydrological settings. The fact that the samples from the wet season form a distinct cluster highlights the influence of seasonal hydrology on the distribution of heavy metals. The close grouping of these samples suggests that during the wet season, higher rainfall and runoff produce a more consistent metal distribution across various areas, hence lowering sample variability. This pattern of clustering is in line with the results of PCA, which showed that samples from the wet season were less scattered and had lower PC1 scores than samples from the dry season. The distinct division between the clusters associated with the dry and wet seasons emphasizes the necessity of taking seasonal fluctuations into account while managing and assessing heavy metal contamination in the MCPW. Significant seasonal fluctuations in hydrology impact metal mobility and bioavailability, outweighing site-specific effects such as proximity to sources of pollution and local geology.

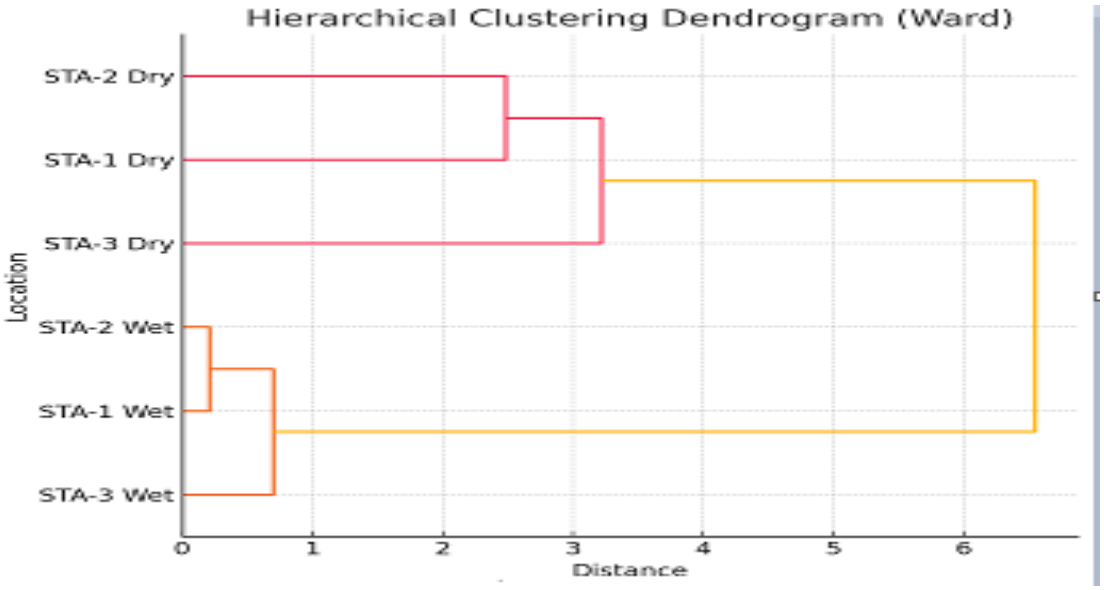


Fig. 3: Hierarchical cluster analysis showing association of different metals spatially and temporally in Otuoke river

Conclusions and Recommendations

According to this study, there may be ecological and health hazards associated with the heavy metals Cu, Mn, Ni, Cr, and Fe being greatly enriched in microplastics in the Otuoke River, especially during the dry season. The high levels were over FEPA and CHR standards, suggesting that anthropogenic activities may have caused the contamination. Seasonal fluctuations point to the impact of hydrological system on pollution dispersion by

indicating diluting effects during the wet season. Routine monitoring of the levels of heavy metals in river systems especially on the microplastics found in the river water will eliminate or reduce these dangers. It is advisable that government agencies in the state place measures to deter casual waste disposal especially plastic materials in the environment on industrial emissions and raise public awareness of the detrimental consequences of plastic pollution. More so, it is important to also investigate the concentrations of toxic metals on microplastics in sediment and to also examine the mechanisms via which metals and microplastics interact in order to fully understand the danger posed to the Otuoke river network

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The authors are grateful to the personnel of the Community leaders of Otuoke for their cooperation during field sampling. Our gratitude goes to the Management of Federal University Otuoke (FUOTUKE) for approving this study via Institution Based Research (IBR) scheme. I also wish to dedicate this article to the memory of the Late Professor AmaloNdu Dibofori-Orji.

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