



Seasonal Abundance and Spatial Distribution of Microplastics in Water and Sediments of Tropical Urban–Agricultural River System; A case of Ngerengere River, Tanzania

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Abstract

Aquatic ecosystems are globally contaminated with microplastics (MP), making water resources in developing countries not spared from this problem. However, data on microplastic levels in Tanzanian's freshwater systems is still scarce. Therefore, this study assessed the microplastic abundance in water and sediment of the Ngerengere river using Fourier-transform infrared spectroscopy technology. Samples from six sampling sites along the Ngerengere River were collected during dry and wet seasons. Quantitative analysis revealed microplastic concentrations in water ranging from 5 to 24 items l^{-1} , with fragments representing 67% to 95% of particles, and in sediments from 0.6 to 1.8 items g^{-1} , where fragments exceeded 60% and fibers reached up to 29%. Microplastic loads peaked midstream near urban-industrial zones, particularly during the wet season. Black and white microplastics dominated color distribution, and polypropylene, polyethylene, and polystyrene were the primary polymer types detected. These findings demonstrate that urban and industrial activities contributed microplastic contamination, with sediments acting as sinks. These concentrations are comparable to or exceed values reported for several developing countries, indicating that medium-sized tropical catchments are significant but underreported sources of microplastic pollution. The findings provide baseline evidence for targeted river management, stormwater control, and long-term microplastic monitoring.

Keywords · Microplastics, Ngerengere river, Sediments, Water, Agriculture, Aquatic

1. Introduction

Microplastics (MP) are tiny plastic particles ranging in size from 0.001 mm to 5 mm. They can be found in common household products such as personal care items, laundry detergents, and pharmaceuticals; these are called primary microplastics. Secondary

microplastics are formed through the breakdown of larger plastic debris (Iroegbu et al., 2025; Rangel-Buitrago et al., 2024). Although this degradation occurs slowly, physical, chemical, and biological processes that fragment macroplastics represent a significant source of microplastics in the environment. The rapid increase in plastic production over recent

decades has caused microplastic contamination to rise substantially across environmental media including soil, water, and air globally (Goswami et al., 2025). In terms of aquatic environments, research focus has recently expanded from marine systems to freshwater and terrestrial ones including agricultural soils (Kato et al., 2025), with streams and rivers recognized as key pathways transporting microplastics to the oceans (Vanavermaete et al., 2024). Microplastics enter rivers via precipitation, surface runoff, stormwater drainage, and treated sewage discharges from wastewater treatment plants (WWTPs). Once in aquatic ecosystems, microplastics pose threats to human health through contamination of freshwater organisms, fish, and associated food webs, as well as water sources (Yakub et al., 2024; Bae et al., 2025).

In 2020, worldwide plastic production hit 367 million tons, with about 14 million tons being released into aquatic environments annually. This figure is projected to rise to 29 million tons per year by 2040 (Lau et al., 2020), posing a serious threat to the safety and health of aquatic ecosystems. It was estimated that between 1.15 and 2.41 MMT of plastic waste is discharged annually from rivers into the seas, largely due to inadequate plastic waste management, with more than 74% of this discharge occurring during the rainy season (Lebreton et al., 2017). Rivers are recognized as key pathways transporting plastic waste and microplastics from land-based sources to marine environments (Quik et al., 2023). According to Gao et al., (2024), microplastics have been detected in some European rivers, with concentrations varying widely across locations. Notably, the highest microplastic levels in both surface waters and in sediments with polymers such as Polyethylene (PE), polypropylene (PP), and polystyrene (PS) as the most common polymers found in water while sediments contained a broader range of polymers including denser types like PET and PVC.

Africa's aquatic ecosystems remain critically understudied regarding microplastic pollution, with limited data on Tanzania's freshwater systems despite documented contamination in farmland soils and marine sediments (Verster et al., 2017; Nyaga et al., 2024; Mtega et al., 2023; Kato et al., 2025). While

global models estimate that 1,000 rivers contribute nearly 80% of annual riverine plastic emissions, available data are strongly biased toward temperate regions (Meijer et al., 2021). Tropical African rivers with mixed urban-agricultural land use such as the Ngerengere River remain largely uncharacterized, particularly regarding seasonal hydrological variability that drives distinct flush and accumulation phases. Published studies have documented the presence of microplastics in African waters, sediments, and biota, underscoring the need for a thorough review of the existing knowledge on microplastics in the continent's aquatic environments including their spatial-temporal variability in the levels of microplastics (Shabaka et al., 2020; Yakubu et al., 2024). To address this critical gap, this study provides spatial-temporal assessment of microplastic abundance, morphology, color, and polymer characterization in both water and sediment of the Ngerengere River. The findings from this work provides baseline data on microplastic contamination in the Ngerengere River. In light of the limited information available on microplastic pollution in urban rivers across tropical aquatic ecosystem, the findings will guide future pollution management and raise community awareness about microplastic pollution and inform freshwater pollution control strategies in rapidly urbanizing Africa.

2. Materials and Methods

2.1 Description of Study Area

This study was conducted in the urban catchment of the Ngerengere River, which originates from the Uluguru Mountains. The river pass through the urban centers of Morogoro from the mountain's slopes, extending downwards to the Morogoro urban centres area, where the water is used for domestic, smallholder irrigation and livestock purposes. The study was conducted in dry and wet seasons. The Ngerengere Catchment has two main rainy seasons, producing an average annual rainfall ranging from 800 mm to 1000 mm per year. The heavy rainfall season (Masika) begins in March, while the light rainfall season (Vuli) begins in November (Shagega et al., 2020). The study area comprises two main geological units: the Precambrian Usagaran basement complex, consisting

of high-grade metamorphic rocks like amphibolite, gneiss, and granulite, and a Neogene formation characterized by thick deposits of red “mbuga” soil and alluvium near the river systems. The alluvial deposits result from riverine sedimentation processes. Compared to the metamorphic rocks, the alluvial and sandy aquifers exhibit higher porosity and

collected sample was passed through a stack of stainless-steel sieves with mesh sizes of 5 mm and 0.05 mm to eliminate large debris, retaining residues on the respective sieves. The residue collected on the 0.05 mm sieve was carefully transferred into a glass bottle, preserved with ethanol, and then transported to the NM-AIST laboratory for preparation and analysis.



Figure 1. A map showing the sampling locations for water and sediments at the Ngerengere River

permeability, with secondary porosity common in the metamorphic formations (Mkumbo et al., 2022).

2.2 Sample Collection

For sample collection of microplastics in water and sediment, a 30-meter section along the riverbank was measured using a tape measure. Within this marked area, grab water samples were collected with a metal jar from a depth of 0–5 cm, accumulating a total volume of 1 liter to form a composite sample. Each

At the same marked location, riverbed sediment samples were collected from a depth of 0–5 cm using a handheld auger, which was employed to extract approximately 1 kg of soil. A composite sample was then formed by combining material from three randomly selected points. The sediment samples were kept in aluminum trays prior to being transported to NM-AIST for further preparation and analysis. The total number of samples from both the water column and sediments of the Ngerengere River was 12, and

subsequent analysis of microplastics was performed using Total Attenuated Reflectance - Fourier Transform Infrared (ATR-FTIR) spectroscopy to identify the polymer types. In-situ water quality parameters like electrical conductivity (EC), total dissolved solids (TDS), temperature, and pH were determined using a well-calibrated multiparameter analyzer obtained from Sokoine University of Agriculture. The sampling approach involved the upstream-midstream and downstream approaches forming a total of six sampling stations, namely S1A, S1B, S2A, S2B, S3A and S3B (Figure 1). Sampling stations S1A and S1B formed the upstream segment, S2A and S2B formed the midstream segment, while S3A and S3B formed the downstream segment of the river.

Sediment samples were collected from the riverbed at a depth of 0–5 cm because this upper layer typically contains the highest concentration of microplastics (Martin et al., 2017). It is the most active zone where microplastics tend to accumulate due to water flow dynamics, sedimentation, and local disturbances. During the sampling of sediments, a hand auger (free from plastic material) was used. About 500 g of the composite sediment sample was obtained from each sampling site. This sampling approach has also been used by Jelimo et al., (2025) and Kundu et al., (2022).

Upon arrival at the laboratory, sediment particles retained on the sieves were dried in an oven at 55 °C for 48 hours to ensure all moisture was removed. The drying temperature was carefully controlled to avoid exceeding 60 °C because higher temperatures can deform or burn the plastic polymers present in the samples. The soil types and textures were determined using mechanical sieving. For this, 500 g of dried soil samples were passed through stainless-steel sieves of varying mesh sizes (2 mm to 0.01 µm) in a hierarchical order and shaken using a mechanical shaker. The percentage of soil particles retained on each sieve was then calculated, which was used to classify the soil type according to the soil texture triangle.

At each station, composite samples were derived from multiple sub-samples to reduce spatial heterogeneity. Procedural blanks were processed

alongside all samples and detected background particles were subtracted from sample counts before data analysis.

2.3 Laboratory Analysis

Dried samples of sediments, water residues, and sieved sediments were subjected to wet peroxide oxidation (WPO) and density separation to extract microplastics. Each sample received 100 ml of 0.05 M Fe (II) and 200 ml of 30% hydrogen peroxide to act as a catalyst and digester, respectively, for removing organic matter (Masura et al., 2015). The samples were left to digest in the fume hood, covered with aluminium foil, for 5 days until no foam or organic matter was visible.

2.4 Density Separation and Polymers Identification

After digesting the organic matter with lower density, the remaining low-density materials in the dried sediments are likely plastic particles. Since low-density compounds float in solutions with higher density, the solution used for density separation must be denser than the polymer expected to be detected. Sodium tungstate dihydrate ($\text{Na}_2\text{WO}_4 \cdot 2\text{H}_2\text{O}$), with a density of 1.6 g/cm³, was added as the density separator to the samples and thoroughly mixed using a metal rod to ensure full interaction. The mixture was allowed to settle for 24 hours in a fume hood, covered with aluminum foil. The supernatant was then decanted and filtered through a 0.45 µm membrane to capture the retained particles. The filtered residues on the glass membrane filters (0.45 µm GF/F, 47 mm diameter, Whatman) were stored in labeled petri dishes and refrigerated for further analysis. For microplastic identification and categorization, residues on the 0.45 µm membrane were examined under a dissecting microscope at 40× magnification to count and classify microplastics by size, color, and type.

Quality assurance measures throughout collection, pretreatment, and analysis aimed to minimize contamination. These included filtering distilled water with a 0.01 µm sieve for rinsing and reagent preparation, requiring all personnel to wear 100% cotton lab coats, favoring glassware over plastic,

covering samples with aluminum foil to prevent airborne contamination, and thorough cleaning of laboratory surfaces such as benches and fume hoods. Procedural blanks consisting of distilled water and refined igneous rock samples were processed alongside actual samples; microplastics detected in controls were negligible relative to the targeted size range. Polymer composition of suspected microplastic particles was non-destructively identified using Attenuated Total Reflectance Fourier Transform Infrared (ATR-FTIR) spectroscopy at the Nelson Mandela African Institute of Science and Technology, Tanzania.

2.5 Quality Assurance

To ensure quality assurance, precautions were implemented throughout sample collection, pretreatment, and analysis to minimize cross-contamination. These measures included: rinsing equipment and preparing reagents using distilled water filtered through a 0.01 μm sieve, and requiring all personnel handling samples to wear 100% cotton lab coats, using glassware instead of plastic whenever possible, covering samples with aluminum foil to prevent airborne contamination; and cleaning all laboratory surfaces, including benches and fume hoods. Additionally, three procedural blank samples consisting of distilled water and refined igneous rocks were analyzed following the same preparation procedures as the actual samples. Any microplastics detected in the blanks were considered negligible relative to the target size range for microplastic enumeration.

2.4 Data Analysis

Microplastic abundance was expressed to particles l^{-1} for water and particles g^{-1} dry weight for sediments. The results were interpreted based on the spatial and seasonal patterns on the variability of types, color and morphology of microplastics following approaches used in recent riverine microplastic studies (Ololade et al., 2024; Dahms and Greenfield, 2025).

3.0 Results and Discussion

3.1 Morphology and Types of Microplastics in Water and Sediments

Based on the data in Tables 1 and 2, fragments were the dominant microplastic morphology across all sites and seasons. During the wet season, fragment counts in water were highest at upstream reaches of the river (12 fragments) and midstream reaches (23 fragments) but dropped at downstream, suggesting dilution or deposition along the river due factors such as variations in the river discharge across the sampling locations. In wet-season sediments, fragments remained abundant at midstream (16 fragments) and downstream (10 fragments), indicating accumulation. During the dry season, fragments in water were more evenly distributed, with moderate counts at upstream, midstream, and downstream. However, dry-season sediments showed high fragment retention at upstream (7 fragments) and (9 fragments) for sampling station S1A and S1B respectively. Fibers and filaments appeared almost exclusively in dry-season sediments. Spatially, midstream reaches generally recorded the highest total microplastic counts in both seasons, while upstream reaches showed moderate levels and downstream reaches varied widely. Overall, fragments dominated everywhere, but their numbers varied seasonally and spatially peaking in wet-season water at midstream and shifting to dry-season sediments across all sites.

These findings align with observations from other regions, such as southwestern Nigeria, where fragments and fibers are also the prevalent microplastic forms in both water and sediments (Ololade et al., 2024). Similarly, in the Dar es Salaam and Zanzibar coastal sediments, fibers were most abundant, but fragments were also prevalent at certain sites, indicating that secondary microplastics are widespread in diverse aquatic systems (Nchimbi et al., 2022). The sediment data from Ngerengere River further support the dominance of fragments, with fibers present mainly in midstream sediments. This pattern aligns with findings from other river systems, where sediments serve as sinks for microplastics, particularly fragments and fibres, which settle due to their density and

interaction with particulate matter (Dahms & Greenfield, 2025). The wet season in Ngerengere, characterized by increased runoff and flow, likely facilitates the transport and deposition of microplastic fragments in sediments, consistent with the sink-source dynamics observed in other tropical rivers (Dalu et al., 2023). The size range of microplastics in sediments (up to 2 mm) compared to water (mostly 500 μm – 1 mm) suggests selective settling of larger or denser particles during the wet season, a process also reported in other studies where sediments accumulate larger microplastics due to hydrodynamic sorting (Ololade et al., 2024). Spatially, the highest microplastic abundance in water was observed midstream coinciding with urban and industrial influences, while upstream and downstream sites showed moderate to lower counts. This gradient aligns with patterns documented in other urban-impacted rivers, where microplastic loads peak near densely populated or industrialized areas due to direct inputs from municipal wastewater, solid waste mismanagement, and industrial effluents (Ololade et al., 2024).

3.2 Abundance of Microplastics in Water and Sediments During the Wet Season

In this study, the total microplastic count in the water column ranged from 5 to 24 particles l^{-1} across the sampling sites, with fragments consistently dominating over fibers. In contrast, sediment samples contained between 6 and 18 particles g^{-1} , with both fibers and fragments present; at some locations, such as the upstream site, fibers were more abundant. In several cases, sediments exhibited higher microplastic concentrations than the overlying water, suggesting that sediments act as sinks where particles accumulate and are retained despite their lower sample mass (Lagarde et al., 2016). These findings relate with the reported microplastics concentration in another research works of Zhang et al., (2020) in Qin River where the results indicated the predominance of large-sized MPs (1–5 mm) in both compartments, together with the high abundance of PE and PP (which have densities close to or less than water), suggests that many particles initially float but later become trapped in sediments due to biofouling, aggregation, or physical entrainment. Thus, sediments integrate MP

inputs over longer periods, often resulting in higher and more stable measured concentrations than the overlying water column.

3.3 The Color of Microplastics in Water and Sediments

During the wet season, black microplastics were the most dominant color category in both water and sediment samples (Tables 1 and 2). In the water column, they accounted for a large share of the particles at most sites for example, 6 of 14 particles at the upstream station and 20 of 24 at the midstream station. White microplastics were also present across the sites but in lower proportions, typically ranging from 1 to 9 particles. Blue microplastics were less common in the water samples but were more notable in the sediment matrix. No yellow, orange, green, or other colored microplastics were detected in either water or sediment. In sediments, black particles remained the predominant category at all sampling points, contributing approximately 44–83% of the total microplastics. White particles occurred less frequently in sediments than in water, which may reflect differences in transport, settling, or degradation. The presence of blue particles in sediments despite being absent from the overlying water at some locations suggests selective deposition or input from specific sources. The predominance of black fragments, accounting for 44 to 83 percent of microplastics in sediments, strongly suggests a substantial contribution from tire wear particles and other carbon black reinforced plastics transported via road runoff. Tire wear particles are now recognized as one of the dominant sources of microplastics in urbanized catchments, particularly in settings where untreated stormwater drains discharge directly into river systems (Baensch-Baltruschat et al., 2020; Kole et al., 2022). Although ATR-FTIR analysis primarily identifies the polymeric matrix such as polyethylene and polypropylene, the black coloration is characteristic of carbon black fillers and ultraviolet stabilizers widely used in automotive tyres and industrial plastic products. These particles are of particular concern because they are associated with traffic-related additives, including N-(1,3-dimethylbutyl)-N'-phenyl-p-phenylenediamine, which can oxidize to the highly

Table 1. Type and Color of Microplastics in the sediments and water during the wet season

Types of samples													
		Water						Sediment					
	Sampling Points in River	S1A	S1B	S2A	S2B	S3A	S3B	S1A	S1B	S2A	S2B	S3A	S3B
Morphology	Fibers	2	-	1	-	1	-	-	-	2	-	-	-
	Fragments	12	9	23	8	3	11	9	7	16	6	7	10
	Films	-	-	-	-	-	-	-	-	-	-	-	-
	Microbeads	-	-	-	-	-	-	-	-	-	-	-	-
	Threads	-	-	-	-	1	-	-	-	-	-	-	-
	Total	14	9	24	8	5	11	9	7	18	6	7	10
Color	Blue	-	-	-	-	-	-	-	3	1	-	-	-
	Black	6	7	20	6	4	2	9	4	17	6	5	10
	White	8	2	4	2	1	9	-	-	-	-	2	-
	Yellow/Orange	-	-	-	-	-	-	-	-	-	-	-	-
	Green	-	-	-	-	-	-	-	-	-	-	-	-
	Others	-	-	-	-	-	-	-	-	-	-	-	-
	Total	14	9	24	8	5	11	9	7	18	6	7	10

Table 2. Type and Color of Microplastics in the sediments and water during the dry season

Types of samples													
		Water						Sediment					
Sampling Points in River		S1A	S1B	S2A	S2B	S3A	S3B	S1A	S1B	S2A	S2B	S3A	S3B
Morphology	Fibers	-	2	4	-	-	1	4	1	4	-	-	6
	Fragments	5	3	2	7	6	7	7	9	3	7	8	5
	Filaments	-	-	-	-	-	-	2	-	5	-	-	3
	Microbeads	-	-	-	-	-	-	-	-	-	-	-	-
	Threads	-	-	-	-	-	-	-	-	-	-	-	-
	Total	5	5	6	7	6	8	13	10	12	7	8	14
Color	Blue	-	1	-	1	-	-	-	-	-	1	-	1
	Black	2	2	3	4	2	5	6	6	4	4	6	4
	White	3	1	2	2	4	2	5	2	6	2	2	8
	Yellow/Orange	-	-	-	-	-	-	-	-	-	-	-	-
	Green	-	1	-	-	-	-	1	2	2	-	-	-
	Pink	-	-	1	-	-	-	1	-	-	-	-	1
	Red	-	-	-	-	-	1						
	Total	5	5	6	7	6	8	13	10	12	7	8	14

toxic transformation product 6PPD-quinone, now widely detected in urban aquatic environments (Tian et al., 2021; Johannessen et al., 2022). The relatively high density and hydrophobic nature of carbon-black reinforced particles promote their preferential settling and accumulation within the sediment matrix, reinforcing the role of riverbeds as long-term sinks for traffic-derived microplastics and associated chemical contaminants. This accumulation poses potential risks to benthic organisms and increases the likelihood of episodic remobilization during high-flow events, particularly in tropical rivers characterized by strong seasonal runoff pulses (Hale et al., 2020; Baensch-Baltruschat et al., 2020).

3.4 Types of Microplastics in Water and Sediments

In water samples, common polymers included polystyrene (PS), polypropylene (PP), polyethylene (PE), polyethylene variants such as low-density PE (LDPE) and high-density PE (HDPE), and polyester compounds (PEC) (Tables 1 and 2). Upstream sites had PS, PP, PE, PEC, and LDPE polymers, while midstream and downstream sites mostly showed PP, PE, HDPE, and polypropylene-polyethylene copolymers. This broad range indicates contributions from various anthropogenic sources such as packaging, textiles, and agricultural materials (Duong et al., 2023). Sediment samples revealed narrower polymer diversity, predominantly comprising PS, PP, PE, and HDPE, with polyester polymers less frequently detected. For example, upstream sediments (S1A) contained PS and PP, while midstream and downstream sediments primarily had PP, PE, and HDPE types. Polymer sizes in sediments ranged typically between 500 μm to 2 mm, slightly broader in spectrum than those in water samples. The observed polymer variability may stem from differential transport and deposition processes: lighter polymers like LDPE and PP often remain suspended in the water column and are transported downstream, while denser polymers such as HDPE and PS tend to settle and accumulate in sediments (Anyaegebu et al., 2024). Moreover, polymer

usage patterns in surrounding communities and land uses likely influence spatial distribution; upstream sites with mixed polymers may reflect inputs from residential or commercial waste, whereas downstream sediments may accumulate more recalcitrant polymers due to settling (Osorio et al., 2021). The size range of these microplastics generally fell between 500 μm to 1 mm, sediment microplastics were slightly larger on average (500 μm to 2 mm). In the dry season, fragments were dominant across the water samples. Overall, the study findings show that fragments represent between approximately 50% to over 90% of the microplastics in both water and sediment samples, making fragments the predominant morphology. Fibers and filaments contribute variably but significantly, especially in sediments downstream. These findings align with literature observations where fragments usually account for a majority of microplastics due to secondary breakdown processes, while fibers signal textile inputs, and filaments are more sediment-associated due to density and hydrodynamics (Fiore et al., 2022).

3.5 Abundance of Microplastics in Water and Sediments During the Dry Season

The study findings revealed that microplastic abundance in the dry season dataset varies between water and sediment samples (Figures 2-5) and across river sampling points located at the upstream, midstream, and downstream reaches. In water samples, total microplastic counts range from 5 to 8 particles per sample, showing moderate variation along the river with midstream having the highest abundance (8 particles). Sediments have higher total microplastic loads, from 7 to 14 particles, with downstream sediments showing the highest abundance (14 particles), likely due to sedimentation processes acting during the dry season's lower flow. These findings are similar to the findings reported by Lestari et al., (2025) highlighting sediments as significant microplastic sinks with greater accumulation downstream. The findings showed that fragments predominate in both water and sediments, constituting about 60-90% of

microplastics depending on the sampling location, for sediments, constituting up to 42% at midstream

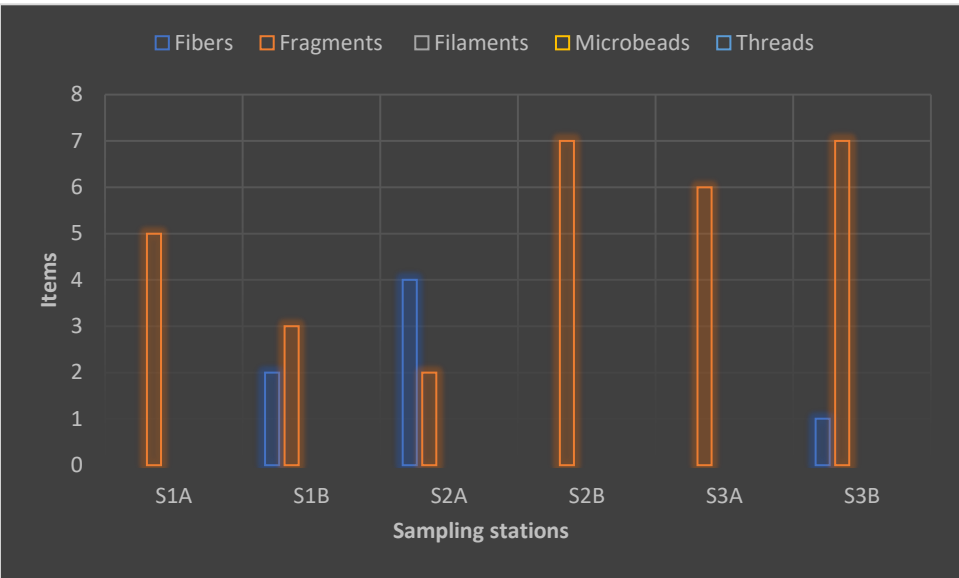


Figure 2. Distribution of microplastics in the water column during the dry season

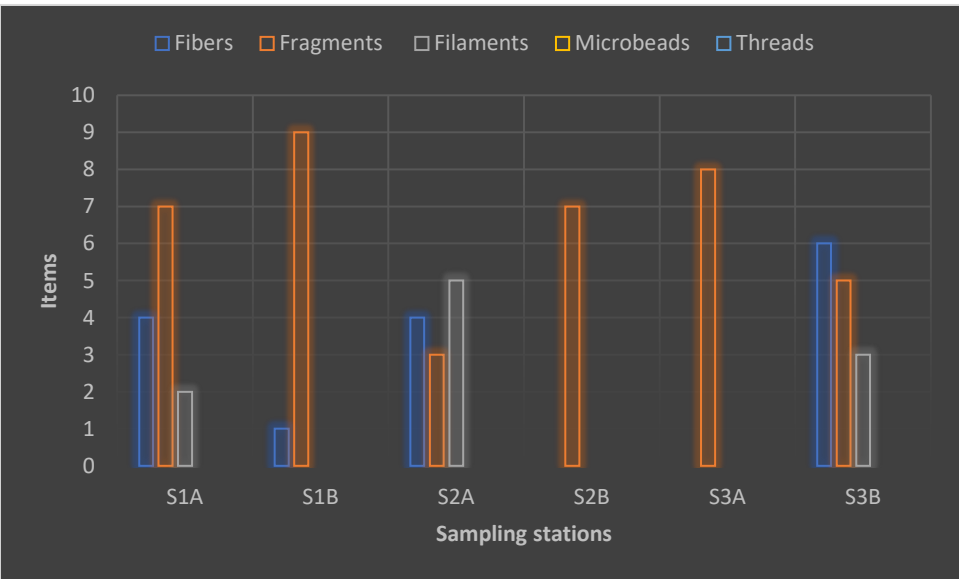


Figure 3. Distribution of microplastics in the sediment during the dry season

instance 100% fragments in upstream water and 90% in upstream sediment (Figures 10 and 11). Fibers are present mainly in water samples upstream and midstream, reaching up to 67% in midstream reaches, but less in sediments. Filaments appear mainly in

sediments, consistent with their tendency to settle. Color distribution also exhibits spatial variability. Black microplastics are the most common color (~30-50%) across all locations and sample types, followed by white (20-40%) and blue colors. The findings

showed that, blue and black colors are predominant among fibers and fragments, linking to common plastic products in the environment. These findings implied

variability signals processes such as hydrodynamic sorting, plastic degradation, and source contributions shaping microplastic fate along the river continuum. In

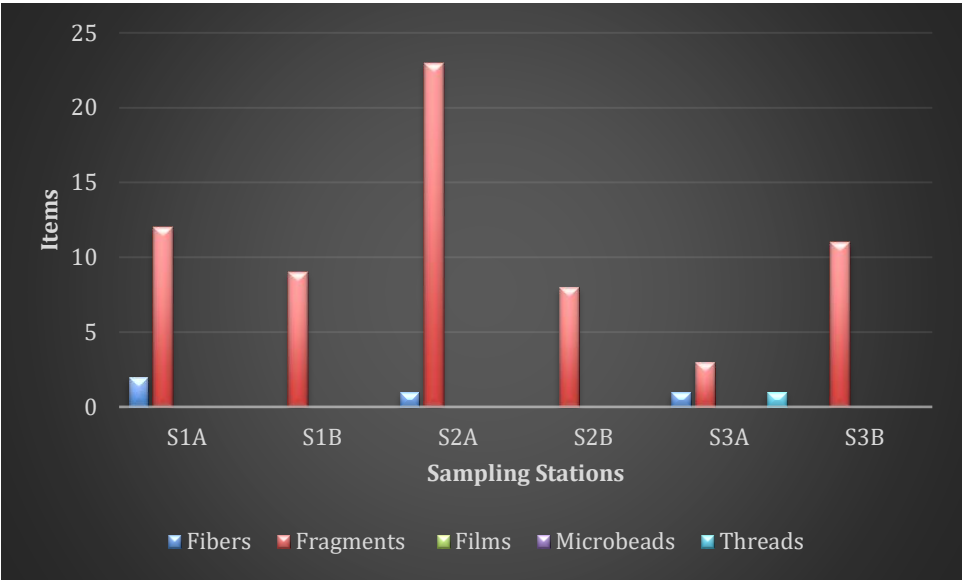


Figure 4. Distribution of microplastics in the water column during the wet season

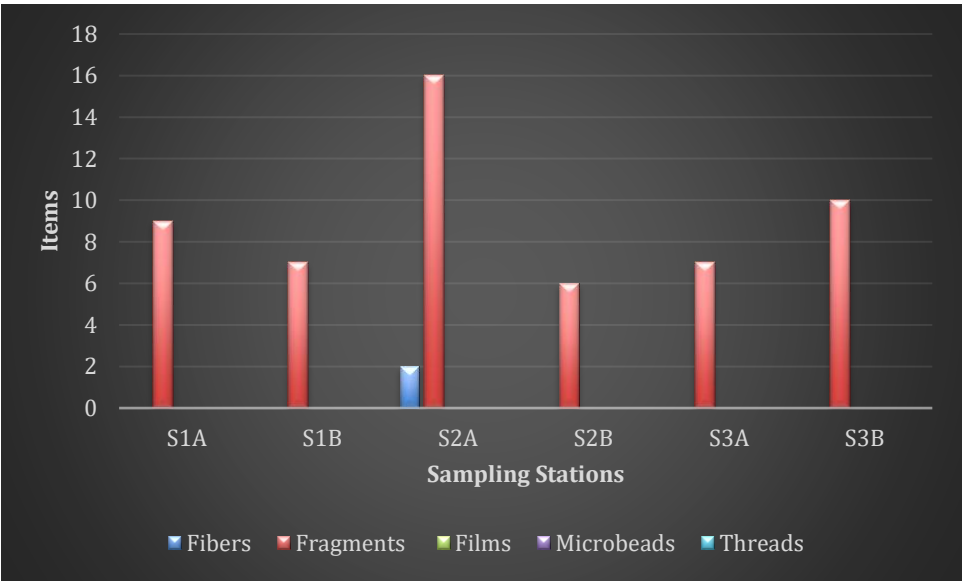


Figure 5. Distribution of microplastics in the sediment during the dry season

that that during the dry season, microplastic abundance increases downstream and is highest in sediments, where fragments dominate morphologically, and black and white dominate color profiles. This quantitative

water, total microplastic counts per sample range from 5 to 8 particles, with downstream reaches exhibiting the highest abundance (8 particles), whereas in sediments the counts are higher, ranging from 7 to 14

particles, with the highest concentration downstream at midstream sediments (14 particles). The findings revealed that black microplastics make up roughly 30-50% of the total water sample across all samples and locations, followed by white (about 20-40%) and blue. Other colors such as green, pink, and red were recorded a small extent reflecting diverse plastic sources including domestic waste and urban runoff. Black and blue colors dominate fragments and fibers, indicating the common polymer products. In the dry season, the results indicate a variability in the microplastic polymer types and particle sizes present in both water and sediment samples across the studied locations during the dry season. Research findings revealed that Polypropylene, polyethylene and PET consistently appear as dominant polymers in both water and sediment samples. Polypropylene and polyethylene are ubiquitous due to their widespread industrial and consumer use, resulting in their persistence and accumulation in aquatic environments (Jamšek et al., 2024). HDPE is frequently observed in water samples, suggesting potential sources related to packaging and plastic containers that disperse largely in aqueous phases (Kunz et al., 2023a). The presence of PVC and PBT selectively in sediment samples points to heavier and denser polymer types that tend to settle out of the water column and accumulate in benthic substrates, consistent with their higher specific gravities compared to PE and PP (Kerubo et al., 2021). Furthermore, the research revealed that the particle size ranges detected mainly ranged from 500 μm to 5 mm in sediments and from 500 μm to 3 mm in water samples. Waterborne microplastics tend to occupy slightly narrower size ranges (500 μm – 3 mm), likely reflecting size-dependent transport and suspension behaviours. Larger particles (>3 mm) are rarely suspended and thus more prevalent in sediment samples where particles from 500 μm up to 5 mm suggest accumulation of coarser fragments, potentially due to fragmentation and sediment transport dynamics (Kunz et al., 2023). The consistency in polymer types across water and sediment samples underscores the prevalence of common consumer plastics in the environment and

their persistent nature. The predominance of polypropylene and polyethylene suggests sustained input sources, possibly linked to domestic and industrial effluents. PET's presence, albeit less abundant, aligns with usage in beverage containers and fibers.

Across both seasons, sediments consistently showed higher microplastic loads than the overlying water, confirming their role as long-term sinks. Wet season samples showed greater spatial variability, while dry season samples showed stronger downstream accumulation. This seasonal contrast highlights the influence of hydrology on microplastic transport and retention.

3.6 Implications for Freshwater Ecosystems and Human Exposure

The spatial and seasonal patterns of microplastics observed in the Ngerengere River suggest sustained ecological pressure on freshwater ecosystems, particularly in sediment-associated habitats. The dominance of fragments and fibres indicates secondary microplastics derived from the degradation of larger plastic items, which are known to persist and accumulate in benthic environments. Sediment-associated microplastics increase the likelihood of interaction with benthic invertebrates, biofilms, and detritivorous organisms, potentially altering feeding behaviour, energy allocation, and sediment biogeochemistry. Polymers such as polypropylene, polyethylene, and polystyrene, which were prevalent in this study, have been widely reported in freshwater systems and are associated with physical abrasion, oxidative stress, and inflammatory responses in aquatic organisms under laboratory and field conditions (Bae et al., 2025; Dahms and Greenfield, 2025).

Beyond ecological effects, the presence of microplastics in the Ngerengere River and the use of the river water for domestic activities, irrigation, and livestock watering creates indirect human exposure pathways. Microplastics present in irrigation water and sediments can be transferred to agricultural soils and

crops, while those in surface waters may be ingested by fish consumed by surrounding communities. Recent studies indicate that freshwater microplastics share similar polymer profiles with particles detected in food and drinking water, raising concerns about cumulative exposure in populations relying on untreated or minimally treated surface water sources (Nyaga et al., 2024; Vanavermaete et al., 2024).

Although this study did not quantify human intake, the concentrations and polymer types detected suggest a need for precautionary management, particularly in urban-influenced river sections. These findings underscore the importance of integrating microplastic monitoring into routine freshwater quality assessments in Tanzania and similar contexts. Targeted mitigation measures should focus on urban runoff control, improved solid waste management, and reduction of plastic inputs at identified hotspots along the river. Future research should move beyond abundance measurements to include bioavailability, uptake by aquatic organisms, and exposure assessment in food and water pathways, providing the evidence base required for risk-informed policy and freshwater resource protection strategies.

The dominance of polyolefins (PP and PE) detected in this study has specific microbiological implications. Due to their high hydrophobicity and chemically distinct surface properties, PE and PP fragments provide stable substrates for the biofilm formation and enrichment of antibiotic-resistant bacteria within the plastisphere (Galafassi et al., 2021). Given that the Ngerengere River serves as a direct domestic water source, these microplastics may act as mobile rafts for pathogens, bypassing conventional filtration mechanisms.

4.0 Conclusion and Recommendations

The findings of this study suggests that the Ngerengere River is consistently impacted by microplastic contamination across both wet and dry seasons, with sediments acting as dominant long-term sinks. The predominance of secondary microplastic

fragments, together with their accumulation in riverbed sediments, indicates sustained inputs from urban, industrial, and road-related activities. Particle sizes and polymer types detected fall within ranges known to interact with freshwater biota, suggesting chronic exposure risks for benthic organisms and the potential for trophic transfer within aquatic food webs. Seasonal contrasts further reveal that hydrological conditions strongly regulate microplastic dynamics, with wet-season runoff driving spatial redistribution and short-term pulses, while dry-season low flows promote downstream accumulation and sediment retention.

From a human exposure perspective, the use of the Ngerengere River for domestic activities, irrigation, and livestock watering creates multiple indirect pathways through which microplastics may enter local food systems. The concentration of microplastics in midstream urban sections highlights priority hotspots where exposure risks may be elevated, particularly during the onset of the rainy season when accumulated road dust and plastic debris are mobilized. Although direct human intake was not quantified in this study, the polymer profiles observed mirror those reported in freshwater fish, crops, and drinking water elsewhere, underscoring the need for precautionary management in river-dependent communities.

Management actions should prioritize midstream urban reaches by strengthening solid waste collection, improving stormwater drainage design, and installing sediment traps and gross pollutant traps at major outfalls to intercept microplastics before they enter the river. Municipal cleaning and street sweeping schedules should be synchronized with the onset of seasonal rains to reduce the magnitude of runoff-driven microplastic pulses. At the policy level, integration of microplastic indicators into routine freshwater quality monitoring programmes would provide an early warning tool for emerging pollution trends. Future research should move beyond abundance measurements to include biological uptake, additive chemistry such as tire-derived compounds, and human exposure assessment, thereby supporting risk-based

regulation and sustainable management of tropical freshwater systems under increasing urbanization pressure.

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Declaration of interest statement

The authors report there are no competing interests to declare.

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Data availability statement

All data used in this work are available upon reasonable request to Authors.

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