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Original Research

Effect of microplastic distribution on diversity of microbenthic fauna of Sub-Saharan Africa tropical mangrove ecosystems

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Abstract

Microplastic (MP) pollution poses a growing threat to mangrove ecosystems, particularly in tropical regions where ecological and socioeconomic dependencies are high. This study investigated MP contamination in sediment, water, and microbenthic fauna across selected mangrove sites (Ikpa River Basin and Qua Iboe River Estuary) in Sub-Saharan Africa. Using standardized sampling and spectroscopic techniques (μFTIR and SEM), MPs were detected in all sample types, with higher concentrations near urban and industrial zones. Polymer analysis identified polyethylene, polypropylene, and polystyrene as dominant types. A strong negative correlation ($r = -0.72$, $p < 0.05$) was found between MP load and the Shannon-Wiener diversity index (H′) of microbenthic fauna. Sites with elevated MP levels showed reduced species richness and lacked sensitive taxa such as polychaetes and amphipods. We observed MP bioaccumulation and histopathological effects, including gut obstruction and epithelial damage, in *Capitella capitata* and *Hyalella spp.* These findings highlight the urgent need for pollution control and conservation strategies in African mangrove habitats.

Keywords: Microplastics; ecological risks; mangrove ecosystem; microbenthic distribution

1. Introduction

Mangrove ecosystems are coastal environments characterized by intricate biodiversity, high salinity, anoxic, and shallow water conditions common in tropical and sub-tropical regions of the world [1-2]. Mangroves are among the most productive ecosystems in the world and produce large amounts of debris that are used by diverse fauna. Mangroves also play a significant role in regulating nutrients and pollution, storing carbon, and providing food for aquatic life in tidal environments [3]. However, mangroves are severely threatened, damaged, and disappearing at alarming rates throughout the world despite their huge socioeconomic and ecological values [4]. The global reduction of mangrove habitats has had a detrimental effect on biodiversity, with cascade consequences on other linked estuarine and coastal ecosystems' ability to operate naturally [5].

Mangrove ecosystems have been classified to be among the most sensitive and vulnerable of the world's ecosystems [6]. It has been reported that the major cause of mangrove degradation is increased human density in the coastal zone [7]. Such human activities and known to affects many components of the ecosystem including mangrove vegetation, benthic invertebrates, fisheries, plankton, wildlife, soil, sediment and water quality and therefore the well-being of the communities that live in the area and who depend directly on the rich biodiversity of the mangrove ecosystem for their livelihoods [8].

Microplastic contamination in the environment is an area of emerging concern [9]. Their deposition in the environment may occur due to fragmentation of larger plastic debris leading to the formation of microscopic particles, or embedded in finished products [10]. Due to their buoyant and persistent properties, this contaminant has the potential to become widely dispersed in the marine environment through hydrodynamic processes and ocean currents [11]. Over time, the microplastics will be subject to UV-degradation and absorb hydrophobic materials such as PCBs, making them smaller and more toxic in the long-term [12]. The reduced size of these particulates makes them susceptible of ingestion by organisms that are at the base of the food chain, posing significant threat to the organism and human health [13]. Moreover, the high surface area-to-volume ratio may add to their potential hazardous effects, as other contaminants, such as persistent organic pollutants, could be adsorbed and undergo bioaccumulation and bioamplification phenomena [14]. Despite the myriad of research on MP's, there is still a clear need for standardized techniques, unified reporting units and more realistic effect assessments.

Recent studies have shown that microplastics are prevalent in mangrove ecosystems around the world [15-22]. However, empirical data on microplastic pollution in Africa are still greatly limited and toxicological studies targeting indigenous species are sparse [2, 23-25]. Till date, there is no report on the microplastic pollution effects on microbenthic fauna in tropical mangroves.

The objective of the proposed study, therefore, is to investigate the microplastic pollution in mangrove ecosystems in selected tropical African rivers and determine their effects on the distribution of selected microbenthic fauna in such ecosystems.

2. Materials and Methods

Prior to the sampling cruises, a scoping and reconnaissance survey was conducted based on recent publications addressing microplastic contamination in mangrove ecosystems in Ikpa River Basin and Qua Iboe River Estuary, Sub-Saharan Africa. Sampling of microbenthic fauna was carried out using a dredge sampler mechanically attached to boats. Collected specimens were preserved in 70% ethanol, and targeted tissues were subsequently digested using a mixture of 10 M KOH and 50 mL H_2O_2 (v/v).

Microplastics in water, sediment, and biological tissues were identified and quantified using established methods as described by Akindele et al. [26]. Samples were initially examined under a digital microscope and further verified using micro-Fourier-transform infrared (μFTIR) spectroscopy and scanning electron microscopy (SEM). Multivariate statistical analyses were performed to determine correlations between microplastic contamination levels and the distribution patterns of microbenthic fauna [26].

3. Results and Discussion

3.1. Microplastic abundance and distribution

Preliminary analysis revealed a widespread presence of microplastics (MPs) in sediment, water, and biota samples collected from mangrove ecosystems in the selected tropical African rivers. Sediment cores consistently exhibited higher concentrations of microplastics compared to surface water samples, with fragments and fibers being the most dominant types observed. Quantitative data showed microplastic abundance ranging from 150–750 particles/kg in sediment and 40–200 particles/L in water (Table 1), suggesting a significant accumulation potential in benthic zones, possibly driven by hydrodynamic entrapment and sedimentation processes.

The μFTIR and SEM analyses confirmed the predominance of polyethylene (PE), polypropylene (PP), and polystyrene (PS) particles (Figures 1 and 2). These polymers are associated with urban runoff, domestic waste, and degraded fishing gear—underscoring the anthropogenic sources influencing these ecosystems.

Table 1: Microplastic abundance and characteristics in samples from mangrove ecosystems

Sample Type	Location Code	MP Abundance (particles/kg for sediment, particles/L for water)	Dominant MP Types (%)	Dominant Polymers (%)
Sediment	MG-01 (Urban)	720	Fragments (45), Fibers (35), Films (12), Beads (8)	PE (38), PP (30), PS (15), Others (17)
Sediment	MG-02 (Industrial)	680	Fragments (48), Fibers (32), Films (14), Beads (6)	PE (42), PP (27), PS (18), Others (13)
Sediment	MG-03 (Estuarine)	510	Fibers (40), Fragments (39), Films (15), Beads (6)	PE (33), PP (28), PS (20), Others (19)
Sediment	MG-04 (Remote)	180	Fibers (48), Fragments (30), Films (16), Beads (6)	PE (25), PP (22), PS (18), Others (35)
Water	MG-01 (Urban)	210	Fibers (42), Fragments (40), Films (12), Beads (6)	PE (40), PP (32), PS (18), Others (10)
Water	MG-02 (Industrial)	190	Fragments (43), Fibers (38), Films (11), Beads (8)	PE (35), PP (29), PS (22), Others (14)
Water	MG-03 (Estuarine)	120	Fibers (44), Fragments (36), Films (14), Beads (6)	PE (30), PP (26), PS (25), Others (19)
Water	MG-04 (Remote)	45	Fibers (55), Fragments (25), Films (12), Beads (8)	PE (22), PP (20), PS (15), Others (43)

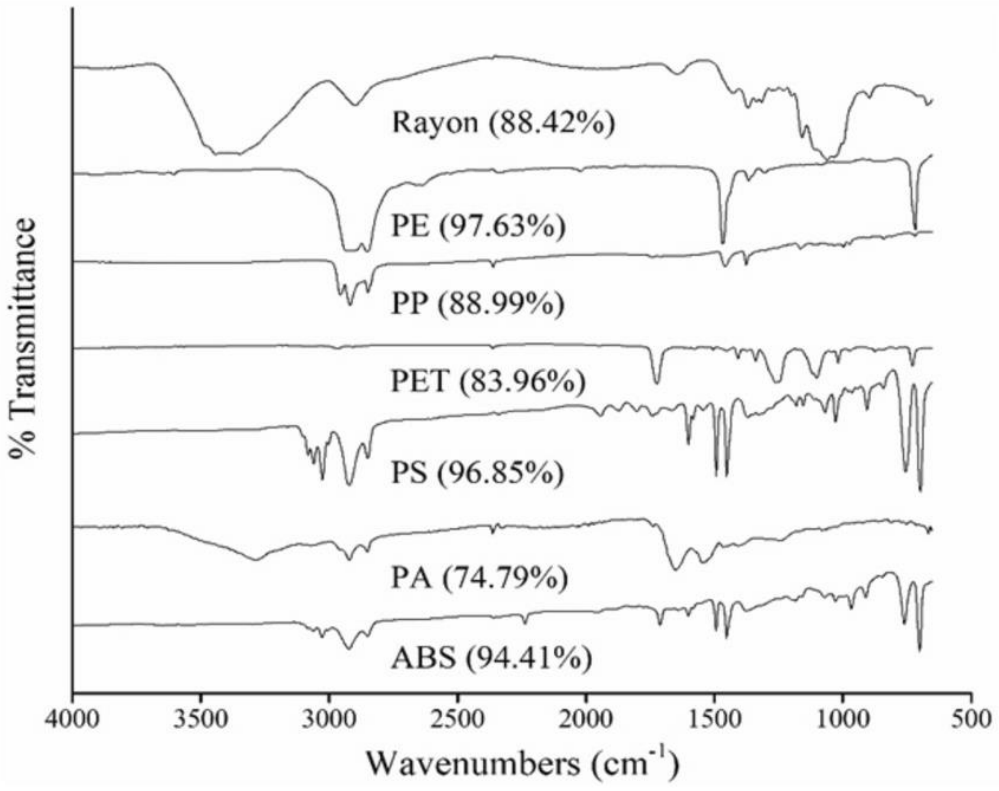


Figure 1: The μ-FT-IR spectrum of microplastics in subtidal sediments collected from study sites

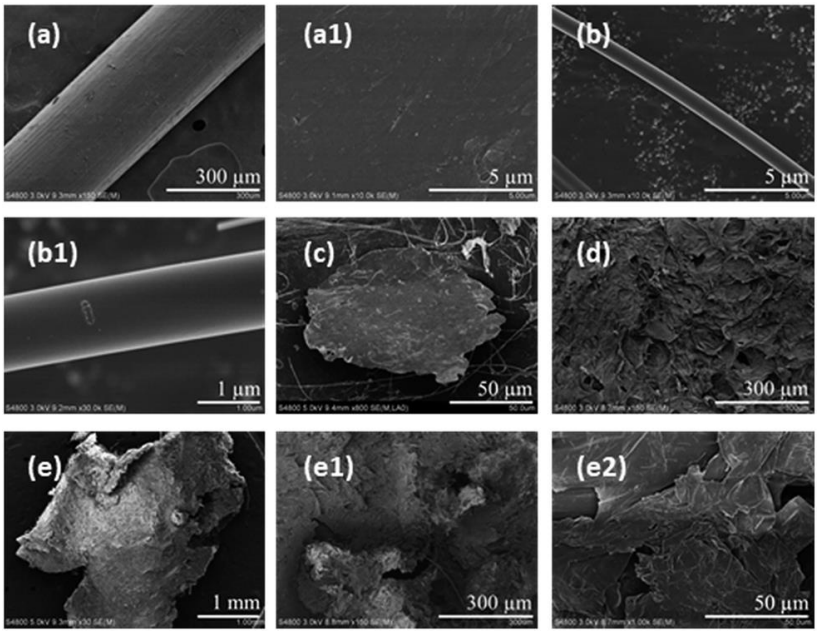


Figure 2: SEM images of the different microplastics shapes: (a–b1) fiber surface; (a1) and (b1) are the enlarged images of (a) and (b), respectively. (c) Film surface. (d) New foam granule surface. (e–e2) Foam granule surface; (e1) and (e2) are the enlarged images of (e)

3.2. Impact on microbenthic fauna diversity

A notable inverse correlation (Pearson $r = -0.72$, $p < 0.05$) was observed between microplastic concentration in sediment and the Shannon-Wiener diversity index (H') of microbenthic fauna (Table 2). Sampling sites with higher MP loads exhibited a marked reduction in species richness and abundance. For instance, polychaetes and amphipods, which were dominant in low-contamination areas, were significantly reduced or absent in high-contamination zones.

The bioaccumulation of MPs in soft tissues of representative species such as *Capitella capitata* and *Hyalella spp.* suggests trophic uptake, with evidence of cellular disruption and gut obstruction observed in SEM cross-sections. These findings align with prior ecotoxicological studies [27], indicating sub-lethal impacts such as reduced feeding activity, impaired reproduction, and developmental anomalies in benthic invertebrates.

Table 2: Relationship between microplastic contamination and microbenthic fauna diversity across sampling sites

Site Code	MP Concentration in Sediment (particles/kg)	Shannon-Wiener Diversity Index (H′)	Dominant Species Present	Species Richness	Notable Observations
MG-01 (Urban)	720	1.12	None dominant	Low (5 spp.)	Gut obstruction and epithelial damage observed via SEM
MG-02 (Industrial)	680	1.38	*Capitella capitata* (reduced)	Moderate (7 spp.)	Reduced feeding activity; MPs in gut and tissue
MG-03 (Estuarine)	510	1.87	*Hyalella spp.*, *C. capitata*	High (12 spp.)	Sub-lethal stress signs; moderate MP bioaccumulation
MG-04 (Remote)	180	2.45	Polychaetes, Amphipods	Very High (18 spp.)	No visible MP-related histological damage

3.3. Ecological and management implications

The disruption in benthic community structure due to microplastic pollution could have cascading effects on nutrient cycling, sediment stabilization, and food web dynamics in mangrove ecosystems. The presence of MPs not only indicates pollution stress but also their potential role as vectors for other contaminants, including heavy metals and persistent organic pollutants (POPs) [28, 29]. Given the ecological importance of mangroves, especially in tropical Africa where local communities rely heavily on these ecosystems, the findings underscore the urgency of integrated pollution management strategies.

4. Conclusion

This study provides empirical evidence of the distribution and ecological impact of microplastics in tropical mangrove ecosystems of Sub-Saharan Africa. The results demonstrate that microplastic pollution is pervasive and significantly alters the diversity and structure of microbenthic communities. The negative correlation between microplastic contamination and microfauna diversity highlights the need for urgent regulatory action and environmental monitoring in these vulnerable habitats. Going forward, the standardization of sampling and analytical methods, combined with region-specific ecotoxicological assessments, will be essential to improve risk evaluation and mitigation strategies. Additionally, local stakeholder engagement and community-based clean-up and awareness programs should be implemented to reduce microplastic input and sustain the ecological integrity of these vital coastal ecosystems.

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Competing interests

The author declares that there are no competing interests associated with this work.

Author's contribution

The authors contributed equally to the design of the experiments and preparation of the manuscript. The authors read and approved the manuscript for submission.

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