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Assessment of Conventional Water Treatment Plant Efficiency in Removing Microplastic Pollutants: A Case Study of Mtoni CWTP, Dar es Salaam

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ABSTRACT

Purpose: Microplastics are defined as plastic particles smaller than 5 mm. This study explores the MP's presence, and efficiency of a conventional water treatment plant (CWTP) in removing microplastic pollutants, in Dar es Salaam, Tanzania.

Methodology: Field sampling was conducted at three treatment stages, at the raw water abstraction point at Kizinga river, after clarification stage, and after filtration (RSF). Microplastics concentrations in raw water were 22,000± 4714 particles/ m^3 during dry season and 13333±943 particles/ m^3 during rainy season.

Findings: The Conventional water treatment plant (CWTP) achieved overall microplastic removal efficiency between 70% and 81% with rapid sand filtration contributing significantly to removal, while clarification showed variable performance. Despite significant reduction, microplastics were still present in treated water, indicating incomplete removal with concentrations ranging 6667±3771 particles/m^3 in dry season and 2500±236 particles/m^3 in rainy season. Microplastics identified included both primary (pellets) and secondary forms (fibres, fragments, films), with polypropylene and polyethylene being the dominant polymers.

Unique Contribution to Theory, Policy and Practice: This study demonstrates that while conventional treatment processes reduce microplastic loads, they are not fully effective, particularly for smaller particles. Findings provide critical baseline data for improving water treatment performance and informing policy on emerging contaminants in Tanzania.

Keywords: *Microplastics, Water Treatment Plant, Removal Efficiency*

JEL Codes: *Q25, Q53, Q56*

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1. Introduction

The rapid increase in global plastic production over recent decades has resulted in widespread environmental contamination by microplastics, defined as plastic particles smaller than 5 mm(Geyer et al, 2017). These particles originate from both primary sources, such as industrial pellets and microbeads, and secondary sources arising from the degradation of larger plastic materials (Xu et al, 2020). Due to their persistence and resistance to degradation, microplastics have been detected in diverse environmental compartments, including oceans, rivers, soils, air, and drinking water systems (Koelmans et al, 2019; WHO, 2019). Freshwater systems are of particular concern as they serve as primary sources of drinking water.

Studies have shown that microplastics are present in raw and treated water, raising concerns about human exposure through ingestion (WHO, 2019). Conventional water treatment plants, which are primarily designed to remove turbidity, pathogens, and organic matter, were not engineered to address emerging contaminants such as microplastics (Na et al, 2021). Globally, treatment processes such as coagulation, flocculation, sedimentation, and filtration have demonstrated varying efficiencies in removing microplastics, often exceeding 70% under optimal conditions (Na et al, 2021). However, removal efficiency is highly dependent on particle size, shape, and polymer type, with smaller particles and fibres often escaping treatment processes. Consequently, treated water is not entirely free from microplastics (Ma et al, 2019;Pivokonský et al, 2020; Negrete Velasco et al, 2022;Radityaningrum et al, 2023;Sun et al, 2024;Koelmans et al, 2019).

In Africa, while detailed assessments of treatment performance are relatively limited, studies have confirmed widespread microplastic contamination of water sources, reflecting both rapid urbanization and insufficient waste management infrastructure. Urban rivers and nearshore waters show significant microplastic presence, and these surface waters often serve as raw water sources for municipal treatment plants (Negrete Velasco et al., 2022; Adewuyi and Li, 2024; Mokgalaka-Fleischmann et al., 2024). Yet, detailed evaluations of how well conventional water treatment plants in African contexts remove microplastics remain scarce, which impedes understanding of local treatment efficacy.

Recent research in Dar es Salaam documented microplastics present in tap water intended for drinking water and other domestic uses, suggesting that conventional treatment does not fully prevent microplastics from reaching consumers (Mtega et al, 2025). This local evidence mirrors global patterns.

Given these observed patterns, this study assesses the occurrence and removal efficiency of microplastics pollutants in conventional water treatment systems in Dar es Salaam, Tanzania. It evaluates the performance of a major water treatment plant units by measuring microplastic concentrations at different treatment stages during both dry and rainy seasons. The findings aim to clarify the effectiveness of treatment processes in removing microplastics. Overall, the study

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provides insights that can support improvements in water treatment processes and informing policy on emerging contaminants in Tanzania.

2. Materials and methods.

2.1 Study area

The study was conducted at Mtoni water treatment plant in Dar es Salaam, Tanzania. Mtoni water treatment plant is managed by Dar es Salaam Water Supply and Sanitation Authority (DAWASA) which serves the southern parts city i.e., Temeke district. The selected CWTP has a design capacity of approximately 9,000 m^3/day making it serve as a supplementary water treatment facility behind Lower Ruvu and Upper Ruvu CWTPs which treat 270,000 m^3 and 190,000 m^3 respectively which is accounts for 80% of total water required by the city (Mahenge & Mato, 2022). It treats surface water from the Kizinga river, which is conveyed through gravity steel pipe DN 400 to the raw water sump located 260 away from the riverbank. From this sump water is lifted at a head of 80m towards the Mtoni CWTP located 5km away via a DN 400 steel pipe. Mtoni CWTP operates using conventional treatment processes, including coagulation, flocculation, sedimentation, filtration, and disinfection, to eliminate suspended particles, microorganisms, and other impurities from water. However, the effectiveness of these processes in removing microplastics is still not well understood.

2.2 Sampling

To assess seasonal variations, two sampling campaigns were carried out, with samples collected during the dry season on 6th and 7th January 2026, and during the rainy season on 1st and 2nd April 2026. Samples were collected from three critical points within the treatment system to evaluate the behaviour of microplastics throughout different treatment stages. The locations included the intake (raw water), Clarification outlet and filtration outlet (treated water before distribution).

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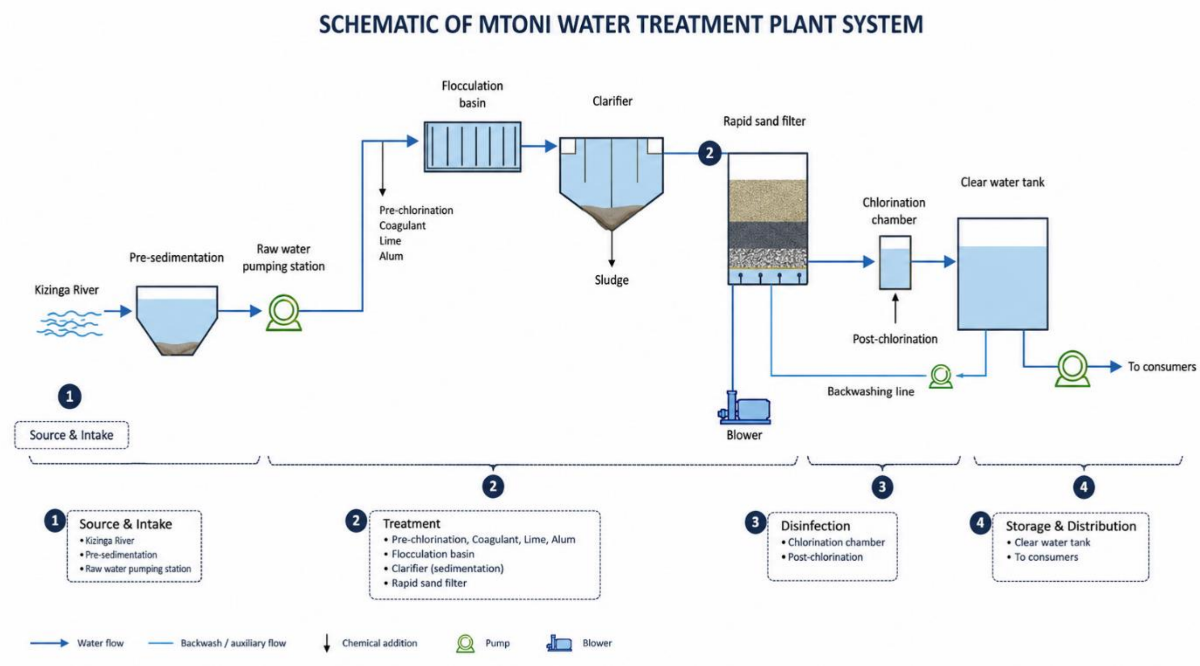

Fig 1: Sampling points along Mtoni CWTP treatment train

At each sampling point, two sets of duplicate samples (four samples, each 750 ml) were collected to ensure consistency and accuracy of the analytical results. Water samples were collected in pre-cleaned glass bottles to minimize contamination and stored at room temperature prior to transportation to the Kenya Marine and Fisheries Research Institute, Mombasa, for laboratory analysis.

2.3 Sample analysis

Microplastic analysis was performed using procedures adapted from Nchimbi et al. (2022) and Ta et al. (2025), with necessary adjustments made to accommodate the characteristics of samples obtained from various stages of the water treatment process. The analytical approach differed depending on the sample type, whereby raw water samples underwent pre-treatment to eliminate organic matter, whereas treated water samples were subjected directly to filtration for microplastic examination.

2.3.1 Sample preparation

2.3.1.1 Microplastic extraction.

Sieving: Each sample was sieved through precleaned metallic sieves of 20 µm. Immediately after sieving, the sieved samples were digested in 50 mls 10% potassium hydroxide (KOH) at 60 degrees centigrade for twelve hours to remove organic matter (Lusher et al, 2017). After 12 hours the digested samples were then sieved through 20µm, thoroughly rinsed with distilled water, and transferred to individual beakers using prefiltered distilled water. The samples were then filtered through a vacuum pump fitted with a cellulose nitrate membrane (Millipore HA of 0.45 µm GFF membrane filters) to maximize extraction of microplastics. The membranes filters were placed in a membrane dish holder (petri dishes), covered and dried at 40 degrees centigrade for 12 hours after which the samples were ready for microplastic enumeration and examination.

2.3.2 Microplastic enumeration and characterisation

The membrane filters were examined under a stereomicroscope (Olympus, SZ51, Japan) at 40 x magnification equipped with a CCD camera as described by Hidalgo-Ruz et al. (2012). The Microplastics were characterised as fibre (thread-like, microfibers, filaments or strands), fragments (irregular shaped particles, crystals, fluffs or granules), pellets and films (sheet-like soft fragments) according to Hidalgo-Ruz et al. (2012). The abundance of suspected microplastics was expressed as the number of particles per unit volume of collected sample.

2.3.3 Polymer identification using Attenuated Total Reflectance (ATR-FTIR).

Suspected microplastics were selected at random for polymer identification. Polymer characterization was conducted using a Nicolet Summit X FTIR Spectrometer (Thermo Fisher Scientific, USA) equipped with an Everest ATR accessory. Spectra were acquired and processed using OMNIC Paradigm software (Version 1.3). Spectra were matched against the Wiley (Sigma-Aldrich) ATR-IR spectral library (Product No. 834-119000). A minimum threshold value of 80% was considered a satisfactory correlation score with the reference database and matches lower than this value was rejected.

2.4 Quality control

Potential contamination during sample handling may originate from airborne particles, laboratory glassware, and equipment(Lu et al, 2021). Sample processing and analysis were done in a clean laboratory room with negative air flow and limited foot traffic. Microplastic contamination through exposure to air was reduced by covering samples with aluminium foil and glass covers the use of distilled water-rinsed glassware and metal equipment (Liebezeit & Liebezeit,2014). The working surface was thoroughly cleaned with 70 % ethanol on non-shedding paper three times and allowed to dry before use(Cole et al, 2014). A cotton laboratory coat was worn over natural or synthetic fibre clothes throughout. Hand gloves were used throughout the sample processing and analysis period. A filter paper of 0.45 micrometre pore diameter was placed in a petri dish and left exposed during the processing and analysis period. The counts per blank were subtracted from the total count in each sample to correct ground contamination**.**

2.5 Statistical analysis

Descriptive statistical analysis was employed to summarize microplastic concentration data across the different stages of the water treatment process. The results were presented using means and standard deviations to illustrate variations in microplastic abundance and characteristics among sampling points.

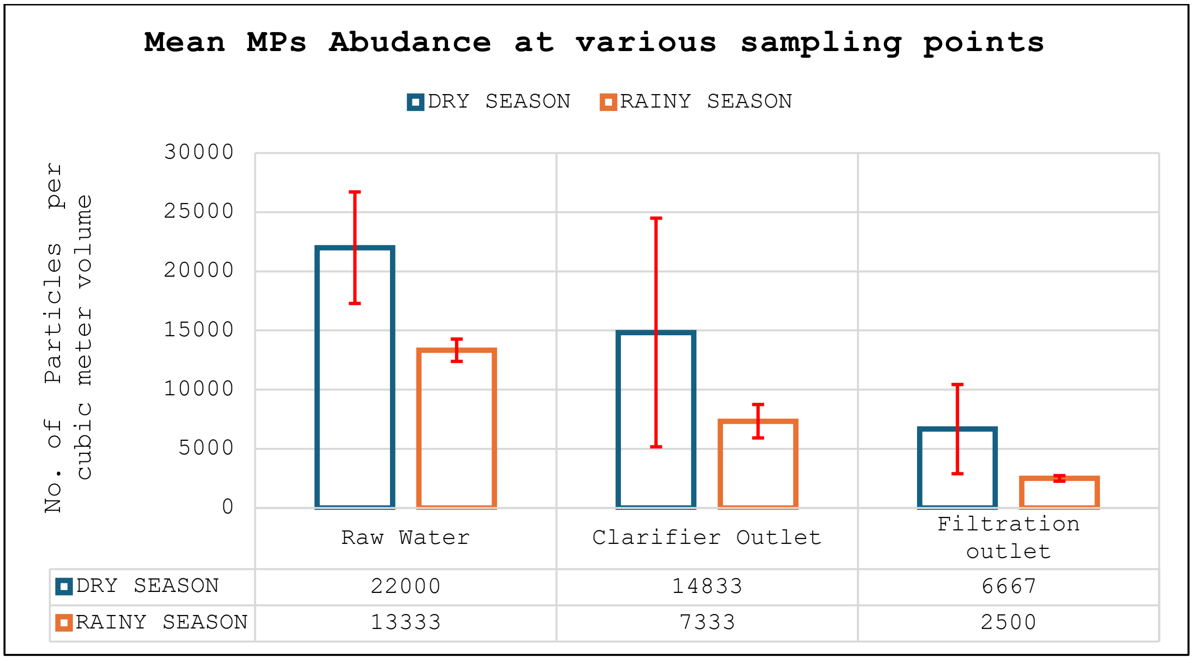

Fig 2. Removal of Microplastics at different treatment stages of Mtoni CWTP.

3.0 Results and Discussion

3.1 Microplastics Abundance and MPs removal efficiency in CWTP

The raw water samples consistently exhibited the highest concentration of MPs during both the dry and rainy seasons, suggesting that the source water serves as a major pathway for MPs entering the treatment system (Ta et al, 2025). In the dry season, the raw water had an average MP concentration of approximately 22000±4714 particles/m^3, nearly double that of the rainy season 13333±943 particles/m^3. This trend aligns with the findings of Ta et al. (2025), which also reported higher concentrations of MPs in raw water samples collected from the Chao Phraya River supplying a water treatment plant in Bangkok, Thailand, with the dry season exhibiting concentrations nearly twice as high as those observed during the rainy season. Furthermore, findings of Hidayat et al. (2025), show similar trend for raw water samples collected from river Cikapundung which is being utilized as water source for Dago Pakar CWTP in Bandung City, Indonesia. Higher MP abundances observed during the dry season suggest that reduced water dilution may have resulted in increased MP concentrations per unit volume compared to the rainy season. However, it's worth noting that during the rainy season, MPs from runoff may significantly contribute to the river.

Along the treatment train, the abundance of MPs progressively decreased through clarification and filtration in both seasons. During the dry season, the concentration in the final treated water was

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www.carijournals.org

reduced to approximately 6667±3771 particles/m^3, while in the rainy season it further declined to about 2500±236 particles/m^3, demonstrating an overall reduction of MP abundance across the treatment stages in both seasons. The treatment process achieved an overall MP removal efficiency of 70% during the dry season and 81% during the rainy season, indicating the plant's effectiveness in substantially reducing MP concentrations, although residual MPs were still detected in the treated water.

Table 1 Summarizes the removal efficiency of MPs at each treatment stage and across different size fractions. During the dry season, the overall removal efficiency ranged from 63% to 78%. Clarification achieved removal efficiencies of 14–57%, filtration accounted for 50–57%. Similarly, in the rainy season, total MP removal ranged from 81% to 82%, clarification and filtration achieved 40-50% and 63-68% respectively. Among all treatment stages, filtration was the most effective. Microplastic abundance and removal efficiency varied among different batches, with noticeable differences observed both between batches within the same season and across different seasons. According to Radityaningrum et al, (2023), this variation may possibly be attributed to differences in raw water quality and operational conditions of the treatment plant.

Table 1: Microplastic Removal efficiencies across treatment stages

Season	**MP Removal Efficiency %**		
	Clarification	**Filtration**	**Overall**
Dry season			
1st Batch	14	57	63
2nd Batch	57	50	79
Rainy season			
1st Batch	40	68	81
2nd Batch	50	63	82

The MP removal efficiency observed in this study was compared with findings reported for various CWTPs worldwide (**Table 2**). Considerable variations in influent MP concentrations were observed among the different WTPs, likely reflecting differences in raw water quality, catchment characteristics, and the intensity of surrounding anthropogenic activities. CWTPs utilizing lake water or groundwater sources, such as those reported in Switzerland (0.0382 ± 0.0155 particles/L) (Negrete Velasco et al, 2022) and Germany (0–7 particles/m³)(Mintenig et al, 2019), exhibited considerably lower influent MP concentrations. This may be attributed to the relatively protected nature of these water sources, lower exposure to industrial discharges, and improved watershed management practices. In contrast, CWTP abstracting water from rivers particularly those located in urban or agricultural catchments generally receive higher microplastic (MP) loads in their influent. For instance, influent concentrations reported in the Czech Republic (3605 ± 497 particles/L) (Pivokonský et al, 2020) and China (2753± 107 particles/L (Shen et al, 2021.). These elevated levels are largely linked to direct wastewater discharges, surface runoff transporting plastic debris, and insufficient waste management practices within the surrounding catchment areas. Under such conditions, the high influent MP burden poses considerable challenges for conventional treatment processes, which may consequently lead to reduced overall removal efficiency.

Overall, the results highlight that the concentration of microplastics in the influent plays a key role in determining treatment performance. CWTPs in developed countries, which often benefit from higher-quality raw water sources and the use of advanced treatment technologies, generally achieve greater microplastic removal efficiencies. In contrast, facilities that depend only on conventional treatment processes, especially those receiving heavily contaminated source water, face constraints in effectively removing microplastics. Consequently, enhancing existing systems with additional treatment barriers may be required to improve microplastic removal in river-fed CWTPs such as the one assessed in this study.

Journal of Environment
ISSN 2789-3863 (Online)
Vol. 6, Issue No. 3, pp 65 – 81, 2026
www.carijournals.org

Table 2: Comparison of Microplastic Removal Performance among CWTPs Globally

Country	Raw water Source	Treatment Capacity (m^3/day)	Treatment Stages	Removal (%)	Reference
Indonesia	River	60,000	Pre sedimentation, Coagulation, flocculation, sedimentation, filtration & disinfection	58.9	Hidayat et al. (2025)
USA	Lake	1,514,000	Coagulation, flocculation, sedimentation, ozonation, filtration and disinfection	87-99	Zhang et al. (2020)
Indonesia	River	86,400 & 151,200	Pre sedimentation, Coagulation, flocculation, sedimentation, filtration & disinfection	62 & 66	Radityaningrum et al. (2023)
Jordan	Lake, Wells & Dam	245,000	Coagulation, flocculation, sedimentation, dual media filtration	75	Al-Mashaqbeh et al. (2026)
Jordan	Spring, River & Dam	115,000	RO, UV disinfection	81	Al-Mashaqbeh et al. (2026)
Jordan	Ocean	5300	RO, Chlorination	80	Al-Mashaqbeh et al. (2026)
Czech Republic	River	16000	Coagulation, Sedimentation, filtration, Ozonation	88	Pivokonský et al. (2020)
Switzerland	Lake	120,000	Coagulation, filtration, Ozonation, GAC filtration	95	Negrete Velasco et al. (2022)
Thailand	River	1,600,000	Coagulation, flocculation, sedimentation, filtration and disinfection	75-81	Ta et al. (2025)
China	River	100,000	Coagulation, flocculation, sedimentation, filtration and disinfection	85-90	Shen et al. (n.d.)
Germany	Ground water	194,000	Multiple filtration and aeration steps	99	Mintenig et al. (2019)
France	River	300,000	Pre-ozonation, coagulation, flocculation, settling, sand filtration, GAC, UV	99	Trevisan et al. (n.d.)
Tanzania	River	9,000	Pre sedimentation, Coagulation, flocculation, sedimentation, filtration & disinfection	71-80	This study

Journal of Environment

ISSN 2789-3863 (Online)

Vol. 6, Issue No. 3, pp 65 – 81, 2026

3.2 Microplastic characteristics

3.2.1 Morphology of Microplastics

Two types of microplastics were identified in the samples analysed at the laboratory i.e., Primary and secondary microplastics. Primary microplastics in the samples were pellets which may likely be linked with industrial effluents (Nchimbi et al., 2022). Secondary microplastics were fragments, fibres, films and sheet foam and according to Nchimbi et al. (2022), they may likely have come from breakdown of unmanaged plastics in the environment. Primary microplastics accounted for 19-20% of the total microplastics in all seasons. In contrast, secondary microplastics accounted for about 80% of the total microplastics in both seasons.

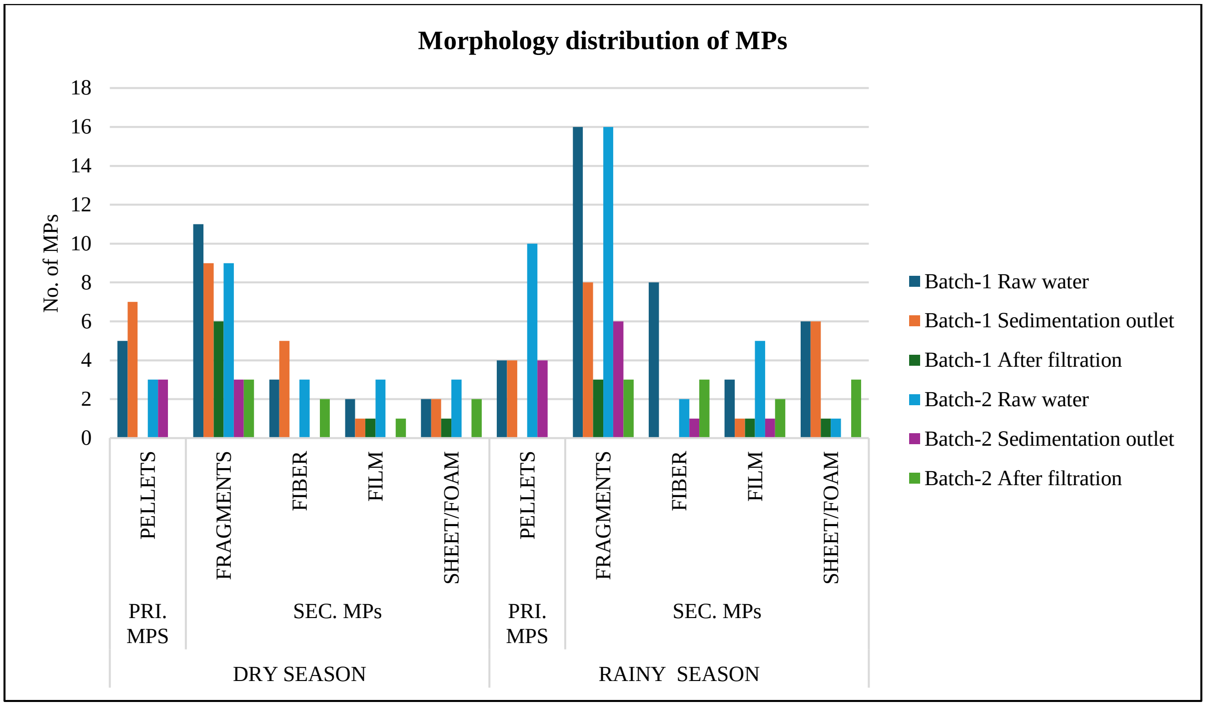

Fig 4: Morphology distribution of MPs in different seasons.

These findings are consistent with a study by (Ta et al, 2025), where secondary microplastics i.e., fragments, fibres and films accounted for more than 60% total MPs in Chao Praya River, Thailand. This finding further indicates that the majority of microplastics (MPs) present in both raw and treated water are derived from the secondary breakdown of larger plastic debris (Primary MPs). In contrast, pellets contributed a comparatively lower fraction, accounting for approximately 20% of the total MPs detected. Their reduction along the treatment train may be attributed to the relatively larger particle size and surface area of pellets, which enhance their removal through clarification and filtration processes. Presence of Secondary microplastics such as sheets, fragments, and films in treated water and various treatment stages suggest less effectiveness of conventional water treatment because of their small size and low density allow them to remain suspended and pass through sedimentation and filtration. Their flexible, thin structures enable them to move with water flow, reducing capture by filter media, while their smooth surfaces limit attachment to flocs during coagulation–flocculation. As a result, they are less likely to settle into sludge and more likely to persist in treated water

A comparison between the MPs morphology identified in this study and those reported from CWTPs in other parts of the world revealed comparable distribution trends. Similar observations have been documented in studies from China, where fragments and fibres were the main shapes in both raw water and treated water (Shen et al, 2021). This observation is further supported by a study from Indonesia, where fragments and fibres accounted for approximately 61–65% of the total microplastics detected, indicating their dominance among the reported morphotypes Radityaningrum et al. (2023). This also aligns with the Thailand study, where fragments and fibres and films accounted for more than 50% of the MPs Ta et al. (2025). These comparisons show that the predominance of secondary MPs i.e., fragments, films, fibres and foams in drinking water systems is strongly influenced by local pollution sources, the type of treatment processes used, and the overall condition of the infrastructure.

3.2.2 Polymer type of microplastics

Four polymer types were identified with spectrum percentage match values above 80%. The polymers were polystyrene (eps), polyethylene (PE), Poly acrylamide and polypropylene. Polypropylene (PP) and polyethylene (PE) were the dominant polymers, accounting for 87–93% of the microplastics identified during both the rainy and dry seasons.

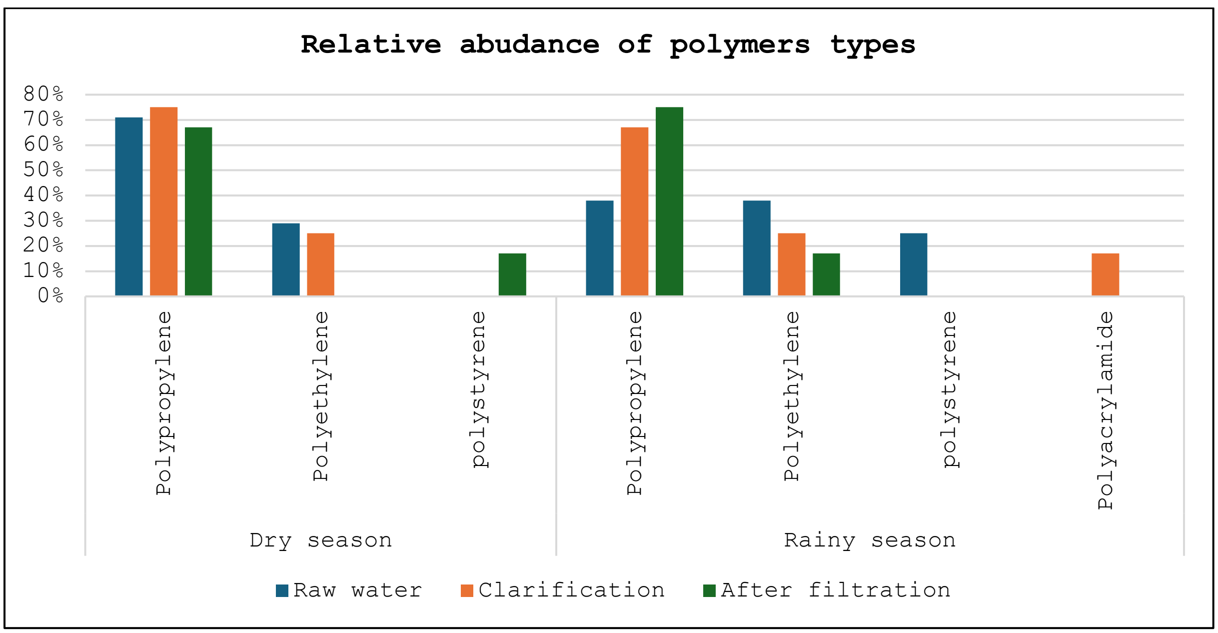

Fig 5: Relative Abundance of polymer types

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PP was more prevalent during the dry season than in the rainy season. During the rainy season, slightly lower concentrations were observed in raw and clarified water, whereas filtered water showed comparatively higher concentrations, possibly due to the release of particles from treatment infrastructure, fragmentation of larger PP particles or the resuspension of solids during treatment processes. Polyethylene dominated in early stages off treatment i.e., raw and clarification stage but gradually reduced across the treatment train. This pattern reflects the strong environmental persistence of these polymers and their widespread use in packaging materials, storage containers, fishing gear, synthetic textiles, industrial products, and other domestic and agricultural plastic applications.

The occurrence of Polystyrene and Polyacrylamide varied between treatment stages and seasons, likely due to differences in their sources and behaviour during water treatment. Polystyrene was detected in filtered water during the dry season and in clarified water during the rainy season. During dry periods, lower water volumes and limited dilution may increase the concentration of smaller PS particles, allowing some to pass through filtration processes. In the rainy season, runoff may transport additional PS materials from urban waste, food packaging, and disposable plastic products into the water source. These particles may then accumulate in the clarification stage before being partially removed during filtration. On the other hand, Polyacrylamide was only identified in clarifier samples during the rainy season. This may be linked to its use as a coagulant or flocculant aid in water treatment. Rainy seasons usually increase turbidity and suspended solids in raw water, which often requires higher chemical dosing to improve settling efficiency. As a result, traces of polyacrylamide may become detectable in the clarifier stage but are later removed in downstream treatment processes.

These findings are consistent with the study by Ta & Babel (2023) on the Chao Phraya River, which also reported Polypropylene and Polyethylene as the dominant polymer types in surface water samples. A similar study by Shen et al. (2021) conducted in Changsha, China reported that Polyethylene and Polypropylene accounted for nearly 50% of the polymers detected in raw water. The remaining fraction consisted of Polyethylene terephthalate, Polystyrene, Polyvinyl chloride, and Polyacrylamide. This distribution highlights the widespread use of these plastics in everyday consumer products such as disposable cups, plastic bags, food packaging, and other common packaging materials.

When comparing polymer types of microplastics reported in different studies globally, a clear and consistent pattern emerges showing the dominance of lightweight, commonly used polymers. This trend aligns well with the findings of my study, where similar polymer types were most frequently detected, reflecting their widespread application and environmental persistence. In China, PE and PP accounted for nearly 50% of the polymers detected in raw water reflecting widespread use of these plastics in everyday consumer products such as disposable cups, plastic bags, food packaging, and other common packaging materials (Shen et al, 2021).

The France study in Paris, similarly, identified PP, PE, and Polyethylene terephthalate were identified as the most commonly occurring polymers accounting for more than 97% of analysed polymers at the water treatment plant inlets and only PP, PE and PS were detected in treated water (Trevisan et al, 2022). In a study from the Czech Republic by Pivokonský et al. (2020), Polypropylene, Polyethylene, and Polyethylene terephthalate were consistently the dominant microplastic types detected in treated drinking water, together accounting for the majority of particles observed. These findings show that low-density plastics, which are widely produced and tend to float easily in water, are found almost everywhere in aquatic environments. Even though different regions have different consumption habits and water treatment systems, these same polymers keep appearing across studies. This consistency highlights how persistent they are in the environment and how difficult they can be for conventional water treatment processes to fully remove.

5.0 Recommendation for Improvement of MP removal.

A practical way forward from this study is to introduce simple, low-cost post-treatment steps after conventional water treatment to further reduce microplastics, especially the low-density polymers that often pass through standard sedimentation and filtration processes. One of the most realistic options is adsorption by activated carbon, in the form of powdered (PAC) or granular (GAC), which is already widely used in drinking water treatment plants. Its main strength lies in its highly porous structure, which allows it to trap very fine particles and adsorb a range of contaminants. While its performance for microplastics depends on how it is applied within the treatment train, it is generally considered a useful polishing step that can improve overall water quality when added after conventional processes(WHO,2019). For example, a study by Ramirez Arenas et al. (2021) GAC was used in treatment processes was analysed for its capacity to adsorb and remove polystyrene (PS) nano plastics which found that removal of nano plastics was dominated by electrostatic attractions between the positively charged PS nano plastics and negatively charged GAC reporting more than 95% removal. Another study by Hazarika et al. (2024) employed the use of rice straws biochar demonstrated removal of Microplastics from water sample by more than 90%.

At the same time, membrane technologies such as ultrafiltration, nanofiltration, and reverse osmosis are known to achieve much higher microplastic removal because they physically block particles based on size. Ultrafiltration alone can remove more than 90% of microplastics, while nanofiltration and reverse osmosis can reach even higher efficiencies, often close to complete removal. However, these systems are expensive to install and operate, require more energy, and are prone to fouling, which makes them less practical for many conventional or resource-limited water treatment plants (Padervand et al, 2020).

Overall, the most realistic approach is a multi-barrier system that combines conventional treatment with simple upgrades rather than relying on one advanced technology. A practical configuration would involve coagulation–flocculation, followed by sedimentation, then sand filtration, and finally a polishing step using activated carbon or even low-cost alternatives like biochar.

6.0 Conclusion

This study provides the first comprehensive assessment of microplastics (MPs) in Dar es Salaam, Tanzania's water supply system, encompassing treatment processes. Results indicated that although the water treatment process achieved a removal efficiency of approximately 71–80%, treated water still contained appreciable residual microplastic particles. Morphologically, fragments were the dominant form across all sampling points, while polypropylene (PP) and polyethylene (PE), were identified as the most prevalent polymer types. Overall, these findings underscore the limitations of conventional treatment systems in fully eliminating microplastics and highlight the vulnerability of urban water distribution networks in rapidly growing cities such as Dar es Salaam. Consequently, improvements in treatment technologies and regular maintenance, and the adoption of post treatment technologies are recommended. These insights contribute to ongoing water quality improvement efforts in Tanzania and offer broader relevance for other urban areas in developing regions facing similar microplastic contamination challenges.

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