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Microplastics in Silver Catfish *(Chrysichthys Nigrodigitatus)* of River Nun in the Niger Delta, Nigeria: Concentration, Distribution Pattern, and Human Health Risk

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ABSTRACT

Microplastic pollution in freshwater ecosystems has become an emerging environmental and public health concern. This study investigates the occurrence, abundance, characteristics, polymer composition, and potential health risks of microplastics in Chrysichthys nigrodigitatus (silver catfish) from River nun in Bayelsa Central, Nigeria. Fish samples were collected from six locations over six months (January–March and July–September 2024) and analyzed using standard methods, micro-FTIR and GC-MS were also used to identify polymer types and chemical additives. Results revealed varying concentrations of microplastics across locations, with values ranging from 236.67 mg/kg to 566.67 mg/kg. Abundance also differed significantly, with higher counts recorded during the wet season. The dominant microplastic colors observed were black, brown, and transparent, while fragments and fibers were the most prevalent shapes. Particle sizes ranged from <0.1 mm to 5 mm, with the majority falling within the 1–0.3 mm and 0.3–0.1 mm categories. FTIR analysis identified polymer types including polyethylene (PE), polypropylene (PP), Nylon 6 (PA6), polyethylene terephthalate (PET), and polyvinyl chloride (PVC). GC-MS analysis revealed high phthalate levels, particularly DiBP and DEHP, with peak concentrations of 69.11 ppm. Human health risk assessment showed hazard index (HI) values exceeding acceptable limits (>1) across all locations, suggesting potential risks to fish consumers. The findings highlight the urgent need for integrated plastic waste management, policy intervention, and environmental education to reduce plastic input into aquatic systems. Further research is recommended to explore the bioaccumulation of microplastics in edible fish tissues and assess their toxicological effects on human health.

Keywords: *Microplastics, Freshwater ecosystems, Chrysichthys nigrodigitatus, Polymer identification, Health risk assessment*

Introduction

Plastic pollution has emerged as one of the most pressing environmental issues of the 21st century, with microplastics becoming a significant concern due to their pervasive presence and potential ecological impacts (Benson et al., 2022; Du et al., 2021). Microplastics, characterized as plastic particles smaller than 5 mm, originate either as primary particles, such as microbeads in cosmetics or as secondary particles from the degradation of larger plastic debris (Guerranti et al., 2017). Their small size, buoyancy, and durability allow them to persist in aquatic environments, where they interact with biota, including fish, which play a crucial role in food webs and human diets (Haque et al., 2023; Debroy et al., 2021). Understanding the extent of microplastic contamination in fish is essential for assessing ecological risks and potential implications for food security and public health (Duan et al., 2021). Globally, microplastics have been detected in various aquatic organisms, ranging from plankton to large fish species, highlighting their pervasive nature and the potential for bioaccumulation within food chains (Haque et al., 2023). Fish, being integral components of aquatic ecosystems and a primary protein source for millions of people, are particularly vulnerable to microplastic ingestion (Adeogun et al., 2020). Microplastics can enter fish through direct ingestion or indirectly via prey, posing risks to their physiological health, including physical blockages, oxidative stress, and reduced feeding efficiency (Ilechukwu et al., 2021). Moreover, microplastics often act as vectors for toxic chemicals, such as persistent organic pollutants (POPs) and heavy metals, which may exacerbate their impact on aquatic organisms and, subsequently, on human consumers (Yan et al., 2020; Koelmans et al., 2018).

In Africa, where fisheries are a critical source of nutrition and economic livelihood, the implications of microplastic contamination in fish are significant (Gideon et al., 2024; Oceng et al., 2023). The continent faces unique challenges related to plastic pollution, including inadequate waste management systems, population growth, and rapid urbanization (Maddela et al., 2023). Rivers, estuaries, and coastal waters, which serve as primary fishing grounds, are increasingly burdened by plastic debris, leading to the infiltration of microplastics into aquatic food chains (Liu et al., 2024; Leslie et al., 2017). Despite the growing awareness of plastic pollution, studies investigating microplastics in African fish species remain limited, creating gaps in understanding the regional extent of the issue and its potential health and ecological consequences (Lavoie et al., 2021). Nigeria, as Africa's most populous country, relies heavily on fisheries for food security and economic sustenance (Oceng et al., 2023). The Niger Delta region, with its extensive river networks and biodiversity, is particularly vital to the nation's fisheries sector (Ogbomida et al., 2023). The River Nun, a major tributary of the Niger River, is a critical resource for communities in Bayelsa Central, supporting artisanal fishing, transportation, and domestic water use (Rochman, 2013). However, the river is increasingly exposed to anthropogenic pressures, including oil exploration, agricultural runoff, and indiscriminate waste disposal (Liu et al., 2024). These activities contribute to the accumulation of microplastics in the river, with fish species in the region at high risk of exposure (Pereao et al., 2020; Pitt et al., 2018). Given the socio-economic importance of fish in the Niger Delta, understanding the prevalence of microplastics in local fish populations is essential for safeguarding both ecological integrity and public health (Uzomah et al., 2021).

The significance of this research lies in its ability to bridge scientific knowledge with practical implications for policy and management (Vanapalli et al., 2021). As microplastic pollution continues to escalate globally, understanding its impacts on fish in the Niger Delta offers valuable insights into the broader challenges facing freshwater ecosystems (Talley et al., 2020). By situating this research within the unique socio-economic and ecological context of Bayelsa Central, the study not only highlights the vulnerability of the region's fisheries to microplastic pollution but also highlights the need for targeted interventions to protect aquatic resources and public health (Yi et al., 2024). This investigation represents a critical step toward addressing the challenges of microplastic contamination in fish, with implications for local communities and global efforts to combat plastic pollution (Shi et al., 2023; Zhilu et al., 2020). The outcomes will inform stakeholders, policymakers, and researchers, fostering collaborative solutions to mitigate the impacts of microplastics and ensure the resilience of aquatic ecosystems in Bayelsa Central and beyond.

This study investigates the occurrence, distribution, and potential risks of microplastics in fish species from the River Nun in Bayelsa Central, Nigeria. By examining fish as biological indicators of microplastic pollution, the research seeks to provide critical insights into the extent of contamination within the aquatic food chain (Rochman et al., 2013). The study will also assess potential sources of microplastics and their implications for fish health and human consumption offering a baseline data on microplastic contamination in the region. The findings aim to contribute to the global understanding of microplastic contamination in tropical freshwater systems while addressing local concerns related to food safety and environmental sustainability.

Materials and Methods

Study Area

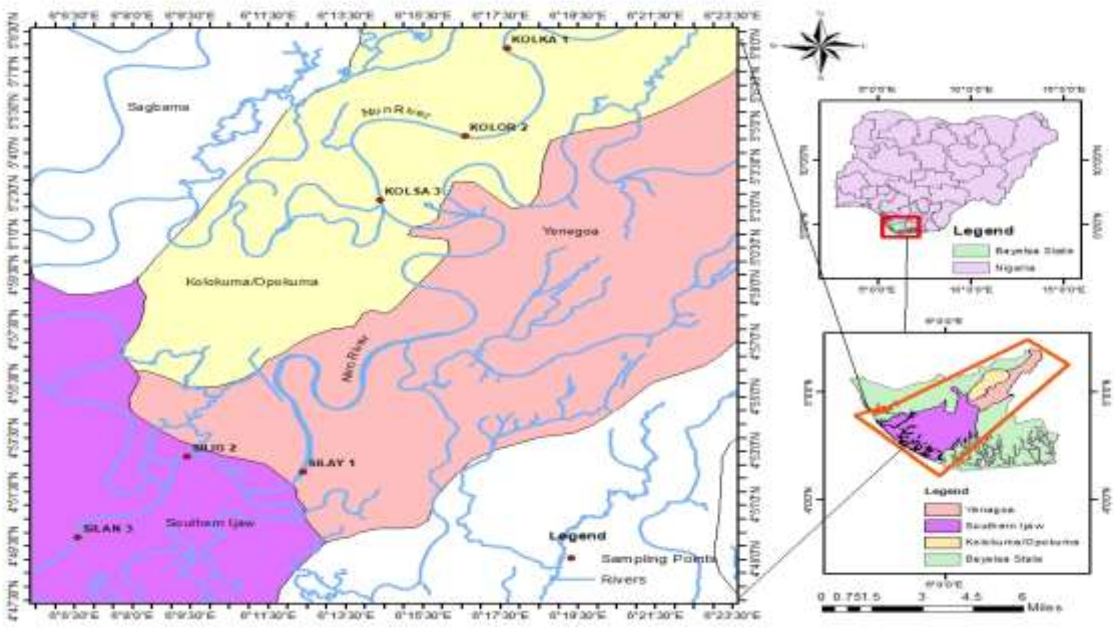

Figure 1. Map of Sediment Sampling Locations for Microplastics in River Nun Bayelsa Central, Nigeria

Bayelsa Central, situated in the heart of Nigeria's Central Niger Delta, spans from Latitude/Longitude 4°48′17″N 6°04′44″E to 5°5′55″N 6°15′50″E. This region is characterized by its complex network of rivers, creeks, estuaries, and vast mangrove forests, fostering a diverse and thriving ecosystem. It serves as an ecological hotspot, home to endangered species such as sea turtles, manatees, and various bird species. The indigenous communities of Bayelsa Central rely on the area's rich aquatic and marine resources, with fishing, farming, and tourism forming the core of their economy and cultural heritage. The River Nun, a crucial freshwater source, plays a vital role in supporting these communities and remains a focal point for ecological and environmental research.

Sample Collection

Samples were collected following the methods outlined by Attah et al. (2023) and Ilechukwu et al. (2021), with modifications to suit the study's specific objectives and conditions. Sampling took place along the River Nun at six locations: Kaiama (KOLKA 1), Orubiri (KOLOR 2), Sabagreia (KOLSA 3), Ayama (SILAY 1), Igeibiri (SILIG 2), and Angiama (SILAN 3), selected for their ecological importance and socioeconomic relevance. The sampling was conducted over six months, from January to March for the dry season and July to September for the wet season in 2024, to capture spatio-temporal variations in microplastic distribution. Silver Catfish *(Chrysichthys nigrodigitatus)* was collected from Six (6) sampling locations from local fishermen, ensuring a representation from each sampling location. Fish specimens was captured using a hand net, followed by wrapping the fish samples in Alluminum foil. A total of 36 fish samples was used in this study for a sampling period of six (6) months. The fish samples were keep in a closed cooler with ice blocks to preserve the fish sample until they were taken to Laboratory for analysis.

Sample Preparation, and Extraction of Microplastics

Microplastics were extracted from Silver Catfish *(Chrysichthys nigrodigitatus)* using filtration, density separation, and a microscope following Masura et al., (2015), NOAA protocol. Fish guts was obtained according to the method described by Ilechukwu et al., (2021) and Lusher & Hernandez-Milian (2018). The weight and length of the fish were recorded. The guts of the fish samples were removed by ventral dissection (cutting straight from the mouth to the tail). It was placed in a clean beaker, and 30% hydrogen peroxide were used three times the volume of the content. This was incubated at 40 ºC for 48 hours to dissolve all organic tissues (organic digestion). This process was replicated until all the tissues are completely dissolved. And 65 ºC were used, anything more than 65 ºC may alter the Microplastics. About 500 ml NaCl saturated solution were added (the solution must be saturated) after complete dissolution, stir for Two minutes, and allow to stand for 24 hours to float the Microplastics. This process is called the density separation method. then decant, the solution was filtered with a vacuum pump once it becomes clear, and the filtrate were discarded while the residue which contained the microplastics was dried in the oven at 60 ºC and stored in glass petri dishes for further analysis. The microplastics were then viewed with Light Electron Microscopy and the following parameters were noted and recorded, such as; Shape, Color, and Length.

Analysis of Microplastics

Microplastics extracted from fish samples were analyzed using micro-Fourier transform infrared (μ-FTIR) spectroscopy (Bruker Vertex 70v, Germany) across a specific wavelength range (4000–400 cm-1) to identify plastics, as described by Wang et al. (2021). In addition, Gas Chromatography-Mass Spectrometry (GC-MS; Agilent Technologies, Santa Clara, USA) was employed to detect chemical additives, such as phthalates, associated with microplastics in fish samples, following the methodology outlined by Masura et al. (2015).

Quality Assurance and Quality Control

To maintain experimental cleanliness, researchers avoided wearing cotton or linen fabrics to prevent particle shedding. Efforts were made to minimize airflow within the laboratory to reduce contamination. All liquids used in the study were filtered through a GF/C filter (1.2 µm, Whatman®) prior to use. Equipment was cleaned with ultrapure water and absolute ethanol, then covered with foil to prevent exposure. A control experiment was performed to assess the potential effects of liquids, air movement, and environmental conditions on the results. Airborne particles were captured by passing air through a 0.45 µm glass microfiber filter via vacuum filtration for 90 minutes, revealing an average of 0.33 ± 0.47 particles. Additionally, filtering 10 liters of ultrapure water through the same filter showed no plastic particles. These findings confirm that contamination during the analysis was minimal.

Statistical Analysis

Data analysis was conducted using one-way ANOVA with SPSS software, version 25.

Microplastic risk assessment method

The potential human health risk assessment of this study was conducted using the method adopted by Liu et al., (2019), Wang et al., (2021) and Mehinto et al., (2022) with some modifications. To assess the potential risks associated with microplastics, Hazard Quotient (HQ) and Hazard Index (HI) methods were employed using the equations:

The Hazard Quotient (HQ) formula used is:

$$HQ = \frac{C}{RfD}$$

Where:

- **C:** Average concentration of microplastics in the medium (e.g., sediment, water, or fish tissue) in mg/kg or µg/kg.
- **RfD:**The Reference Dose (mg/kg/day), representing the safe daily exposure limit to a substance without significant adverse health effects.

Two RfD values were used for this study (Mehinto et al., 2022):

1. **RfD Low** = 10 mg/kg/day
2. **RfD High** = 676 mg/kg/day

The HQ was calculated separately for both low and high RfD values to provide a range of potential risks.

The Hazard Index (HI) is calculated as the average of HQ values from the low and high RfD:

HI = 2

The risk is interpreted as follows:

- **HI<1:** Acceptable level of exposure with no significant health risk.
- **HI≥1:** Potential for adverse health effects.

Results and Discussion

Concentration of Microplastics

The concentration of microplastics in sliver catfish (*Chrysichthys nigrodigitatus*) varied notably across the six sampling sites and months, with the highest values recorded during the dry season as displayed in Figure 2. In July, SILAY 1, SILIG 2, and KOLKA 1 recorded peaks of 900 mg/kg, 740 mg/kg, and 840 mg/kg respectively. SILAY 1 consistently exhibited elevated levels throughout the sampling period, while sites like KOLKA 1 and SILAN 3 recorded zero values in the early dry months, suggesting spatial differences in microplastic exposure. A decline in microplastic concentrations was observed during the wet season (August–September), likely due to increased water volume and dilution, which may reduce microplastic availability or alter fish feeding behavior which agrees with previous study by Garcia-Torné et al., (2023). The seasonal fluctuation suggests that hydrological changes strongly influence microplastic ingestion rates as observed similarly by Geremia et al., (2023) and Adeogun et al., (2020). Sites located near urban or high-activity zones, such as SILAY 1 and SILIG 2, maintained higher concentrations, indicating proximity to pollution sources such as waste discharge, boat traffic, or fishing activities as similarly stated in pervious study conducted by Du et al., (2021).

The ingestion of microplastics by C. nigrodigitatus raises ecological and physiological concerns according to Ilechukwu et al., (2021). Potential impacts include intestinal blockage, reduced feeding efficiency, and bioaccumulation of toxic additives or adsorbed pollutants, which may impair growth, reproduction, and survivalwhich aligns with pervious study by Adeogun et al., (2020) and Benson et al., (2022). As noted similarly by Benson et al., (2022), chronic exposure could also lead to long-term health effects, affecting fish populations and food web stability. These findings highlight the urgent need for pollution control measures, particularly during the dry season when fish are more vulnerable to microplastic ingestionas similarly established by Ellen et al., (2019).

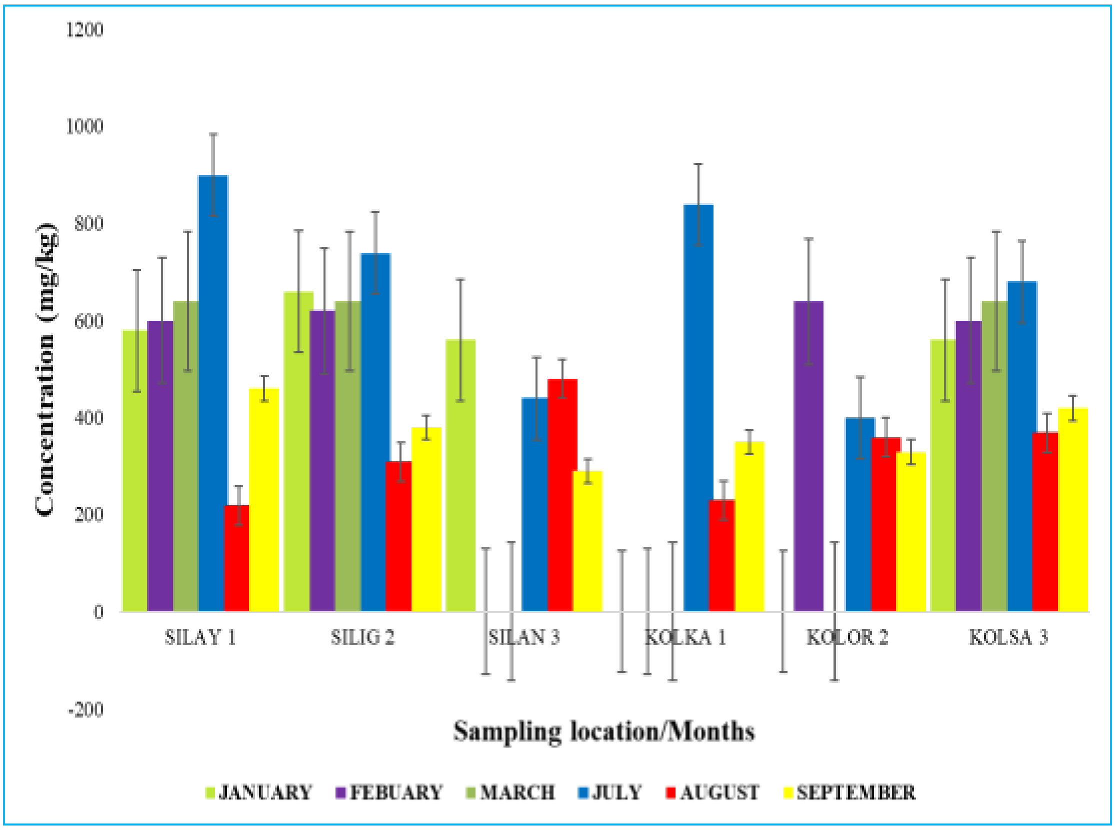

Figure 2. Mass concentration of microplastics in *Silver Catfish (Chrysichthys nigrodigitatus)* during both dry (January-March) and wet (July – September) seasons 2024 across sampling locations in River Nun

Abundance of Microplastics

The abundance of microplastics in sliver catfish(*Chrysichthys nigrodigitatus*) varied across sites and months, reflecting both seasonal and spatial influences as shown in Figure 3. SILIG 2 showed the highest overall abundance, peaking at 147.5 particles/kg in September, followed by KOLOR 2 with 142.5 particles/kg in the same month. SILAY 1 also recorded a steady increase from January (72.5 particles/kg) to September (107.5 particles/kg). In contrast, KOLKA 1 showed no microplastic presence from January to March, with a sharp rise in July (112.5 particles/kg) and a decrease in September (60 particles/kg). The absence of microplastics in some months, especially in KOLKA 1 and SILAN 3 during the early dry season, suggests fluctuating contamination levels or varying feeding and ingestion patterns which aligns with the study conducted by Geremia et al., (2023). The dry-to-wet season transition played a significant role in abundance trends. Most locations recorded relatively low to moderate levels from January to March, with a sharp increase beginning in July, likely due to increased human activities and waste accumulation during the dry season as similarly observed in a study by Haque et al., (2023) and Guven, (2021). The consistently high abundance at sites like SILIG 2 and KOLOR 2 indicates persistent exposure, possibly due to proximity to domestic or industrial waste sources which agrees with the findings of Huang et al., (2021) and Guerranti et al., (2017). According to the observation by Guven, (2021), these trends highlight the influence of seasonal runoff, water flow, and local pollution pressure on the abundance of microplastics ingested by fish.

Microplastic ingestion poses significant ecological and physiological risks to C. nigrodigitatus, as similarly reported by Ilechukwu, et al., (2021). High abundance levels may lead to intestinal obstruction, false satiation, inflammation, or chemical toxicity due to adsorbed pollutants, consistent with the previous study by Junaid et al., (2023) and Kim et al., (2022). Over time, these effects could reduce the fish's fitness, impair growth, and threaten reproductive success, as stated similarly by Klasios, & Tseng, (2023). Since C. nigrodigitatus is both ecologically important and widely consumed, microplastics in its system may also raise food safety concerns for humans, underlining the broader implications of plastic pollution in aquatic environments which agrees with a similar study by Ilechukwu, et al., (2021).

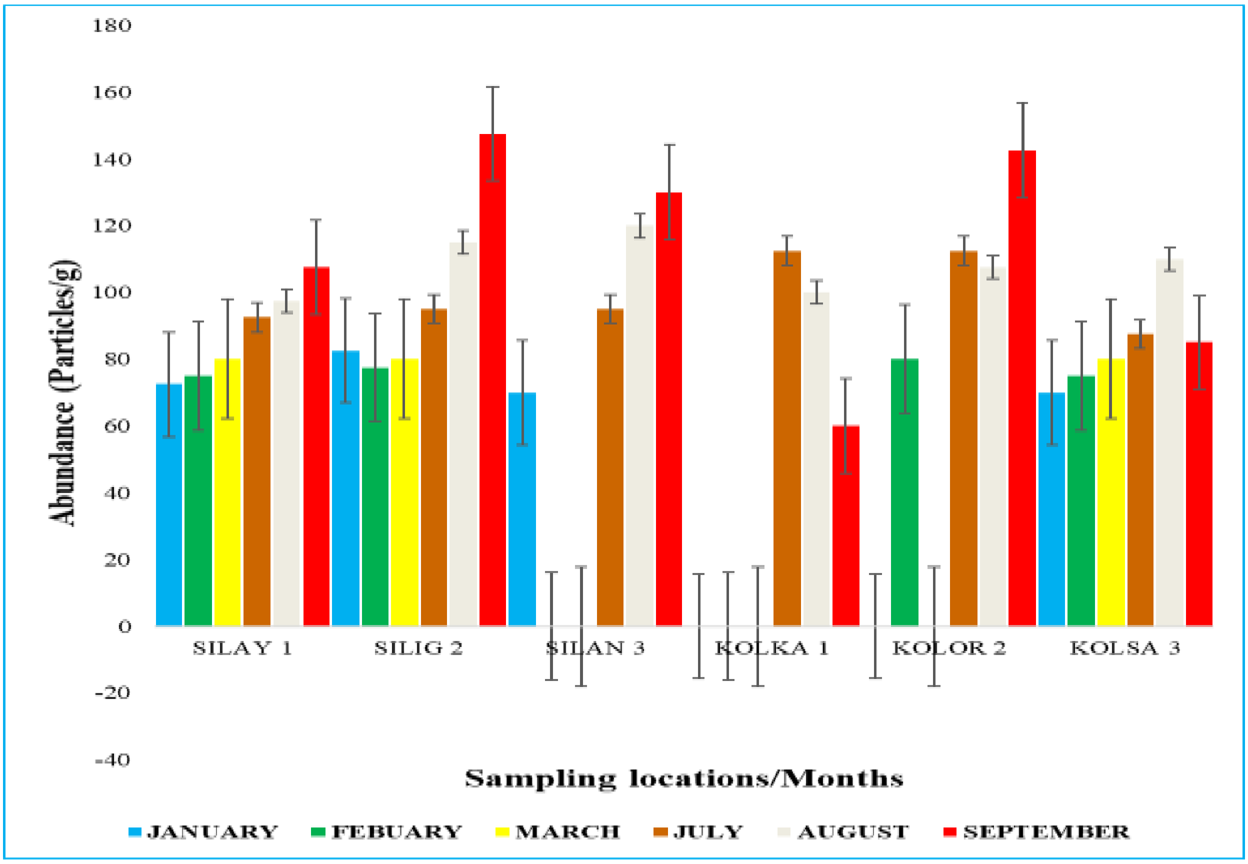

Figure 3. Abundance of microplastics in silver catfish *(Chrysichthys nigrodigitatus)* during both dry (January-March) and wet (July – September) seasons 2024 across sampling locations in River Nun

Shapes Distribution of Microplastics

The dominant shapes of microplastics identified in silver catfish*(Chrysichthys nigrodigitatus)* across all locations and months as revealed in Figure 4, were fibers, filaments, and fragments, with minimal occurrence of pellets, films, and others. Fibers were consistently present across most samples, particularly in SILAY 1, SILIG 2, and KOLSA 3 during the dry season (January to March), with counts ranging from 14% to 18%. Filaments were also prevalent, peaking in SILIG 2 (33%) and SILAN 3 (30%) during September. Fragments, on the other hand, showed a noticeable rise in August and September, especially in SILAN 3 (26%) and SILAY 1 (18%). Locations like KOLKA 1 and KOLOR 2, which showed no particles in early months, recorded significant presence of filaments and fibers in the wet season, consistent with the observations by Attah et al. (2023). Temporal patterns revealed that during the dry season, fibers and fragments were more common, likely from textile runoff and degraded plastics as noted similarly by Guven (2021). In the wet season, especially in August and September, filament and bead-like structures became more abundant. This finding agrees with the study by Liu et al., (2019) and Wang et al., (2021). Beads and pellets appeared sparsely, mostly in SILIG 2 and KOLOR 2 during August and September, suggesting input from personal care products or industrial sources as reported similarly by Wang et al., (2021). The emergence of films and "other" unidentified shapes, although rare, indicates possible diversity in microplastic origin, including packaging and multi-layered composites as similarly noted in previous study by Lusher et al., (2013).

The presence of various shapes has biological implications as similarly stated by Mattsson et al., (2017). Fibers and filaments, due to their elongated forms, are more likely to cause entanglement or blockage in the gastrointestinal tract, potentially affecting digestion and nutrient uptake which is consistent with the finding of Lusheret al., (2023) and Ilechukwu et al., (2021). Fragments and beads may penetrate tissues or cause abrasion, leading to internal injuries or inflammation, which agrees with the finding by Liu et al., (2024) and Lusher et al., (2013). Furthermore, different shapes can influence how microplastics carry or release harmful chemicals, thereby posing varying degrees of toxicological risk to fish health. This is consistent with previous study by Mehra et al., (2021). These findings highlight the importance of characterizing not just the quantity, but also the shape of microplastics when assessing ecological risks as reported similary in previous research by Ogbomida et al., (2023).

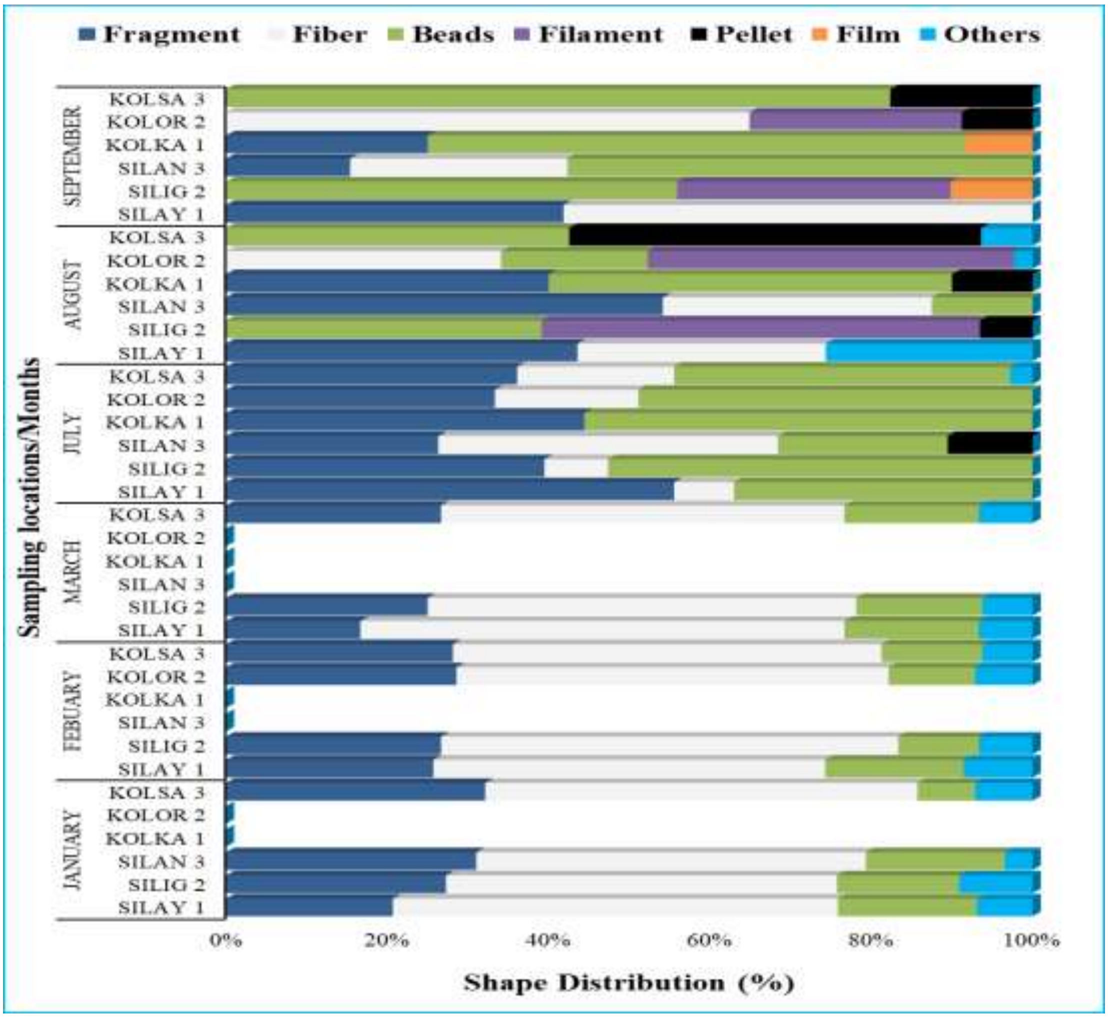

Figure 4: Shapes distribution of microplastics in silver catfish*(Chrysichthys nigrodigitatus)* during both dry (January-March) and wet (July – September) seasons 2024 across sampling locations in River Nun, Bayelsa Central, Nigeria

Colors Distribution of Microplastics

The color distribution of microplastics in silver catfish *(Chrysichthys nigrodigitatus),* as shown in Figure 5, reveals marked differences across seasons and locations, with certain colors being more prevalent than others. Across all sampling periods, white, black, and transparent microplastics were the most prevalent colors observed in C. nigrodigitatuswhich is consistent with previous study by Ilechukwu et al., (2021). During the dry season (January to March), white microplastics dominated the samples—accounting for over 50–60% of total colors in sites like SILAY 1, SILIG 2, and KOLSA 3. In contrast, black particles became increasingly dominant during the wet season (July to September), especially at sites such as SILIG 2 and KOLSA 3, where black microplastics made up to 35–40% of total color composition. Transparent particles also maintained a consistent presence in all months, particularly in SILAY 1 and KOLKA 1 in July and August, representing up to 25–30% of total microplastics. Notably, red and brown colored particles appeared more prominently during the wet season. These finding were consistent with previous study by Attah et al. (2023) and Oceng et al., (2023). Red microplastics, which were below 10% in earlier months, rose significantly in July and August, reaching up to 20% in some samples (e.g., SILAY 1 and KOLOR 2). Similarly, brown-colored particles showed a spike in August and September, particularly in SILAY 1 and SILIG 2, suggesting a shift in sources of pollution—likely runoff from soil-based plastics or degraded materials, as similarly reported in previous study by Pereao et al., (2020) and Rochman et al., (2013). The emergence of pale yellow microplastics was limited to the wet season and appeared in moderate proportions (up to 15%) at locations like SILIG 2 and KOLKA 1, possibly indicating packaging or agricultural plastic inputs, which agrees with the study by Ogbomida et al., (2023).

The color diversity of ingested microplastics is ecologically significant. Fish may mistake colored particles for prey, especially red, brown, or transparent ones that mimic natural food items. This can increase ingestion rates and internal accumulation, as reported similarly by Pitt et al., (2018) andRochman et al., (2013). Furthermore, darker-colored plastics like black and brown tend to absorb and carry more toxic pollutants (e.g., PAHs and heavy metals), as similarly stated by Yan et al., (2020), increasing the risk of chemical toxicity, consistent with previous study by Uddin et al., (2022) and Rochman et al., (2013). The varying presence of colors across seasons reflects dynamic pollution inputs, as reported similarly by Vanapalli et al., (2021)and suggests that both urban and agricultural sources contribute to microplastic contamination, potentially affecting fish health and food safety in the ecosystem. This agrees with recent study by Xu et al., (2021).

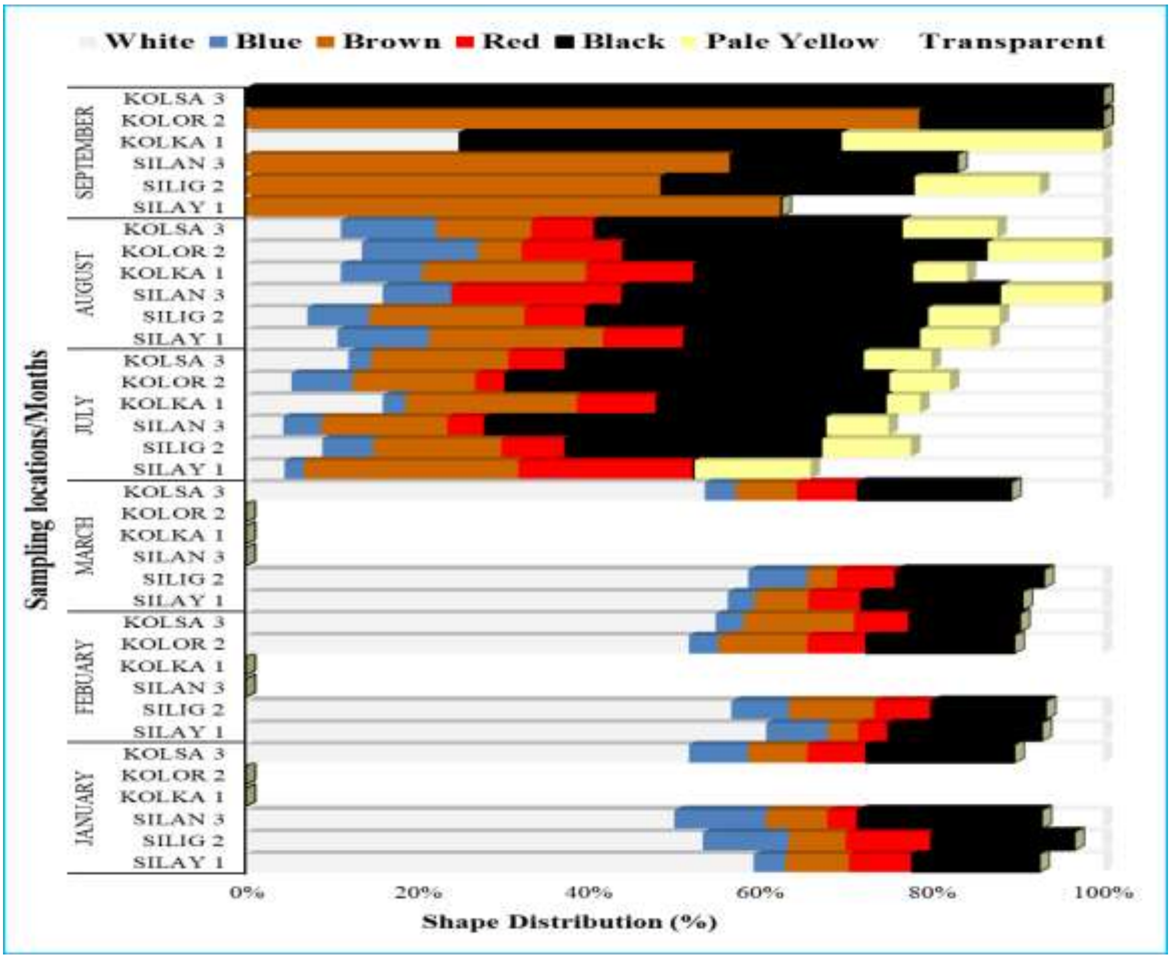

Figure 5. Color distribution of microplastics in silver catfish*(Chrysichthys nigrodigitatus)* during both dry (January-March) and wet (July – September) seasons 2024 across sampling locations in River Nun, Bayelsa Central, Nigeria

Sizes Distribution of Microplastics

The size distribution of microplastics in silver catfish *(Chrysichthys nigrodigitatus)* as illustrated in Figure 6, highlights significant seasonal and spatial variations. Microplastics within the 1–0.3 mm size range were consistently the most dominant across all locations and months, contributing between 45% and 60% of the total microplastic particles ingested by the fish, consistent with the findings of Vanapalli et al., (2021). During the dry season (January to March), this size category peaked in SILAY 1, SILIG 2, and KOLSA 3, often accounting for more than 55% of the particles recovered. In the wet season (July to September), the trend remained consistent, with locations such as SILIG 2 and SILAN 3 recording even higher proportions (up to 58%) in this size class, emphasizing the persistent availability of these particles in the aquatic environment. These findings align with previous study by Yi et al., (2024). A notable increase was observed in smaller particles within the 0.3–0.1 mm range, particularly during the wet season. Locations such as SILIG 2 and KOLKA 1 in July and August showed elevated concentrations, with these microplastics comprising between 35% and 50% of total sizes, which is consistent with a study by Uzomah et al., (2021) andZhilu et al., (2020). Similarly, particles smaller than 0.1 mm, although less frequent, were present in significant proportions—reaching up to 20% in certain months at SILIG 2 and SILAY 1. In contrast, larger microplastics (5–2 mm and 2–1 mm) were the least represented, rarely exceeding 10%, indicating a high prevalence of degraded or weathered particles likely resulting from secondary fragmentation, as similarly reported in previous study byGideon et al., (2024).

As stated similarly by Geremia et al., (2023), the dominance of smaller-sized microplastics has important ecological and physiological implications. These particles are more readily ingested due to their resemblance to natural prey like plankton or detritus and can penetrate deeper into fish tissues, potentially leading to chronic health effects such as inflammation or organ impairment, which agrees with similar study by Haque et al., (2023) and Huang et al., (2021). Moreover, smaller particles tend to adsorb more toxins per unit surface area, thus increasing the risk of chemical exposure to both fish and, through trophic transfer, to humans, which is reported similarly by Junaid et al., (2023) and Kim et al., (2022). Their abundance during the wet season also suggests enhanced fragmentation and runoff-related inputs during periods of high rainfall as noted in a study by Lavoie et al., (2021).

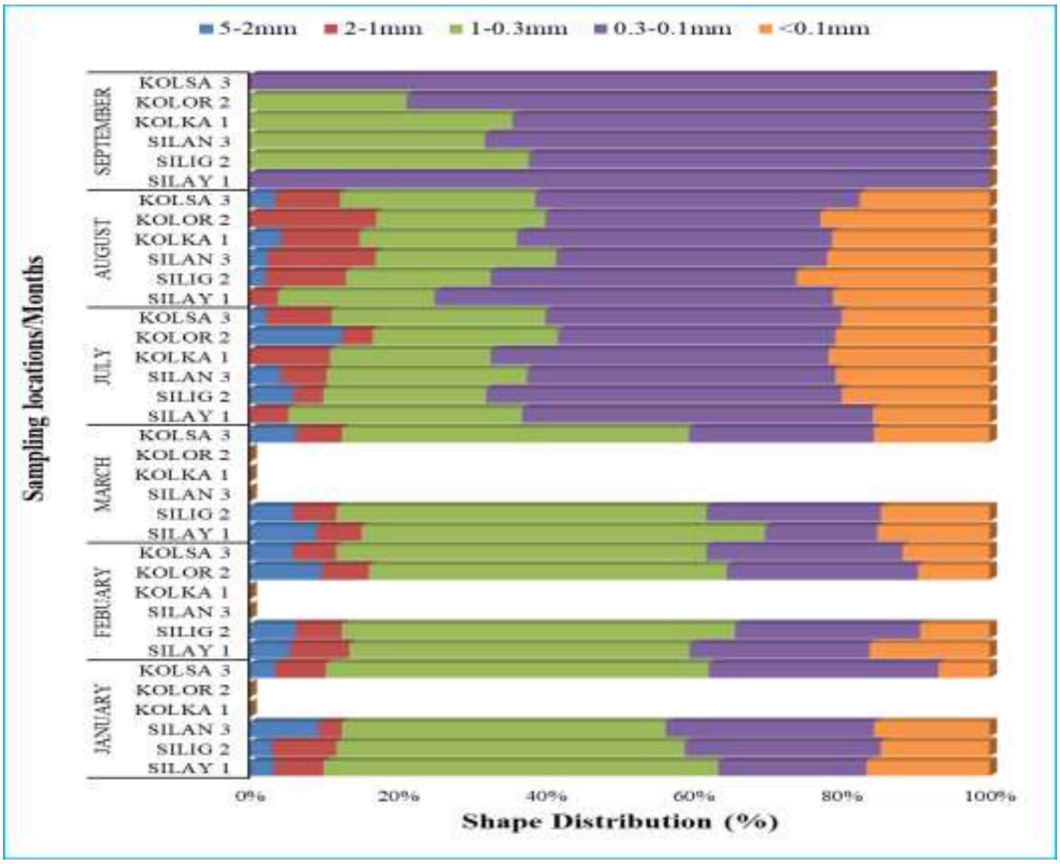

Figure 6. Size distribution of microplastics in silver catfish*(Chrysichthys nigrodigitatus)* during both dry (January-March) and wet (July – September) seasons 2024 across sampling locations in River Nun, Bayelsa Central, Nigeria

Phthalate and additives as associated microplastics

Table 1, shows phthalates and additives detected in silver catfish*(Chrysichthys nigrodigitatus)* samples collected from multiple locations during both dry and wet seasons. Dibutyl phthalate was the most prevalent, detected in several sampling locations including SILIG 2 AUG, KOLSA 3 JUL, and KOLOR 2 JUL, with peak concentrations ranging from 4.51 to 32.16 ppm. These findings align with previous study by Koelmans et al., (2016). Diethyl phthalate, benzylbutyl phthalate, and di(2-ethylhexyl) phthalate (DEHP) also showed widespread occurrence, with DEHP reaching the highest concentration (52.49 ppm) in KOLKA 1 SEPT. The high presence of these compounds across both seasons indicates continuous inputs, likely from plastic materials, industrial effluents, and municipal waste discharges, as stated similarly in previous study by Sorensen et al., (2021) and Wang et al., (2018). The occurrence of mono(2-ethylhexyl) phthalate and other derivatives further highlights the degradation and transformation of parent plasticizers in the aquatic environment as reported similarly by Ma et al., 2020).

Similarly, in a study by Sorensen et al., (2021) stated that the frequent detection of phthalates in fish tissues is of significant concern due to their known endocrine-disrupting effects. Compounds like DEHP, dibutyl phthalate, and benzylbutyl phthalate have been linked to reproductive toxicity, hormonal imbalance, and developmental abnormalities in aquatic organisms, which is consistent with previous study by Lusher et al., (2023) and Rochman, et al., (2013). Their accumulation in biota raises serious ecological risks, potentially disrupting aquatic food webs as reported similarly by Shi et al., (2023). Moreover, since fish are a common protein source for local communities specifically in the Niger Delta region of Nigeria, human health could be adversely impacted through dietary exposure, particularly in vulnerable populations such as pregnant women and children as noted similarly in previous study by Ogbomida et al., (2023) and Ilechukwu et al., (2021). These findings emphasize the urgent need for improved waste management practices, enforcement of environmental regulations, and routine monitoring to mitigate the risks associated with phthalate pollution in aquatic ecosystems as similarly stated by Uzomah et al., (2021).

Identification of Polymer Functional Groups

The FTIR analysis of microplastics extracted from sliver catfish (*Chrysichthys nigrodigitatus)* as shown in Table 2, revealed the presence of several polymer types across multiple locations and months. The most frequently detected polymers were Polyethylene (PE) and Polypropylene (PP), as indicated by characteristic C–C single bond and methyl group stretching within the 2970–2840 cm^{-1} range, which agrees with the findings by Pitt et al., (2018). These polymers were consistently found in KOLSA 3 (January, February, July), SILAY 1 (March), and SILAN 3 (September), suggesting widespread contamination by common packaging plastics, fishing gear, and household materials, which is consistent with previous study by Pereao et al., (2020) and Rochman, (2013). Polyamide 6 (Nylon 6), detected via amide groups at 3500–3200 cm^{-1} and 1680–1630 cm^{-1}, was also recurrent, particularly in KOLSA 3 (January, February, July), SILAY 1 (March), and SILAN 3 (September). Nylon 6 presence points to the possible input of fishing nets, ropes, and textiles into aquatic environments, as similarly reported by Xu et al., (2021) and Rochman et al., (2013). Additionally, Polyethylene Terephthalate (PET) was identified in the 1300–1100 cm^{-1} range at the same locations and months, possibly originating from beverage bottles and synthetic fibers, which consistent with Yi et al., (2024) and Rochman, (2013). Less frequently but notably, Polyvinyl Chloride (PVC)—identified by chlorine-related peaks in the 550–850 cm^{-1} range—was found in KOLSA 3 (February), SILAY 1 (March), KOLSA 3 (July), and SILAN 3 (September), pointing to contamination from plumbing materials or industrial packaging, as noted similarly by Uzomah et al., (2021).

In a previous study by Zhilu et al., (2020) and Talley et al., (2020), similarly noted that the identification of these synthetic polymers in fish tissues highlights a significant environmental and public health concern. Persistent exposure to PE, PP, PET, and PVC can lead to ingestion-related issues in fish, including internal blockages, oxidative stress, and reduced nutrient uptake, which is consistent with Pitt et al., (2018) and Rochman et al., (2013). For humans, the bioaccumulation of polymers especially those associated with additives like phthalates and heavy metals raises the risk of dietary exposure, as similarly stated by Yan et al., (2020). The presence of these polymers across multiple sampling periods and locations indicates chronic pollution, emphasizing the urgent need for plastic waste control, enforcement of fishing gear regulations, and targeted public education in the region, which is similarly reported in previous study by Garcia-Torné et al., (2023) andLv et al., (2020).

Table 1: Phthalate and additives detected in Silver Catfish *(Chrysichthys nigrodigitatus)* During Both Dry (January–March) and Wet (July–September) season 2024.

Phthalate/Additives	RT (min)	Peak Area (ppm)	Location
Dibutyl phthalate	5.139, 5.150, 5.156, 6.010, 6.028, 6.056, 6.062, 7.799	9.20, 8.20, 14.28, 8.53, 15.77, 29.46, 22.59, 4.51	SILIG 2 AUG, KOLSA 3 JUL, SILAY 1 JUL, KOLOR 2 JUL, SILAN 3 AUG, KOLKA 1 AUG, KOLKA 1 JUL, SILIG 2 AUG
Diethyl phthalate	5.733, 6.004, 6.010, 6.022, 6.027, 6.056, 6.812	2.85, 10.89, 10.42, 20.23, 8.28, 11.86, 1.08	KOLOR 2 JUL, KOLOR 2 AUG, KOLKA 1 JUL, SILIG 2 JUL, SILAN 3 AUG, KOLSA 3 JUL
Benzylbutyl phthalate	6.022, 14.110, 14.116	10.37, 19.26, 2.00	SILAY 1 JUL, KOLOR 2 JUL, SILIG 2 JUL
Di(2-ethylhexyl) phthalate	11.191, 12.218, 12.223, 12.229	52.49, 12.45, 9.53, 6.07	SILIG 2 AUG, KOLKA 1 AUG, KOLKA 1 SEPT
Mono(2-ethylhexyl) phthalate	7.983, 7.989	14.27, 7.86	SILIG 2 MAR, SILAY 1 MAR
Di-n-octyl phthalate	7.389	0.48, 0.48, 8.06	KOLSA 3 JAN, SILIG 2 FEB, SILAY 1 MAR
Diisooctyl phthalate	7.389	0.29	KOLSA 3 MAR,
Phthalic acid, di(2-propylpentyl) ester	7.389	18.86	SILIG 2 MAR
Phthalic acid, 2-ethylhexyl isohexyl ester	7.389	18.86	SILIG 2 MAR
Dimethyl Phthalate	5.133, 5.179, 5.508, 14.133	1.17, 1.12, 0.34, 29.43	SILAN 3 SEPT, KOLSA 3 SEPT, SILAY 1 SEPT

Diisodecyl Phthalate	5.110, 5.133, 5.139, 5.174, 5.999	0.52, 2.56, 1.95, 1.99, 26.95	KOLSA 3 SEPT, SILIG 2 SEPT, KOLOR 2 SEPT

Table 2: Identification of Polymer Types Using FTIR in Silver Catfish *(Chrysichthys nigrodigitatus)*

Wavenumbers (cm^{-1}) Ranges	Functional Groups	Polymer Types	Location
3500–3200	Amide (–CONH–)	Polyamide 6 (Nylon 6)	KOLSA 3 JAN, KOLSA 3 FEB, SILAY 1 MAR, KOLSA 3 JUL, SILAN 3 SEPT
2970–2840	Carbon-carbon single bond	Polyethylene (PE)	KOLSA 3 JAN, KOLSA 3 FEB, SILAY 1 MAR, KOLSA 3 JUL,SILAN 3 SEPT
2975–2840	Methyl group	Polypropylene (PP)	KOLSA 3 JAN, KOLSA 3 FEB, SILAY 1 MAR, KOLSA 3 JUL,SILAN 3 SEPT
1680–1630	Amide I (–CONH–)	Polyamide 6 (Nylon 6)	KOLSA 3 JAN
1300–1100	Ester (–COO–)	Polyethylene Terephthalate (PET)	KOLSA 3 JAN, KOLSA 3 FEB, SILAY 1 MAR, KOLSA 3 JUL,SILAN 3 SEPT
550-850	Chlorine (–Cl)	Polyvinyl Chloride (PVC)	KOLSA 3 FEB, SILAY 1 MAR, KOLSA 3 JUL, SILAN 3 SEPT

Statistical Analysis

Table 3 presents the mean microplastic concentrations (± standard error) in silver catfish *(Chrysichthys nigrodigitatus)* across various sampling locations during both the dry season (January to March) and the wet season (July to September). The analysis of variance (ANOVA) showed a statistically significant difference in mean microplastic concentrations among the fish collected from the various sampling locations ($F = 2.207$, $p = 0.045$). The highest mean concentration was recorded in SILAY 1 with 566.67 ± 91.17 mg/kg, followed closely by SILIG 2 (558.33 ± 70.07 mg/kg) and KOLSA 3 (545.00 ± 50.58 mg/kg). These three sites, located within Southern Ijaw LGA, appear to have elevated levels of microplastic contamination in fish, potentially linked to anthropogenic activities such as fishing, domestic waste discharge, or proximity to boat routes. These findings align with previous study byAttah et al., (2023) and Ilechukwu et al., (2021), Conversely, lower mean concentrations were observed in SILAN 3 (295.00 ± 99.93 mg/kg), KOLOR 2 (288.33 ± 101.54 mg/kg), and KOLKA 1 (236.67 ± 134.78 mg/kg). Despite showing variability, these locations in Kolokuma/Opokuma and Yenagoa LGAs appeared to have comparatively reduced microplastic loads, which may reflect differences in hydrodynamics, source input, or environmental management practices, as observed similarly by Haque et al., (2023) and Ellen et al., (2019). However, the high standard errors, particularly in KOLKA 1, indicate some inconsistencies within samples, possibly due to seasonal or individual variation, as noted similarly in previous study by Ezeudu, &Kevudo, (2023).

Furthermore, according to the observation by Geremia et al., (2023) in a previous study that the observed spatial differences have critical implications for ecosystem health and human exposure risk. Higher microplastic concentrations in fish from SILAY 1, SILIG 2, and KOLSA 3 suggest increased environmental pollution that could impair fish physiology affecting feeding, digestion, and reproduction in accordance with a study by Adeogunet al., (2020). This also raises concerns for food safety, especially among local populations that consume these species regularly as noted in similar study by Benson et al., (2022). The statistically significant variation emphasizes the need for localized mitigation strategies and more stringent environmental regulations to reduce plastic waste discharge in the most affected regions as reported similarly by Lusher et al., (2013).

Human Health Risk Assessment of Microplastics in Silver Catfish (Chrysichthys nigrodigitatus) of River Nun

The human health risk assessment of microplastics in *Chrysichthys nigrodigitatus* from River Nun as displayed in Table 4, revealed elevated hazard quotient (HQ) values across all sampling locations. Using the lower reference dose (RfD) of 10 mg/kg, HQ values ranged from 23.67 (KOLKA 1) to 56.67 (SILAY 1), all significantly exceeding the threshold value of 1. This finding agrees with similar study by Liu et al., (2019), Wang et al., (2021) and Mehinto et al., (2022). This indicates a high potential for non-carcinogenic health risks through dietary exposure to microplastics in fish, which is consistent with previous study by Geremia et al., (2023) andMehinto et al., (2022). Notably, SILAY 1 and SILIG 2 presented the highest HQs, closely followed by KOLSA 3, aligning with their higher mean concentrations. Under the higher RfD estimate of 676 mg/kg, HQ values dropped considerably (e.g., 0.35 in KOLKA 1, 0.84 in SILAY 1), all falling below 1. This illustrates how risk estimations can vary depending on the assumed toxicity thresholds, with is in accordance with the findings in a previous study by Huang et al., (2021)and Wang et al., (2021). However, the calculated Hazard Index (HI) values which consolidate both HQ scenarios ranged from 12.01 (KOLKA 1) to 28.76 (SILAY 1), and were universally above the safety margin, confirming consistent high health risks regardless of RfD range. This trend suggests chronic exposure to microplastics in fish is a potential threat to consumers in the area, as noted similarly in a study by Huang et al., (2021) and Rochman, (2013).

However, in a study by Ezeudu, &Kevudo, (2023) and Ellen et al., (2019), similarly reported thatthe consistent “High” risk level across all locations raises concerns for food safety and public health, especially among communities reliant on local fish as a dietary staple. Prolonged intake of microplastic-contaminated fish could lead to inflammation, endocrine disruption, and accumulation of toxic substances in humans, which is consistent with previous study by Haque et al., (2023) and Lusher et al., (2023). These results highlight the urgent need for public health interventions, environmental policy enforcement, and awareness programs on plastic pollution and its health impacts in the Niger Delta region, as highlighted similarly in previous study by Ilechukwu et al., (2021).

Table 3: Analysis of Variance (ANOVA) of Mean Microplastic Concentrations (± Standard Error) **in Silver Catfish *(Chrysichthys nigrodigitatus)* Across Sampling Locations.**

Variable	Mean±Std Error (mg/kg)	F(p-value)
SILAY 1	566.67±91.17	2.207 (0.045)
SILIG 2	558.33±70.07	
SILAN 3	295.00±99.93	
KOLKA 1	236.67±134.78	
KOLOR 2	288.33±101.54	
KOLSA 3	545.00±50.58	

Table 4: Human Health Risk Assessment of Microplastics in Silver Catfish *(Chrysichthys nigrodigitatus)* of River Nun

Location	Average Concentration (mg/kg)	RfD_{low}	HQ_{Low}	RfD_{High}	HQ_{High}	HI	Risk Level (Low/High)
SILAY 1	566.67	10	56.67	676	0.84	28.76	High
SILIG 2	558.33	10	55.83	676	0.83	28.33	High
SILAN 3	295	10	29.50	676	0.44	14.97	High
KOLKA 1	236.67	10	23.67	676	0.35	12.01	High
KOLOR 2	288.33	10	28.83	676	0.43	14.63	High
KOLSA 3	545	10	54.50	676	0.81	27.66	High

Conclusion

This study confirms the widespread presence of microplastics in silver catfish (*Chrysichthys nigrodigitatus*), with fragments and fibres being the most prevalent forms. Most particles were black or brown in color and predominantly measured between 1–0.3 mm, indicating degradation of larger plastics and ease of ingestion by aquatic organisms. FTIR analysis identified common synthetic polymers such as polyethylene, polypropylene, nylon, PET, and PVC, suggesting diverse sources of pollution from domestic and industrial activities. The concentration levels of microplastics in fish samples were significantly high and varied across sampling points. Human health risk assessment revealed high hazard indices, indicating potential risks associated with the consumption of contaminated fish. These findings emphasize the urgent need for improved waste management strategies, public education, and regulatory measures to reduce microplastic pollution and safeguard ecosystem and human health. Further research should focus on the bioaccumulation patterns of microplastics in different tissues, their long-term effects on aquatic food chains, and potential toxicological impacts on humans, especially through dietary exposure.

Declaration of Competing Interest

The authors declare that there is no competing interest.

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