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Original Article

Household Water Handling and Secondary Microbial Contamination in High-Density Urban Communities of the Philippines

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Abstract. Access to safe and stable water sources is a key indicator of Sustainable Development Goal (SDG) 6. However, in the Philippines, water scarcity and water quality deterioration remain serious challenges. Using a cross-sectional field assessment, this study investigated domestic water quality and microbial contamination of household utensils in barangays within the densely populated Sampaloc District of Manila. A total of 28 households were surveyed, and tap water and drinking water samples were collected. Physicochemical parameters (water temperature, pH, electrical conductivity, and total dissolved solids) and biological indicators (Escherichia coli and total coliforms) were measured. In addition, *E. coli* and total coliform contamination on household utensil surfaces was assessed using swab tests. The results showed that tap and drinking water generally maintained acceptable water quality prior to use, whereas high levels of microbial contamination were detected on utensils during water handling. Furthermore, frequent water-supply interruptions were reported in some households, raising concerns about the reliability of the water supply. These findings suggest that, in addition to improving water supply infrastructure, enhancing community awareness and education on water, sanitation, and hygiene (WASH) is essential to ensuring safe water use at the household level.

Keywords: *Domestic water use; Microbial contamination; SDG 6; Urban Philippines; Water, Sanitation and Hygiene (WASH).*

Access to safe and stable water sources is a key indicator of Sustainable Development Goal (SDG) 6 and a global challenge. Although efforts to achieve the SDGs are underway in the Philippines, progress on water-related indicators remains insufficient, with significant disparities in water access, particularly in peri-urban areas (Alfonso et al., 2022). While these areas should have access to safe water given their income levels, living standards, and piped network availability, water resource issues such as the water crisis have occurred, and water shortages and water pollution remain serious challenges (Lee et al., 2020). Furthermore, in the densely populated areas targeted in this study, the effects of water pollution are likely to spread rapidly and widely due to poor sanitation and high population density. Therefore, understanding the actual state of the water environment in these areas is important from a public health perspective (Lasco & Hardon, 2024; Cortez & Siringan, 2025).

In recent years, it has been increasingly recognized that access to improved or piped water sources does not necessarily ensure microbiological safety at the point of consumption (Rosa & Clasen, 2010; Yazawa et al., 2025). Water quality can deteriorate substantially between the point of collection and the point of use due to household factors, including storage conditions, handling practices, and contact with contaminated utensils. Even when drinking water meets safety standards at the source, improper storage, repeated refilling, shared containers, and inadequate utensil hygiene can introduce or amplify microbial contamination (Wright et al., 2004; Santos et al., 2023). Such household-level contamination pathways have been identified as critical yet often overlooked determinants of actual exposure risk, highlighting the need to assess water safety beyond infrastructure-based access indicators.

However, water quality monitoring systems in the Philippines are underdeveloped due to cost constraints and a lack of specialized laboratory equipment (Yazawa et al., 2024a; 2024b; Yazawa et al., 2025). As a result, regional-level water quality data are not being accumulated, even in urban areas, and it has been pointed out that understanding the current situation is lagging behind (Ulep et al., 2024). Although there has been an increase in research addressing the inadequacies of water quality monitoring systems and regional disparities in recent years, most of these studies are limited to secondary data sources, and there remains a large gap between the goal of "access to safe and stable water" set forth in SDG 6 and actual observation data (Chouler & Di Lorenzo, 2015; Pfadenhauer & Rehfuess, 2015).

This study aims to conduct water-quality monitoring at the barangay level and to collect bottom-up data from the community. Specifically, this study addresses the following research questions: (1) How do physicochemical and microbiological water quality characteristics differ between tap water and drinking water in high-density urban households? (2) To what extent does secondary microbial contamination occur at the household level, particularly through water handling practices and utensil use? By accumulating evidence from high-density urban communities in the Philippines, this study seeks to contribute to improved understanding of household-level water safety and to support progress toward achieving SDG 6.

Methodology

Study Site and Survey

This study was conducted in Barangays 550 and 551 in the Sampaloc District, a densely populated area of Manila (Figure 1). Sampaloc is located in the 4th congressional district of Manila and comprises 241 barangays, numbered from 395 to 636. This area, known as the University Belt, contributes to its high population density and mixed residential–commercial landscape (Elardo, 2025). A total of 28 households were visited for the survey, and tap and drinking water samples were collected. Households were eligible for inclusion if they were permanently occupied, used tap water for daily domestic purposes, and consented to participate in both water sampling and interviews. Households that were vacant at the time of the survey or that declined to participate were excluded. Physicochemical [water temperature, pH, electrical conductivity (EC), and total dissolved solids (TDS)] and biological (*E. coli* and total coliforms) indicators were measured for the collected samples. Additionally, *E. coli* and total coliforms on the surfaces of utensils in each household were measured using a swab test.

Supplementary household interviews were conducted during the visits to obtain contextual information on domestic water sources, drinking-water handling, experiences with water outages, and coping strategies (e.g., filter use). The sample size was determined by feasibility and access constraints in the densely populated study area and is consistent with exploratory, community-level water quality assessments. All surveys were conducted with permission from the barangay chief and in collaboration with local community members. Informed consent was obtained verbally from all participating households prior to data collection.

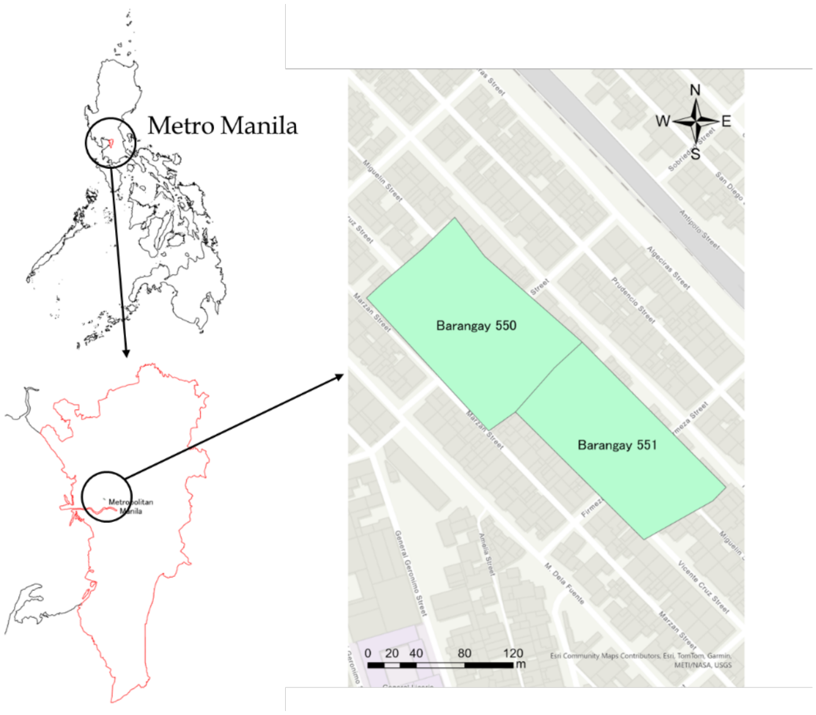

Figure 1. *Barangays 550 and 551 in the Sampaloc District, Metro Manila, Philippines*

Water Quality Assessment Based on National Water Quality Guidelines

The water quality parameters analyzed in this study, along with their corresponding reference standards, are summarized in Table 1. Water quality was evaluated in accordance with the Philippine National Standards for Drinking Water (PNSDW, 2017), which provides nationally defined criteria for assessing drinking water safety. The PNSDW was adopted as the primary benchmark in this study because it specifies relatively stringent thresholds compared with other available guidelines. The PNSDW does not define guideline values for water temperature and EC. Therefore, water temperature was evaluated by comparing sample types, and TDS was used as a surrogate for EC, given their well-established correlation. In accordance with the PNSDW, threshold values for pH and TDS were applied separately for drinking water and for water intended for non-potable domestic use.

Physicochemical parameters, including water temperature, pH, EC, and TDS, were measured directly on site prior to sample collection using a portable water quality meter (EA776AE-3A, Hanna Instruments, USA). The instrument was calibrated in the laboratory before field deployment using certified standard solutions (pH 4.01 and 7.01; EC 1413 µS/cm; TDS 1382 ppm). Following in situ measurements, approximately 20 mL of tap or drinking water was collected from each household into sterilized polyethylene bottles for microbiological analysis. To assess household-level microbial contamination, drinking utensils used in each household were also examined. Approximately 100 cm^2 of each utensil surface was sampled using a sterile swab (Promedia Swab Test kit, ST-25PBS, ELMEX, Japan). All water and swab samples were processed within one hour of collection to minimize changes in microbial abundance.

Microbiological water quality was evaluated using *E. coli* and total coliforms as indicator organisms of fecal and general microbial contamination. Analyses were conducted using 3M™ Petrifilm™ Rapid *E. coli*/Coliform Count Plates (REC plates; 3M Japan Co., Ltd., Japan), which contain violet red bile agar. For each water sample, 1 mL was aseptically pipetted onto a REC plate. Plates were incubated at 37°C for 24 hours in a temperature-controlled incubator (CALBOX, model CB-101), after which colonies were counted manually. Colony counts up to 200 CFU per plate were recorded, while samples exceeding this number were classified as too numerous to count (TNTC).

Statistical Evaluation

All statistical analyses were performed to evaluate differences in physicochemical and microbiological parameters among water sample types. Non-parametric tests were applied throughout the analysis. For physicochemical indicators (pH, water temperature, EC, and TDS), comparisons between tap and drinking water samples were conducted using the Mann–Whitney U test. For microbiological indicators (*E. coli* and total coliforms), TNTC results were assigned an upper bound of 200 CFU/mL and were included in the analyses. Subsequently, concentration values were transformed using log10(x + 1) to stabilize variance and account for the highly skewed distribution typical of microbial count data. Differences among the three sample categories (drinking, tap, and utensils) were assessed using the Kruskal–Wallis test. When the Kruskal–Wallis test indicated significant differences, pairwise comparisons were performed using Mann–Whitney U tests. For visualization, violin plots were generated to illustrate the distributional characteristics of each parameter across sample types. Statistical significance was determined at $p < 0.05$.

Table 1. *Water Quality Standards Referred to in this Study (Department of Health, 2017)*

Parameter	Water Quality Standard/Maximum Allowable Level	Source
Temperature (°C)	Unavailable	Philippine National Standards for Drinking Water of 2017
pH for Drinking Water	5.0–7.0	
pH for Other Water	6.5–8.5	
EC (µS/cm)	Unavailable	
TDS for Drinking Water	<10 mg/L	
TDS	600 mg/L	
E. coli	<1 colony/100 mL	
Coliform	<1 colony/100 mL	

Results and Discussion

Water Quality Assessment

Figure 2 presents the measurement results for physicochemical parameters of tap and drinking water. The median pH of tap water was approximately 7.5, and all samples were within the acceptable range specified by the PNSDW. In contrast, the median pH of drinking water was higher, at approximately 7.8, and many samples exceeded the standard value. With respect to water temperature, most tap water samples exhibited relatively stable values between 25 and 30 °C. In contrast, drinking water samples showed a wider distribution, with many samples exhibiting lower temperatures, reflecting differences in household storage conditions, including refrigeration.

Because the PNSDW does not specify environmental standards for EC, TDS was used as an alternative indicator for evaluation. TDS values, calculated as approximately half of EC using a portable meter, were higher in tap water than in drinking water; however, all tap water samples were below the standard limit of 600 mg/L. In contrast, although drinking water is required to have a TDS below 10 mg/L, many samples exceeded this threshold, with a median TDS of approximately 40 mg/L. Statistical comparisons between tap and drinking water revealed significant differences across all physicochemical parameters examined. The Mann–Whitney U tests indicated significant differences in pH, water temperature, EC, and TDS between the two water types ($p < 0.05$ for all parameters). These results confirm that tap and drinking water exhibited distinct physicochemical characteristics.

Figure 3 presents the results of biological parameter measurements for drinking water, tap water, and utensil surfaces. *E. coli* was not detected in drinking water samples, whereas total coliforms were detected in some cases. Both *E. coli* and total coliforms were detected in multiple tap water samples. Furthermore, higher concentrations of both microbial indicators were observed on utensil surfaces compared with tap and drinking water, indicating the highest levels of microbial contamination among the three sample types. Pairwise statistical comparisons were conducted among drinking water, tap water, and utensil samples using the Mann–Whitney U test on log-transformed data [log10(x + 1)], with TNTC values treated as 200 CFU/mL. For *E. coli*, no statistically significant differences were detected among any of the sample pairs (Drinking vs. Tap: $p = 0.236$; Drinking vs. Utensil: $p = 0.065$; Tap vs. Utensil: $p = 0.301$).

In contrast, total coliform concentrations differed significantly among sample types. Significant differences were observed between drinking and tap water ($p < 0.05$), between drinking water and utensil samples ($p < 0.01$), and between tap water and utensil samples ($p < 0.01$). Among the three sample types, utensil samples consistently exhibited the highest total coliform concentrations. In summary, while *E. coli* concentrations did not differ significantly among sample types; total coliform levels were significantly higher in utensil samples than in both tap and drinking water, indicating pronounced secondary contamination at the household level.

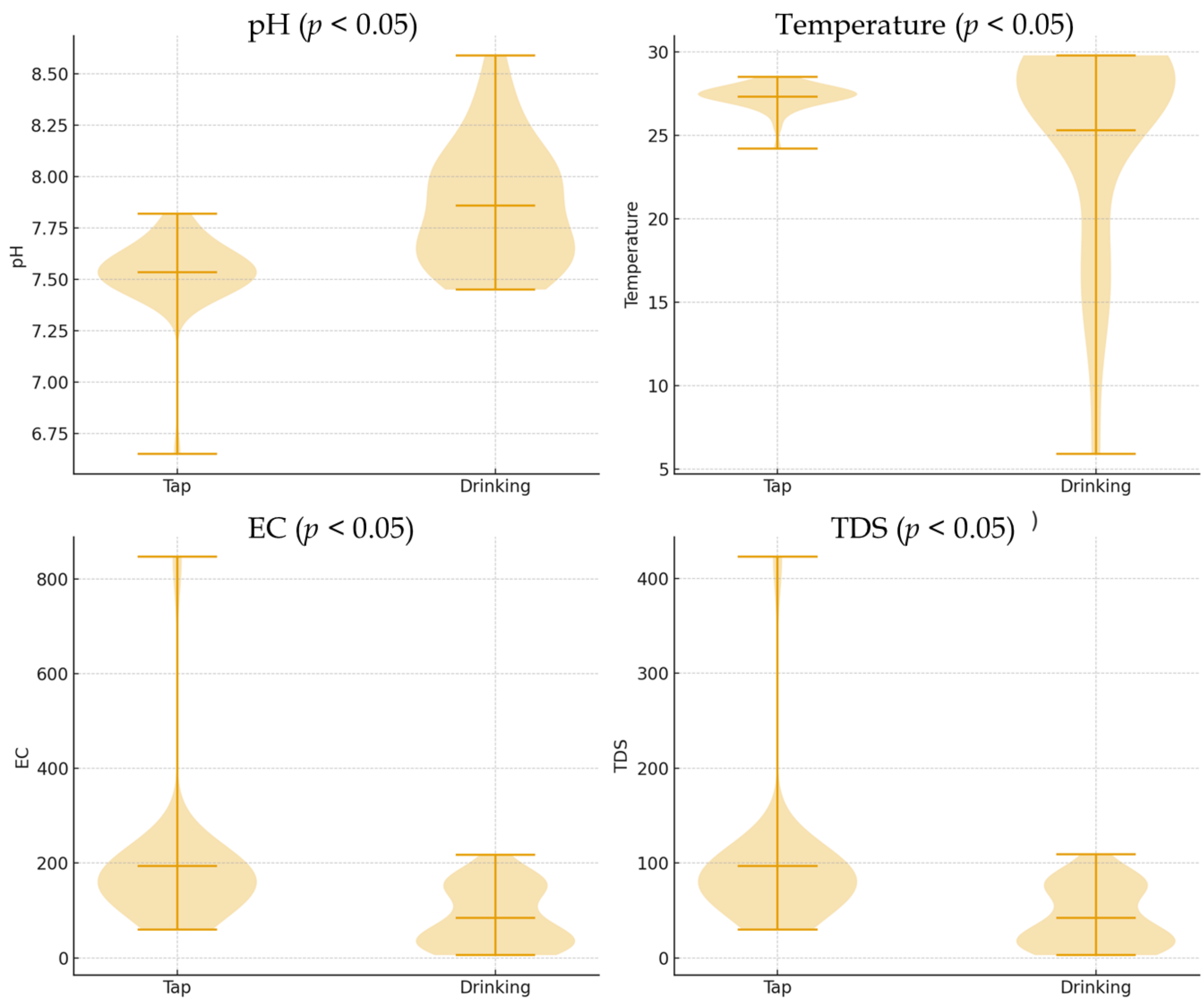

Figure 2. *Distribution of Physicochemical Parameters (pH, Water Temperature, EC, and TDS) for Tap and Drinking Water Samples (Whiskers Represent the Full Data Range)*

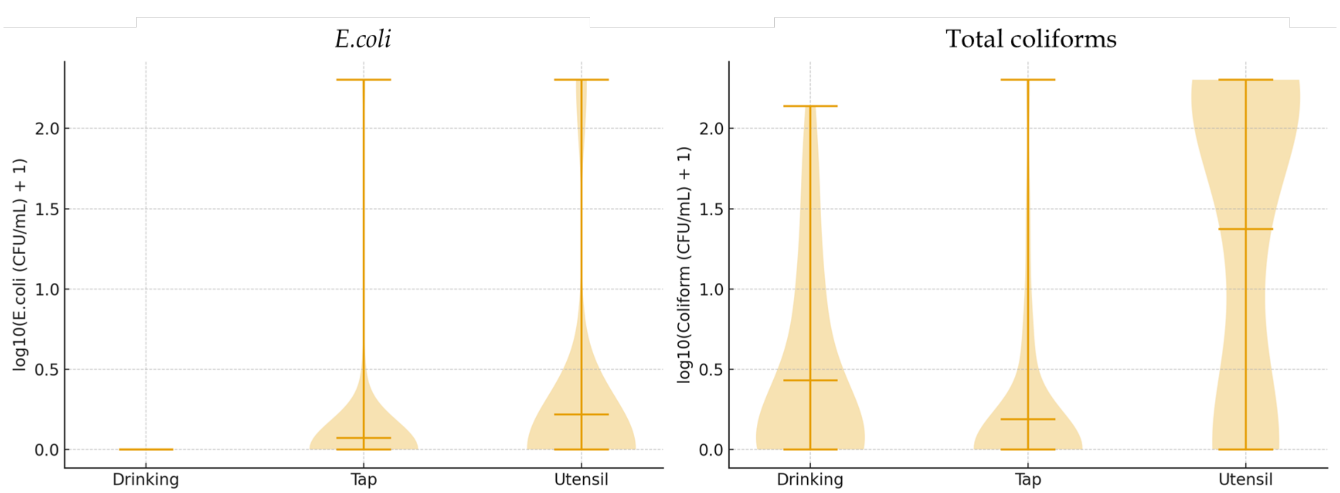

Figure 3. *Distribution of Microbiological Parameters (E. coli and Total Coliforms) in Drinking Water, Tap Water, and on Utensil Surfaces (Values are shown on a Log-Transformed Scale [log10(x + 1)], with TNTC Values Treated as 200 CFU/mL)*

Secondary Contamination Linked to Household Water Use Practices

In this study, statistically significant differences in physicochemical parameters were observed between tap and drinking water, particularly in pH, temperature, EC, and TDS. These differences indicate that drinking water exhibits distinct chemical characteristics compared with tap water, which cannot be explained solely by differences in water sources. The relatively high pH and TDS values observed in many drinking water samples suggest that household-level factors, such as storage containers, storage duration, and cooling practices, play an important role in shaping water quality after supply. The wide variation in water temperature among households further supports the notion that household water management practices substantially influence physicochemical water quality.

With respect to biological parameters, *E. coli* was not detected in drinking water samples, whereas total coliforms were detected in some cases. This finding suggests that drinking water that is microbiologically safe at the point of supply may become contaminated during household handling and storage. Interview data support this interpretation, as several households reported practices such as refilling containers with drinking water, sharing cups, and storing water without lids, all of which may increase the risk of microbial contamination. Similar deterioration of water quality between the point of collection and the point of use has been widely reported in low- and middle-income countries, where household storage and handling practices contribute to microbial contamination of drinking water (Wright et al., 2004).

In contrast, both *E. coli* and total coliforms were detected in tap water, indicating the presence of microbial risks in the water used for domestic purposes. Moreover, microbial concentrations on utensil surfaces were higher than those observed in both tap and drinking water. Previous studies have shown that household behaviors, including the use of shared drinking vessels and uncovered storage containers, significantly increase the risk of secondary microbial contamination (Trevett et al., 2005; Brick et al., 2004). Statistical analyses (the Kruskal–Wallis test followed by multiple comparisons) in this study confirmed that utensil samples exhibited significantly higher contamination levels than the other sample types. These results strongly suggest that secondary contamination is occurring within households, likely through daily water use and cleaning practices.

The elevated microbial contamination observed on utensils may be attributed to a combination of behavioral and environmental factors, including washing utensils with microbiologically contaminated tap water, insufficient drying, the use of cloths for multiple purposes, and suboptimal hygienic conditions in storage environments. Interview responses further revealed that many households rely on water stored in buckets during water outages, which may promote microbial growth and exacerbate secondary contamination risks.

These findings indicate that household water-use practices and utensil handling play a critical role in amplifying the risk of microbial contamination. Utensils and kitchen surfaces have been identified as important but often overlooked pathways for microbial transmission, particularly in settings with intermittent water supply and limited sanitation infrastructure (Evans & Redmond, 2019; Afonso et al., 2025). Access to safe drinking water alone does not necessarily ensure microbiological safety at the point of consumption. Instead, interventions grounded in water, sanitation, and hygiene (WASH) principles, particularly those addressing household behaviors and utensil hygiene, are essential to reducing secondary contamination risks. Even when purchased drinking water is perceived as clean, its safety may be compromised by storage conditions, handling practices, and the quality of utensils used.

Limitations and Future Research Directions

This study has several limitations. First, the sample size was limited to 28 households in two barangays within Sampaloc. Given the restricted spatial coverage, caution is required when generalizing the findings to the entire Sampaloc District or to other densely populated urban areas in the Philippines. Future research should aim to increase sample size and temporal continuity. To achieve this, establishing community-implementable monitoring systems through the transfer of sampling and analytical techniques and the adoption of citizen science approaches will be important.

Second, while this study identified evidence of secondary contamination on household utensils, the extent to which such contamination translates into actual health risks remains insufficiently quantified. Future studies should incorporate more detailed exposure and microbial risk assessments to evaluate potential health impacts better and generate evidence to inform risk communication strategies. Finally, broader dissemination of monitoring results beyond participating households to the wider community is essential. Sharing locally generated data and fostering community engagement may support the development of resident-led WASH practices and contribute to more sustainable progress toward achieving SDG 6.

Conclusion

This study investigated household-level water quality and secondary microbial contamination in densely populated barangays of the Sampaloc District, Manila, using combined physicochemical and biological indicators, along with household interviews. The results demonstrate that significant water quality risks persist at the household level even in urban and peri-urban settings where access to improved water sources is expected. Physicochemical analyses revealed statistically significant differences between tap and drinking water, particularly in pH, temperature, EC, and TDS. These differences indicate that drinking water quality is influenced not only by the source of supply but also by household-level storage and handling practices. Variability in water temperature and elevated TDS in drinking water suggest that post-supply management plays a vital role in shaping water quality. Microbiological analyses further highlighted the importance of household practices. While *E. coli* was not detected in drinking water samples, total coliforms were present in some cases, indicating potential contamination during storage and handling.

In contrast, both *E. coli* and total coliforms were detected in tap water, and the highest microbial contamination levels were observed on household utensil surfaces. Statistical comparisons confirmed that utensil contamination was significantly greater than that of both tap and drinking water, providing strong evidence of secondary contamination occurring within households. Interview findings supported these quantitative results, revealing common practices such as refilling drinking water, using shared cups, storing uncovered water, and relying on stored water during supply interruptions. Together, these behaviors form pathways through which microbiological risks can be amplified, even when drinking water is perceived as safe at the point of purchase.

Overall, this study demonstrates that access to safe drinking water alone does not guarantee microbiological safety at the point of consumption. Household water use practices and utensil hygiene play a critical role in determining actual exposure risks. From a policy and community perspective, these findings highlight the need for (1) the incorporation of household-level hygiene education and utensil management into existing WASH programs, and (2) the promotion of simple, low-cost interventions, such as covered storage, dedicated drinking utensils, and safe drying practices, at the community level. By providing barangay-level, bottom-up monitoring data in a high-density urban setting, this study contributes empirical evidence to bridge the gap between SDG 6 targets and on-the-ground realities.

Future research should focus on (1) expanding sample size and temporal coverage to capture seasonal and interannual variability, (2) integrating quantitative microbial risk assessment to evaluate health implications better, and (3) assessing the effectiveness of targeted household-level WASH interventions in reducing secondary contamination. Expanding community-based monitoring and integrating household practices into water safety strategies will be essential for achieving sustainable and equitable access to safe water in rapidly urbanizing contexts such as Metro Manila.

Contribution of Authors

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Conflict of Interests

The authors declare that they have no conflict of interest.

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