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Physicochemical Characterization of Microplastics in Refillable Water Gallon Containers

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Abstract

Microplastic contamination in drinking water has become an emerging environmental health concern, particularly in communities that rely on refillable water gallon containers for household consumption. This study aimed to determine the presence, physical characteristics, and chemical composition of microplastics in drinking water collected from refillable water gallon containers used by selected households in Barangay 641, San Miguel, Manila. A descriptive-quantitative research design was employed. Twenty 250-mL water samples were collected and subjected to vacuum filtration using a 0.45 µm membrane filter. The retained particles were examined through USB digital microscopy and the Hot Needle Test to screen, classify, count, and measure suspected microplastics. Representative particles were further analyzed using Fourier Transform Infrared spectroscopy to identify probable polymer composition. Results showed that 12 out of 20 samples, or 60%, tested positive for microplastics. A total of 32 microplastic particles were detected, with an average of 1.6 particles per 250-mL sample. The particles were classified as fibers and microfibers, each accounting for 50% of the detected particles. Fibers ranged from 1.01 to 3.22 mm, while microfibers ranged from 0.27 to 0.95 mm. FTIR analysis identified the representative particles as probable polyamide based on characteristic absorption peaks. The findings provide baseline evidence of microplastic occurrence in refillable water gallon samples and support the need for improved monitoring, handling practices, and consumer safety assessment in refillable drinking-water systems.

Keywords: *microplastics; refillable water containers; drinking water quality; FTIR spectroscopy; polyamide; environmental health*

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1. Introduction

Plastic pollution has become a significant environmental and public health concern because of the increasing detection of microplastics in aquatic environments, food products, and drinking-water systems. Microplastics are generally defined as plastic particles measuring less than 5 mm and may originate either from the degradation of larger plastic materials or from manufactured plastic particles used in consumer products (National Oceanic and Atmospheric Administration [NOAA], 2024; Wong et al., 2021). Their small size allows them to persist in water systems, pass through certain treatment processes, and become possible contaminants in water intended for human consumption. As plastic waste continues to accumulate in aquatic ecosystems, the risk of human exposure through ingestion has become an important issue in environmental health research.

The global concern over microplastics is linked not only to their environmental persistence but also to their possible biological effects. International reports estimate that large volumes of plastic waste enter water bodies annually, increasing the likelihood that degraded particles will circulate through natural and treated water systems. Prior studies have associated microplastic exposure with possible adverse health outcomes, including oxidative stress, DNA damage, metabolic disruption, and other chronic biological effects, although the long-term consequences of repeated low-level exposure remain incompletely understood (Li et al., 2023). These concerns make drinking-water safety a relevant area for continued laboratory investigation, particularly in communities that depend heavily on plastic-based water storage and distribution systems.

In the Philippines, drinking-water consumption patterns make the issue especially relevant. A substantial proportion of Filipino households rely on commercial water-refilling stations as their primary source of drinking water, while a smaller proportion uses household taps (Catilogo, 2023). This reliance on refillable water systems creates a practical public health concern because water is often stored, transported, and consumed through reusable plastic gallon containers. Although such containers are economical and widely accessible, repeated refilling, washing, handling, heat exposure, and prolonged use may contribute to material degradation and the release of microplastic particles into stored drinking water.

The concern is also regulatory and institutional. Current water-quality monitoring in the Philippines has traditionally emphasized microbiological safety, particularly indicators such as coliform contamination. However, microplastic contamination is not yet routinely incorporated into the monitoring and licensing procedures for water-refilling systems. Under Department of Health Administrative Order No. 2017-0010, no standardized filtration method is specifically established for licensing water-refilling stations in relation to microplastic contamination (Department of Health, 2017). This creates a gap between emerging environmental health concerns and existing water-quality assurance practices.

At the local level, households in Barangay 641, San Miguel, Manila commonly use refillable water gallon containers for daily drinking-water needs. While these containers are generally perceived as safe and practical, limited localized evidence is available regarding whether microplastics are present in water stored in such containers and, if present, what physical and chemical characteristics they exhibit. Most available studies on microplastics in the Philippine context focus on marine environments, sediments, seafood, rivers, and other ecological matrices, while fewer studies directly examine household drinking-water systems and refillable gallon containers.

This study responds to that gap by investigating the presence and characteristics of microplastics in drinking water collected from refillable water gallon containers used by selected households in Barangay 641, San Miguel, Manila. It is aligned with broader concerns under Sustainable Development Goal 3 on good health and well-being, Sustainable Development Goal 6 on clean water and sanitation, and Sustainable Development Goal 12 on responsible consumption and production. By examining microplastic occurrence in a commonly used household drinking-water system, the study contributes baseline evidence that may inform consumer awareness, water-refilling quality assurance, container-use practices, and future environmental health monitoring. This SDG positioning is consistent with Philippine sustainability-education scholarship arguing that SDG integration requires systematic institutional alignment rather than merely declarative reference (Atento, 2025).

This study aimed to assess the presence of microplastics in refillable water gallon containers from selected households in Barangay 641, San Miguel, Manila, and to evaluate their physical and chemical characteristics. Specifically, it sought to: (1) determine the presence and percentage occurrence of microplastics in drinking water collected from refillable water gallon containers; (2) describe the physical characteristics of detected microplastics in terms of classification, size, and quantity using USB digital microscopy and the Hot Needle Test; and (3) identify the chemical composition of detected microplastics using Fourier Transform Infrared spectroscopy.

2. Review of Related Literature

2.1 Microplastic Contamination in Drinking-Water Systems

Microplastic contamination has increasingly been documented in drinking-water systems, including tap water, bottled water, treated water, and water stored in plastic containers. Microplastics are generally understood as plastic particles smaller than 5 mm, and their presence in drinking water raises concerns because they may pass through treatment systems, enter distribution networks, or be introduced through packaging and storage materials (NOAA, 2024; Wong et al., 2021). Menon et al. (2023) noted that microplastics are now frequently reported in potable water systems worldwide, suggesting that drinking water has become a relevant pathway for human exposure. Similarly, Singh et al. (2022) emphasized that microplastics in drinking water represent a public health concern requiring improved monitoring, standardization, and policy attention.

The occurrence of microplastics in treated water further suggests that conventional purification processes may not completely remove very small particles. Adib et al. (2021) identified microplastic fragments in different stages of drinking-water treatment, while Weber et al. (2021) reported synthetic particles in treated drinking-water systems. Cao et al. (2024) also observed that smaller microplastic particles may escape filtration, indicating that treatment systems may reduce but not eliminate microplastic contamination. Comparative studies have also shown that bottled water may contain higher concentrations of microplastics than tap water, partly because plastic packaging and bottle components can contribute particles during manufacturing, capping, transport, and storage (Gambino et al., 2022; Weisser et al., 2021). These findings support the need to examine not only water sources but also post-treatment storage and distribution systems.

2.2 Sources and Pathways of Contamination in Plastic and Refillable Containers

Microplastic contamination may originate from multiple pathways, including environmental pollution, water treatment limitations, plastic packaging, repeated container use, and handling practices. Chandra and Walsh (2024) explained that microplastics may remain in water even after conventional and tertiary treatment because of their small size, buoyancy, and resistance to degradation. Velmurugan et al. (2023) identified surface water as a major pathway through which plastic debris can enter water systems, while Sumam et al. (2025) noted that groundwater and distribution networks may also be affected by contamination from landfills, pipelines, and processing facilities.

Plastic containers themselves may also contribute to contamination. Polychronopoulos and Vlachopoulos (2023) associated microplastic formation in bottled water with abrasion between caps and bottle necks, while Culpepper (2023) reported that repeated twisting of plastic caps may release plastic particles. Studies on food and beverage containers further show that heat exposure, washing, repeated use, and mechanical stress may accelerate plastic degradation and increase microplastic release (Hee et al., 2022; Hu et al., 2022; Kelishadi et al., 2024). In refillable drinking-water systems, Natsir et al. (2025) found that washing frequency may influence microplastic contamination in refilled drinking water. Rosariawari et al. (2021) similarly identified microplastics in refilled drinking water, suggesting that contamination may arise from source water, processing equipment, containers, or repeated handling. These studies are directly relevant to refillable gallon containers because such containers undergo repeated washing, refilling, transport, and consumer reuse.

2.3 Physical and Chemical Characterization of Microplastics

The characterization of microplastics commonly involves the determination of particle number, morphology, size, and polymer composition. Physical classification is important because microplastics may occur as fibers, fragments, films, foams, pellets, or microbeads, with fibers often appearing in environmental and drinking-water samples (Altunışık, 2023; Wong et al., 2021). Fiber-type particles may be associated with synthetic textiles, airborne deposition, handling contamination, packaging wear, or container degradation. O'Brien et al. (2023) emphasized that atmospheric microplastics, particularly synthetic fibers, can settle onto surfaces and enter water or food systems, making contamination control important during sampling and laboratory analysis.

Chemical characterization is necessary because visual or heat-based screening alone cannot definitively identify polymer composition. Fourier Transform Infrared spectroscopy is widely used to identify microplastic polymers by matching absorption peaks with known functional groups and reference spectra (Schymanski et al., 2021; Tirkey & Upadhyay, 2021). In drinking-water and bottled-water studies, commonly identified polymers include polyethylene, polypropylene, polyethylene terephthalate, polystyrene, polyester, and polyamide (Altunışık, 2023; Gambino et al., 2022; Weisser et al., 2021). Polyamide has been reported in drinking-water container studies and is associated with characteristic functional groups such as N-H, C-H, C=O, and C-N absorption peaks. Since different polymers may point to different sources, FTIR analysis provides a useful basis for interpreting possible contamination pathways, although source attribution still requires cautious interpretation.

2.4 Human Health and Public Health Implications

Microplastics in drinking water are a public health concern because ingestion represents one of the possible routes of human exposure. Sun and Wang (2023) identified ingestion, inhalation, and dermal contact as potential exposure pathways, while Li et al. (2023) noted that microplastics may carry chemical additives, adsorbed pollutants, or microorganisms. Blackburn and Green (2021) emphasized that the health effects of microplastics remain incompletely understood, but possible biological responses may include inflammation, oxidative stress, and cellular damage. Kumar et al. (2022) further discussed possible links between microplastic exposure and carcinogenic mechanisms, although such findings should be interpreted cautiously because human exposure levels, particle size, polymer type, and biological dose-response relationships remain under investigation.

Recent studies have also reported microplastics in human biological samples, including blood, feces, saliva, placental tissue, and other tissues, strengthening concerns about chronic exposure (Borenstein, 2024; Plastic Pollution Coalition, 2024; Yang et al., 2025). Zhao et al. (2023) associated common plastic polymers with cytotoxicity, oxidative stress, immune dysfunction, and possible endocrine-related effects. However, the literature also indicates that the precise health risk from drinking-water exposure remains uncertain because toxicity depends on particle size, polymer type, concentration, shape, surface chemistry, additives, and co-contaminants. Thus, microplastic detection in household drinking water does not automatically establish direct disease risk, but it does indicate the need for surveillance, exposure assessment, and preventive public health measures. In parallel Philippine public-health contexts, community evidence indicates that awareness should be paired with enabling supports and practical preventive guidance because knowledge alone may have limited association with actual preventive behavior (Temporada et al., 2025).

2.5 Philippine Context and Drinking-Water Monitoring Gap

In the Philippines, microplastic pollution has been increasingly documented in marine, freshwater, atmospheric, and food-related environments. Studies have identified microplastics in Laguna de Bay, Manila Bay river mouths, Puerto Princesa beach sand, Pasig River sediments, and ambient air in Metro Manila (Arcadio et al., 2022; Osorio et al., 2021; Romarate et al., 2023; Sajorne et al., 2022). Additional local studies have reported microplastics in consumer food products, seafood, and fish, suggesting multiple exposure pathways for Filipino consumers (Espiritu et al., 2024; Ylagan et al., 2026). These findings show that microplastic contamination is not limited to marine ecosystems but may intersect with food safety, water safety, and public health. Recent local work further supports this consumer-exposure framing: Nacino and Basit (2025) documented microplastic occurrence in the widely consumed fish Decapterus macrosoma from Cavite, while Ylagan et al. (2025) demonstrated the value of localized contaminant biomonitoring using edible aquatic vegetation from the Manggahan Floodway.

Despite the growing Philippine literature on microplastics, drinking-water studies remain comparatively limited. Much of the local evidence focuses on aquatic ecosystems, sediments, seafood, and atmospheric contamination rather than household drinking-water systems. This gap is important because many Filipino households rely on commercial water-refilling stations and refillable containers for daily consumption (Catilogo, 2023). Existing Philippine drinking-water standards and monitoring systems emphasize microbiological and chemical safety parameters, but microplastic testing is not yet routinely incorporated into water-refilling station regulation or household-level water quality assessment. This creates a practical gap between emerging contamination concerns and current monitoring practices. The present study responds to this gap by examining microplastics in refillable water gallon containers used by selected households in Manila.

2.6 Synthesis and Literature Gaps

The reviewed literature shows that microplastics are increasingly detected in drinking-water systems and may originate from source water, treatment limitations, packaging materials, distribution systems, repeated container use, atmospheric deposition, and laboratory handling conditions (Adib et al., 2021; Cao et al., 2024; Gambino et al., 2022; Natsir et al., 2025; Weisser et al., 2021). The literature also shows that physical and chemical characterization is necessary because microplastic particles vary in morphology, size, and polymer composition, and these properties influence possible source interpretation and risk assessment (Altunışık, 2023; Schymanski et al., 2021; Tirkey & Upadhyay, 2021). From a public health perspective, microplastic exposure remains a developing field, with evidence suggesting possible biological effects but with continuing uncertainty regarding long-term risks from low-level exposure through drinking water (Blackburn & Green, 2021; Li et al., 2023; Sun & Wang, 2023).

The major gap is contextual and methodological. Philippine microplastic studies have expanded, but household-level drinking-water studies involving refillable gallon containers remain limited. There is also a need for more localized evidence on occurrence, particle morphology, and polymer composition in water consumed through commonly used refillable systems. The present study addresses this gap by providing baseline laboratory evidence on the presence, physical characteristics, and probable polymer composition of microplastics in drinking water collected from refillable water gallon containers in Barangay 641, San Miguel, Manila. These gaps also indicate the value of integrated health-analytics perspectives, in which data integration, analytics capability, and decision quality are treated as mechanisms for translating fragmented monitoring results into usable institutional decisions (Atento et al., 2025).

3. Methodology

3.1 Research Design

The study employed a descriptive-quantitative research design to determine the presence and physicochemical characteristics of microplastics in drinking water stored in refillable water gallon containers. This design was appropriate because the study focused on detecting, counting, classifying, measuring, and chemically characterizing microplastic particles obtained from household water samples rather than testing causal relationships or experimental treatment effects.

3.2 Study Locale and Data Sources

The study was conducted in Barangay 641, San Miguel, Manila. The data sources consisted of drinking-water samples collected from selected households that used refillable water gallon containers. The target area had 91 households, from which 20 water samples were included for laboratory analysis. Each sample represented one household water source and was collected directly from the refillable gallon container used for household consumption.

3.3 Sampling Technique and Sample Size

Purposive sampling was used to select households that met the inclusion criteria. Only households using refillable water gallon containers were included. Boarding houses, rented spaces, and households using water dispensers were excluded to keep the sampling frame focused on the selected household container type.

The sample size was determined using G*Power 3.1.9.7. The original study used an exact proportion test comparing an observed proportion with a constant value of 0.50, with a two-tailed test, moderate effect size of 0.30, significance level of 0.05, and desired statistical power of 80%. Based on this computation, 20 water samples were considered sufficient for the study’s descriptive detection and characterization objectives.

3.4 Sample Collection Procedure

One 250-mL water sample was collected from each selected household using pre-sterilized borosilicate glass bottles. The use of glass containers helped reduce the risk of additional plastic contamination during collection. The researchers used contamination-control procedures such as gloves and masks during collection. After collection, the bottles were sealed, stored in insulated coolers at approximately 4°C, and transported on the same day to the Centro Escolar University laboratory. Upon receipt, each sample was logged using a record sheet that documented the sample code, source location, and collection details for traceability.

3.5 Sample Processing and Instrumentation

The laboratory process involved both physical and chemical analysis. Physical analysis was conducted through vacuum filtration, USB digital microscopy, and the Hot Needle Test. Chemical analysis was performed using Fourier Transform Infrared spectroscopy.

For filtration, each 250-mL water sample was subjected to vacuum filtration using a 0.45 µm membrane filter. The purpose of this procedure was to isolate particles retained on the filter surface. After filtration, the membrane filter was removed using sterile forceps and transferred to a covered sterile glass Petri dish for further examination. The manuscript reports the use of sterilized filtration equipment, sterile glass containers, and personal protective equipment to reduce contamination risk.

The retained particles were examined using a calibrated USB digital microscope, with the manuscript indicating a magnification range of 50x to 1600x. The researchers used hiView software to observe and measure particles and applied a battlement scanning technique to inspect the filter area systematically. Suspected particles were classified by type and size using the study's reference classification table, which included categories such as fibers, microfibers, fragments, films, foams, pellets, and related subtypes.

The Hot Needle Test was used as a preliminary screening method. Particles that melted, curled, deformed, or coiled upon contact with the heated needle were recorded as suspected microplastics and selected for further analysis. This method was used for physical confirmation prior to chemical characterization.

3.6 FTIR Spectroscopy Analysis

Representative particles that tested positive during the physical screening stage were subjected to FTIR spectroscopy to determine probable polymer composition. The study used an Agilent Cary 630 FTIR Spectrometer with Attenuated Total Reflection and a diamond crystal at the CEU-Manila Science Laboratory. The instrument was warmed up, the ATR crystal was cleaned, and a background spectrum was collected before sample analysis. The particles were placed onto the crystal using metal tweezers and pressed to obtain sufficient contact for spectral reading.

The resulting spectra were interpreted by a registered chemist. The analysis focused on absorption peaks, wavenumber values, peak intensity, and peak shape. These spectral characteristics were compared with reference ATR-FTIR spectra to identify the probable functional groups and polymer type of the detected particles. In the manuscript, the representative particles were interpreted as probable polyamide based on characteristic absorption peaks.

3.7 Data Analysis

The study used descriptive statistical analysis. Frequency counts and percentage distributions were used to determine the number and proportion of samples that tested positive or negative for microplastics. To characterize the detected particles, the researchers computed descriptive measures such as mean, standard deviation, range, mode, and percentage distribution. These measures summarized the classification, size, quantity, and chemical composition of the observed microplastic particles. The data were encoded and processed using Google Sheets and organized into tables for analysis and presentation.

3.8 Ethical Considerations

The researchers obtained formal permission from Barangay 641, San Miguel, Manila, before sample collection. Since the study involved water samples rather than biological specimens from human participants, the risk to participants was minimal. The study complied with the Centro Escolar University Institutional Ethics Review Board under control number CEU-IERB_SY25-26_1239_MedTech and was granted a certificate of exemption because it did not involve biological samples. The researchers also committed to honesty, transparency, and objectivity in data collection, analysis, and reporting.

3.9 Methodological Limitation

Although the researchers used practical contamination-control procedures, the study's original scope and limitations note that filtration was not conducted inside a laminar flow hood and that control samples or procedural blanks were not used. This limitation should be acknowledged because microplastic studies are vulnerable to airborne or handling-related contamination. Therefore, the findings should be interpreted as baseline evidence of microplastic occurrence in the analyzed refillable water samples, not as definitive proof of the exact contamination source.

4. Results and Discussion

This section presents the occurrence, physical characteristics, and chemical composition of microplastics detected in drinking water samples collected from refillable water gallon containers used by selected households in Barangay 641, San Miguel, Manila. The results are organized according to the study objectives: detection of microplastics, physical characterization, and FTIR-based polymer identification.

4.1 Occurrence of Microplastics in Refillable Water Gallon Samples

Table 1 presents the occurrence of microplastics in the 20 analyzed water samples. Based on the Hot Needle Test, 12 samples tested positive for microplastics, representing 60% of the total samples. The remaining eight samples, or 40%, tested negative.

Table 1. *Occurrence of Microplastics in Refillable Water Gallon Samples*

Result	Number of Samples	Percentage
Positive for microplastics	12	60%
Negative for microplastics	8	40%
Total	20	100%

Note. n = 20.

The results indicate that more than half of the analyzed refillable water gallon samples contained suspected microplastic particles. This finding suggests that drinking water stored in refillable containers may serve as a possible exposure pathway for microplastics. The result is consistent with previous findings that microplastics may be detected in treated and potable water systems (Adib et al., 2021; Menon et al., 2023; Weber et al., 2021). However, the finding should be interpreted cautiously because the study identifies occurrence in the analyzed water samples but does not conclusively establish whether the contamination originated from the water source, refilling process, container material, handling practices, or environmental exposure.

4.2 Physical Characteristics of Detected Microplastics

Table 2 presents the physical characteristics of the detected microplastics. A total of 32 particles were identified across the positive samples. The particles were classified into two categories: fibers and microfibers. Each category accounted for 16 particles, or 50% of the detected microplastics.

Table 2. *Physical Characteristics of Detected Microplastics*

Classification	Size Range (mm)	Average Size (mm)	SD	Quantity	Percentage
Fiber	1.01–3.22	1.47	0.57	16	50%
Microfiber	0.27–0.95	0.61	0.22	16	50%

Classification	Size Range (mm)	Average Size (mm)	SD	Quantity	Percentage
Total	—	—	—	32	100%

The detected microplastics were entirely fibrous in morphology, appearing either as fibers or microfibers. Fibers ranged from 1.01 to 3.22 mm, with an average size of 1.47 mm. Microfibers ranged from 0.27 to 0.95 mm, with an average size of 0.61 mm. These measurements fall within the accepted microplastic size range of less than 5 mm. The total count of 32 particles corresponds to an average of 1.6 particles per 250-mL sample, based on the 20 samples analyzed.

The dominance of fibers and microfibers is consistent with studies reporting fibers as common microplastic forms in drinking-water and environmental samples (Altunışık, 2023; O'Brien et al., 2023; Wong et al., 2021). Fibrous particles may arise from synthetic textiles, airborne deposition, container abrasion, repeated washing, handling, or water-processing systems. In the present study, the absence of procedural blanks or laminar-flow-controlled filtration prevents definitive source attribution. Thus, the finding should be framed as evidence of microplastic occurrence and morphology in the collected samples, not as conclusive proof that the refillable containers alone produced the particles.

4.3 FTIR Characterization and Probable Polymer Composition

FTIR spectroscopy was used to analyze representative black fiber particles that tested positive during physical screening. The spectra of Black Fiber 1 and Black Fiber 2 showed similar absorption patterns, particularly at peaks associated with N-H, C-H, C=O, and C-N functional groups. These spectral features supported the probable identification of the particles as polyamide.

Table 3. *FTIR Absorption Peaks and Probable Functional Group Assignments of Representative Black Fibers*

Absorption Peak (cm^{-1})	Black Fiber 1	Black Fiber 2	Assignment
3295–3296	Medium	Medium	N-H stretch
2935	Weak	Weak	C-H stretch
2866	Weak	Weak	C-H stretch
1636	Strong	Strong	C=O stretch
1541	Strong	Strong	N-H stretch, C-H stretch
1476	Weak	Weak	C-H bend
1416	Weak	Weak	C-H bend
1373	Weak	Weak	C-H bend
1291	Not reported	Weak	C-N stretch
1263	Weak	Weak	C-N stretch

The FTIR results showed that both representative fibers had highly similar spectra. Medium absorption peaks were observed at approximately 3295–3296 cm^{-1}, while strong peaks appeared at 1636 cm^{-1} and 1541 cm^{-1}. These were interpreted as corresponding to N-H and C=O functional groups, with additional C-H and C-N-related peaks. The original analysis indicates that the spectra were evaluated by a registered chemist and compared with reference ATR-FTIR spectra, leading to the probable identification of the particles as polyamide.

The identification of polyamide is relevant because polyamide has also been reported in studies of plastic water containers and bottled water (Altunışık, 2023; Gambino et al., 2022). However, the result should be stated as probable polymer identification of representative particles, not as a definitive characterization of all 32 detected particles. Only selected black fibers underwent FTIR analysis. Therefore, while the FTIR findings strengthen the evidence that at least some detected particles were synthetic polymeric material, they do not establish that all particles had the same polymer composition.

4.4 Discussion

The results provide baseline evidence that microplastics were present in a substantial proportion of the analyzed refillable water gallon samples. The 60% occurrence rate indicates that microplastic contamination may be a relevant drinking-water safety concern among households using refillable containers. This aligns with broader literature showing that microplastics can occur in potable water systems and may persist even after treatment processes (Adib et al., 2021; Menon et al., 2023; Weber et al., 2021). The finding is also consistent with studies suggesting that treated drinking water may still contain synthetic particles because very small particles can evade conventional filtration or enter water after treatment through packaging, storage, handling, or distribution systems (Cao et al., 2024; Gambino et al., 2022; Weisser et al., 2021).

The predominance of fibers and microfibers is an important finding because it narrows the likely morphology of contamination in the analyzed samples. Fibers are commonly documented in water and environmental microplastic studies, and their occurrence may be linked to several possible sources, including airborne deposition, synthetic textiles, repeated container handling, washing, or environmental contamination (Altunışık, 2023; O'Brien et al., 2023). In refillable water systems, repeated use, washing, transport, and consumer handling may increase opportunities for particle introduction or release (Hee et al., 2022; Natsir et al., 2025; Rosariawari et al., 2021). Nonetheless, the present findings cannot isolate a single source. The detected particles may have entered the water before refilling, during refilling, from container surfaces or caps, during household storage, or during sample handling.

The FTIR findings strengthen the analytical value of the study because visual microscopy and the Hot Needle Test alone are not sufficient for chemical confirmation. The representative black fibers showed spectral features consistent with polyamide, including N-H, C=O, C-H, and C-N-related peaks. This supports the interpretation that at least some of the detected particles were polymeric. Polyamide identification is consistent with previous reports of polyamide in bottled or container-associated drinking water (Altunışık, 2023; Gambino et al., 2022). From an environmental health perspective, this finding is significant because polymer composition helps clarify the nature of contamination and may guide future investigation into possible sources.

At the same time, the study must avoid overclaiming. The results demonstrate the presence of microplastics in sampled water from refillable gallon containers, but they do not prove that the container itself was the only or primary source. The absence of procedural blanks, field blanks, or filtration under a laminar flow hood limits the capacity to rule out airborne or laboratory-introduced particles. This is a critical methodological qualification because microplastic research is highly sensitive to contamination during sampling, filtration, microscopy, and storage. Therefore, the study is best framed as a localized baseline assessment rather than a definitive source-apportionment study.

The findings have practical implications for household drinking-water safety, water-refilling quality assurance, and environmental health monitoring. For consumers, the results suggest the need for careful handling, regular inspection of refillable containers, and avoidance of visibly degraded containers. For water-refilling stations and regulators, the findings support the value of exploring microplastic monitoring as a future extension of drinking-water quality assessment. For researchers, the study points to the need for larger samples, procedural blanks, controlled laboratory environments, polymer confirmation of more particles, and comparative analysis across water sources, container ages, reuse cycles, and storage conditions.

5. Conclusions, Recommendations, and Implications

5.1 Conclusions

The study confirmed the occurrence of microplastics in drinking water collected from refillable water gallon containers used by selected households in Barangay 641, San Miguel, Manila. Based on the analysis of 20 water samples, 12 samples, or 60%, tested positive for microplastics. This finding indicates that microplastic contamination was present in more than half of the analyzed household water samples, making refillable drinking-water systems a relevant concern for localized environmental health monitoring.

The detected microplastics were physically characterized as fibers and microfibers. Both types accounted for equal proportions of the detected particles, with fibers representing 50% and microfibers representing the remaining 50%. The fiber sizes ranged from 1.01 to 3.22 mm, while microfibers ranged from 0.27 to 0.95 mm. These measurements fall within the accepted microplastic size range and indicate that fibrous particles were the dominant form of contamination in the samples.

The FTIR analysis of representative black fiber particles indicated probable polyamide composition based on absorption peaks associated with N-H, C-H, C=O, and C-N functional groups. However, the conclusion should be stated carefully: the study chemically characterized representative particles rather than all detected particles. Thus, the results support the presence of probable polyamide microplastics in selected samples, but they do not establish that all particles had the same polymer composition.

Overall, the study provides baseline evidence that drinking water stored in refillable water gallon containers may contain microplastic particles. However, the results do not conclusively identify the exact source of contamination. The microplastics may have originated from the water source, refilling process, repeated container use, container degradation, environmental deposition, handling practices, or laboratory-stage contamination. Therefore, the study should be interpreted as an occurrence and characterization study, not as a definitive source-attribution study.

5.2 Recommendations

Consumers who rely on refillable water gallon containers should observe proper handling, storage, and container-maintenance practices. Containers should be inspected regularly for scratches, discoloration, cracks, brittleness, surface wear, or other signs of degradation. Old or visibly damaged containers should not be used for prolonged drinking-water storage. Consumers should also avoid exposing containers to direct sunlight or excessive heat, as such conditions may contribute to plastic deterioration.

Water-refilling stations should strengthen quality assurance practices by reviewing filtration systems, container-cleaning procedures, and storage protocols. Since the detected particles were fibers and microfibers, refilling stations may consider technologies and procedures that improve removal of fine particulate matter. Routine inspection of refillable containers before refilling may also help reduce the risk of continued use of degraded containers.

Regulatory agencies, particularly the Department of Health and local government units, may consider exploratory guidelines for microplastic monitoring in drinking-water systems. Current monitoring practices remain more focused on microbiological safety, particularly coliform testing, while microplastic contamination is not yet routinely included in water-refilling station quality assessment.

Container manufacturers should improve product durability and provide clearer consumer guidance on recommended container lifespan, storage conditions, and maximum reuse cycles. Since representative particles were identified as probable polyamide, manufacturers may also examine whether container materials, accessories, handling components, caps, or related contact surfaces contribute to microplastic release. Product labeling and reuse guidance may help consumers and refilling stations prevent excessive reliance on degraded containers.

Future researchers should conduct larger, multi-site studies across different barangays, municipalities, and types of water-refilling systems. Future studies should also incorporate field blanks, procedural blanks, laboratory blanks, laminar-flow-controlled filtration, and stricter contamination-control protocols. These controls are necessary because microplastic analysis is highly sensitive to airborne fibers and handling-related contamination.

Future investigations should also examine container age, number of reuse cycles, storage duration, exposure to heat and sunlight, type of water-refilling station, filtration technology, and cap or seal condition. FTIR or Raman spectroscopy should be applied to a larger proportion of detected particles, not only representative particles, to strengthen polymer identification. Comparative studies involving tap water, bottled water, refillable gallon water, and household-stored water would also clarify whether contamination differs across water sources and storage systems.

5.3 Implications of the Study

The study has practical implications for household drinking-water safety. The finding that 60% of analyzed samples contained microplastics suggests that consumers should treat refillable water gallon containers not only as reusable storage vessels but also as possible points of contamination. This does not mean that refillable systems should be rejected outright. Rather, it indicates the need for better inspection, storage, sanitation, and container-replacement practices.

The study also has public health and regulatory implications. If microplastics are present in household drinking-water samples, drinking-water quality assessment may need to expand beyond conventional microbiological and chemical parameters. The findings support the value of developing preliminary monitoring protocols, especially for communities with heavy dependence on commercial water-refilling stations. In related regulated consumer-health systems, strategic analysis has similarly emphasized that regulatory compliance and consumer trust function as safeguards of service legitimacy and public confidence (Atento & Atento, 2025).

Methodologically, the study contributes a small but useful baseline for local microplastic research. It demonstrates the feasibility of combining vacuum filtration, USB digital microscopy, Hot Needle Test, and FTIR spectroscopy in an undergraduate laboratory setting. At the same time, it highlights the need for more rigorous contamination-control procedures in future studies.

Finally, the study has environmental and policy implications. It reinforces the importance of responsible plastic use, container-life-cycle management, and improved standards for reusable plastic containers. In contexts where refillable water systems are widely used, microplastic monitoring may become part of broader conversations on consumer safety, sustainable packaging, public health surveillance, and responsible production and consumption.

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