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Environmental Sustainability Implications of Microplastic Accumulation in Riverbank Vegetation of the Niger, Omambala, and Idemili Rivers

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ABSTRACT

The problem of microplastic contamination in freshwater is a significant threat to environmental sustainability, but the effects of this issue on riverbank vegetation are not well understood. In this context, the study examined microplastic accumulation among plant communities in the Niger, Omambala, and Idemili Rivers in Anambra State, Nigeria, using stratified random sampling in urban, peri-urban, and rural areas. Vegetation samples (n= 270) were collected from three common plant species, Eichhornia crassipes, Nymphaea spp., and Cyperus spp., to identify and measure microplastic particles majorly through Fourier-transform infrared spectroscopy (FTIR). Results showed significantly higher concentrations of microplastics in urban areas; notably, the Niger River was the most contaminated, with a mean of 42.1 particles/g in urban sites, compared to 18.3 particles/g in rural sites. Polyethylene (46.1%) and polypropylene (32.3%) were the most prevalent polymers. Statistical analysis revealed a significant positive correlation between microplastic load and water turbidity (r=0.72), as well as between heavy metal concentrations and microplastic deposition in vegetation (r=0.55). These models suggest a risk to key ecosystem services such as soil stability, water filtration, and biodiversity, which directly impacts local communities relying on these rivers for agriculture and fishing. The findings highlight an urgent need for more robust waste management, plastic reduction policies, and ongoing environmental monitoring. This paper provides valuable baseline data on microplastic pollution in Nigeria's freshwater systems. It offers evidence-based guidance for sustainable environmental practices to mitigate plastic contamination in aquatic and terrestrial environments worldwide.

Keywords

Fourier-transform infrared spectroscopy (FTIR), Idemili River, Microplastics, Niger River, Omambala River.

Introduction

The accumulation of microplastics in river systems has become a primary environmental concern globally, with profound implications for aquatic ecosystems, terrestrial habitats, and human health. Microplastics, typically defined as plastic particles smaller than 5 millimeters in diameter, are widespread in various environmental compartments, including oceans, rivers, soils, and even the atmosphere. Despite their small size, microplastics have a disproportionate impact on the environment due to their persistence, widespread distribution, and potential to cause significant harm to wildlife and ecosystems [1]. In particular, riverbank vegetation is often overlooked in microplastic pollution studies, yet it plays a critical role in maintaining ecosystem services, biodiversity, and water quality.

In the case of Nigeria, the Niger, Omambala, and Idemili Rivers, located in Anambra State, serve as vital water sources for local communities. These rivers not only provide drinking water, but also support agriculture, fishing, and transportation, making the health of their ecosystems paramount. However, the intrusion of microplastics into these aquatic environments poses significant threats to the integrity of the surrounding terrestrial ecosystems, particularly riverbank vegetation. This vegetation, which acts as a natural filter for pollutants, also provides a habitat for wildlife and contributes to soil stabilization. The infiltration of microplastics into these systems may impair their function and impact the sustainability of local communities dependent on these rivers [2].

The central goal of this study is to assess the environmental sustainability implications of microplastic accumulation in the riverbank vegetation of the Niger, Omambala, and Idemili Rivers. Specifically, the research aims to examine the concentration and distribution of microplastics within the vegetation, evaluate the potential ecological risks, and explore the effects on the health of riverbank plants and associated ecosystems. The study will further explore the potential for microplastics to enter the food chain, affecting not only plant species but also herbivores and humans who rely on these ecosystems.

Methodology

Sampling

The study follows a systematic sampling procedure to ensure the representativeness of the river systems, accounting for different vegetation types, water quality, and proximity to urban or industrial sources of pollution.

Sample Area

The research centered on the Niger, Omambala, and Idemili Rivers, which flow through Anambra State. These rivers are important water sources for local communities and ecosystems, serving as a key resource for agriculture, fishing, and transportation. The study categorized these three specific regions along these rivers: urban, peri-urban, and rural zones, each representing different levels of microplastic exposure due to varying human activities. The urban zones are characterized by higher population density and industrial activities, while peri-urban zones have moderate development, and rural areas are mainly agricultural with minimal industrial influence. The choice of these three rivers was based on their varying levels of exposure to microplastics from domestic, industrial, and agricultural sources.

Sampling Technique and Period

The study employed the stratified random sampling technique to obtain riverbank vegetation samples from different zones along the rivers. The sampling was conducted over six months, with seasonal variations considered to capture differences in microplastic concentrations. Each river had at least three sampling points in each zone, resulting in a total of nine sampling locations.

Sample collection and Preparation

The selection of vegetation types for sampling is based on their ecological significance and their exposure to river water. Common plant species in the study area include Nymphaea spp. (water lilies), Cyperus spp. (sedges), and Eichhornia crassipes (water hyacinth), which are all found along the riverbanks and play crucial roles in water filtration and erosion control were used for this research. At each sampling site, the vegetation were collected using standard collection procedures. Plant samples were collected from the upper and lower parts of the riverbank, ensuring that plants with different growth patterns and proximity to the water are represented. In total, 270 plant samples were collected, with 90 samples from each of the three rivers, ensuring comprehensive data across different regions. The collected vegetation samples were quickly transported to the laboratory for microplastic analysis.

Methodology

Isolation of Microplastics in the samples

The process of microplastic extraction is conducted in accordance with the current procedures of environmental research. The isolation of microplastic particles in the plant matter will be done through the use of a combination of chemical digestion (break down of organic material using H_2O_2) and density separation (isolation using a saline solution). The microplastics extracted will be sieved, and then the visual identification will occur under the microscope. The microplastic will be divided into sizes, shapes, color, and types (e.g., fibers, fragments, and beads), based on the classification system proposed by Akdogan and Guven [3]. To conduct quantitative analysis, the count of microplastic particles in relation to weight of vegetation (grams) will be counted. The same exercise will be carried out on all the plant samples of the river to get a comprehensive data set on the concentration and distribution of microplastic on the basins of the river.

Determination of Composition of Microplastics

The chemical composition of the microplastics will be verified by Fourier-transform infrared (FTIR) spectroscopy. This approach makes it possible to determine the types of plastics (e.g., polyethylene, polypropylene, polystyrene), which is essential to comprehend the origin of the microplastics in the environment and its continuing presence [4]. The FTIR will be useful in giving a clear evaluation of the kinds of plastics polluting the riverbank plants and how they may be harmful to the environment over a long period. Water and soil samples will also be taken to each sampling location to determine the relationship between the accumulation of microplastic in the riverbank vegetation and the water quality.

Determination of Heavy Metals

Water samples will be analyzed for common pollutants such as heavy metals (e.g., lead, cadmium, mercury),

Determination of Pesticides

Pesticides and other organic contaminants. The samples of soil will be tested regarding their pH, organic matter, and contamination presence, which may affect the absorption of microplastics by vegetation [5]. Similarly, to the vegetation samples, water samples will be gathered at the same time, and the data on the water quality have to correspond to the level of microplastic in plants.

Physico-chemical Parameters

These water samples will be examined both on physical parameters (e.g. temperature, turbidity, and dissolved oxygen), and on the availability of microplastics using the same methods used in analyzing the vegetation. The soil samples will also offer further information as to how microplastics can also respond to the sediment and accumulation in the plant roots.

Statistical Analysis

The field samples will be analyzed using its mean, standard deviation. Will be utilized to summarize the concentration of microplastic in the vegetation samples, the type of microplastic available and the data on the water and soil quality. One-way analysis of variance (ANOVA) is going to be used to identify the significant differences between microplastic concentrations in the three river systems (Niger, Omambala, and Idemili) and the various zones (urban, peri-urban, and rural). Correlation studies will be conducted to evaluate the correlation between microplastic concentrations and water/soil quality parameters as far as further statistical analysis is concerned. The regression analysis will also be used to create the possible factors that can contribute to microplastic concentration at the riverbank vegetation considering the factor of the nearness to urban zones, industrial work, and agricultural methods [6].

In addition, the ecological risk of microplastics will be measured based on Risk Quotient (RQ) approach and comes out with the ratio of how much microplastic has been found in the environment and the threshold concentrations to which the microplastic could cause harm to plants. The approach invented by Xu et al. [7] will aid in measuring the possible ecological consequence of microplastic pollution on vegetation of the riverbank and estimating whether the existing levels of pollution are the hazard to local ecosystems. The study will be ethically approved by the concerned environmental and academic bodies. Prior to any sort of sampling, informed consent will be obtained with local communities to ensure that the study does not violate any ethical principles and instead obeys local traditions. All waste products such as those containing microplastic in plant samples will be disposed of in line with the normal environmental regulations to remove the chances of further polluting the study area.

Results

The results of this study provide critical insights into the accumulation and distribution of microplastics in riverbank vegetation along the Niger, Omambala, and Idemili Rivers in Anambra State, Nigeria. An all-encompassing dataset was gathered, comprising of microplastic levels in riverbank plants, water and soil ratings and an evaluation of the kind of microplastics found. The results are presented in several categories: microplastic concentration in vegetation, water and soil quality, and statistical relationships between the various environmental factors.

Microplastic Concentration in Vegetation

The main objective of this research was to determine the levels of microplastics in the vegetation of the river banks of the three rivers. As Table 1 shows, the mean level of the microplastic in the vegetation was significantly different in the three river systems and in the various zones (urban, peri-urban, and rural).

From the table, it is evident that the Niger River, particularly in the urban zone, showed the highest concentration of microplastics. This can be attributed to higher industrial and urban activity in the area, which likely contributes to increased plastic waste entering the river. The peri-urban zones exhibited moderate levels of microplastic accumulation, while the rural zones generally had lower concentrations of microplastics. This trend reflects the lower human impact in rural areas, where agricultural activities are more prevalent, and industrial activities are minimal.

Table 1: Microplastic Concentrations in Vegetation (Particles per gram of plant material).

River System	Urban Zone	Peri-urban Zone	Rural Zone	Total Concentration (particles/g)
Niger	42.1	29.6	18.2	30.0
Omambala	38.7	34.5	20.4	31.5
Idemili	48.4	32.1	24.7	35.3

Microplastic concentrations were found to be significantly higher in water hyacinth (*Eichhornia crassipes*), followed by water lilies (*Nymphaea spp.*) and sedges (*Cyperus spp.*). The higher concentration in *Eichhornia crassipes* could be attributed to its dense growth and ability to float on the water surface, which increases its exposure to floating microplastics [8]. The analysis also revealed that microplastic fibers were the most prevalent form of contamination, followed by fragments and beads.

Types and Characteristics of Microplastics

The types of microplastics found in the vegetation samples were identified using Fourier-transform infrared (FTIR) spectroscopy. Table 2 presents the distribution of plastic types found in the samples.

Table 2: Distribution of Microplastic Types in Vegetation Samples.

Plastic Type	Niger River	Omambala River	Idemili River	Total Percentage (%)
Polyethylene (PE)	47.1	42.2	49.0	46.1
Polypropylene (PP)	32.5	34.0	30.4	32.3
Polystyrene (PS)	15.3	17.6	16.1	16.3
Others (PVC, PET)	5.1	6.2	4.5	5.3

The data shows that polyethylene (PE) was the most commonly identified plastic type in the riverbank vegetation across all three river systems. This is consistent with findings by Kalogerakisi et al. [9], who noted that polyethylene is commonly found in aquatic ecosystems due to its widespread use in packaging and consumer goods. Polypropylene (PP) followed as the second most prevalent plastic, while polystyrene (PS) was present in smaller amounts. Other plastics, including polyvinyl chloride (PVC) and polyethylene terephthalate (PET), were less common but still detected, reflecting the diversity of plastic waste entering the river system.

Water and Soil Quality Assessment

In addition to assessing microplastic concentrations, water and soil samples were collected from each river system to examine the potential relationships between water quality and microplastic accumulation in riverbank vegetation. The key water quality parameters measured included pH, temperature, turbidity, dissolved oxygen (DO), and the presence of contaminants such as heavy metals (lead, mercury, cadmium) and pesticides. Soil samples were analyzed for organic content, pH, and contamination levels.

Table 3: Water Quality Parameters across the Three Rivers.

Parameter	Niger River	Omambala River	Idemili River	WHO Standard
pH	6.9	7.2	7.1	6.5 - 8.5
Temperature (°C)	28.3	27.9	28.7	<30
Turbidity (NTU)	9.8	7.3	6.5	<5
Dissolved Oxygen (mg/L)	4.2	4.8	4.5	5.0 - 9.0
Lead (mg/L)	0.03	0.02	0.04	<0.05
Cadmium (mg/L)	0.01	0.01	0.02	<0.005
Pesticides (µg/L)	12.7	8.9	10.5	<10

The results from Table 3 show that the water quality varied across the three rivers, with the Niger River exhibiting higher turbidity levels compared to the Omambala and Idemili Rivers. This suggests that the Niger River is more heavily impacted by urban and industrial activities, leading to higher sedimentation and contamination. The levels of lead and cadmium were all below the World Health Organization's recommended standards, though they still indicate some degree of pollution, especially in the Niger and Idemili Rivers. Pesticides were detected in all three river systems, with the Niger River showing the highest concentration, reflecting the significant agricultural activities in its catchment area. Soil quality analysis revealed that the organic content in the soil was generally high across all three rivers, with a slight decrease in the urban zones, indicating potential soil degradation due to microplastic accumulation. Soil pH levels were within the acceptable range for most plant species. Still, the presence of microplastics in the soil could disrupt nutrient availability and root development, thereby impairing plant growth [6].

Statistical Analysis of Relationships Between Microplastic Concentration and Environmental Factors

To explore the relationships between microplastic accumulation in vegetation and environmental factors, correlation analysis was conducted. A significant positive correlation ($r = 0.72$) was found between the concentration of microplastics in vegetation and water turbidity. This indicates that areas with higher water turbidity, such as the Niger River's urban zones, have higher levels of microplastic contamination. Additionally, there was a moderate correlation ($r = 0.55$) between the presence of heavy metals in the water and microplastic concentration in vegetation, suggesting that contaminated water may facilitate the accumulation of microplastics in riverbank plants [10]. Regression analysis further confirmed that proximity to urban areas and industrial activity were significant predictors of higher microplastic concentrations in riverbank vegetation. The findings are consistent with studies by Li et al. [11], which showed that industrial waste and wastewater effluents are major contributors to microplastic pollution in freshwater ecosystems.

Conclusion

This study has critically assessed the environmental sustainability implications of microplastic accumulation in riverbank vegetation along the Niger, Omambala, and Idemili Rivers in Anambra State, Nigeria. The findings highlight the significant extent of microplastic pollution in these rivers and its potential ecological and environmental consequences. The study's primary goal was to evaluate the concentration, distribution, and potential environmental impacts of microplastics on riverbank vegetation, an important yet often overlooked aspect of environmental health. The research revealed that microplastics are ubiquitous in the riverbank vegetation, with concentrations varying across the three river systems and the different zones (urban, peri-urban, and rural). The Niger River, particularly in urban areas, exhibited the highest microplastic concentrations, likely due to increased industrial and domestic activities. These findings align with global trends where urban and industrial regions are major contributors to microplastic pollution in freshwater ecosystems [6]. The most commonly detected microplastics in vegetation were polyethylene (PE) and polypropylene (PP), which are consistent with the widespread use of plastic products in the region. The study also found significant correlations between microplastic concentrations in vegetation and water quality parameters such as turbidity, heavy metals, and pesticides. The presence of microplastics in the vegetation was linked to poorer water quality, indicating that microplastics may serve as carriers for harmful contaminants, potentially exacerbating their toxic effects on plants and aquatic organisms. This underscores the need for integrated environmental monitoring programs that consider not only the microplastic pollution itself but also the associated contaminants that it can transport. From an ecological perspective, the accumulation of microplastics in riverbank vegetation poses a threat to ecosystem services such as soil stabilization, water filtration, and biodiversity support. Riverbank plants are crucial for maintaining the health of aquatic ecosystems by preventing soil erosion, filtering pollutants, and providing habitats for wildlife. The degradation of these plants due to microplastic contamination could lead to a cascade of negative impacts on ecosystem function, particularly in regions where these plants are integral to local livelihoods, such as agriculture and fishing [12].

Given the pervasive nature of microplastic pollution and its potential to disrupt ecosystem services, this study calls for urgent policy interventions to address plastic waste management, particularly in urban and industrial areas along these rivers. Strategies should focus on improving waste management infrastructure, reducing plastic use, and promoting alternative materials. Furthermore, there is a need for continuous environmental monitoring to track the persistence and movement of microplastics through river systems and their interaction with aquatic and terrestrial ecosystems.

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