JEE Journal of Ecological Engineering

Journal of Ecological Engineering, 2025, 26(12), 221–228
https://doi.org/10.12911/22998993/208486
ISSN 2299–8993, License CC-BY 4.0

Received: 2025.07.18
Accepted: 2025.09.01
Published: 2025.10.01

Microplastic contamination in refilled drinking water: The impact of gallon washing frequency

Muh. Fajaruddin Natsir[1*], Amaludin[1], Basir Rasyid[1], Andi Arsunan Arsin[2]

[1] Department of Environmental Health, Faculty of Public Health, Hasanuddin University, Makassar, Indonesia
[2] Department of Epidemiology, Faculty of Public Health, Hasanuddin University, Makassar, Indonesia
* Corresponding author's e-mail: fajarnatsir@unhas.ac.id

ABSTRACT

Microplastic contamination in drinking water has become an increasing global concern due to its potential health impacts. This study aimed to assess the presence and characteristics of microplastics in refillable drinking water stored in gallon containers subjected to different washing frequencies. The research was conducted at a refillable water depot in Makassar City using a quasi-experimental design. Three washing treatments were applied – single wash (1×), moderate wash (50×), and frequent wash (100×) – each with three replicates. Microplastics were identified through membrane filtration and microscopic observation. A total of 56 particles were detected, with fiber-shaped particles being dominant (91.1%). The most frequently observed colors were transparent and red, and particle sizes ranged from 0.064 to 1.944 mm. The highest average microplastic count was found in the moderate wash group (8.33 particles/L), followed by the single wash group (5.33 particles/L), and the lowest in the frequent wash group (5.00 particles/L), although the differences among groups were not statistically significant. These findings suggest that moderate washing frequency may increase microplastic release due to mechanical abrasion of the container surface. The study underscores the importance of evaluating washing procedures and selecting appropriate cleaning tools to reduce microplastic contamination in refillable drinking water.

Keywords: microplastics, refillable, drinking water, water quality, gallon.

INTRODUCTION

Microplastics, typically defined as plastic fragments smaller than 5 mm, have become a significant concern in both environmental and public health contexts. These particles primarily originate from the degradation of larger plastic debris and are now widely found across terrestrial and aquatic ecosystems. As the global production of plastic continues to rise while waste management systems struggle to keep up, microplastic contamination has become alarmingly widespread. Much of this plastic debris ends up in rivers, lakes, and oceans, accumulating over time and contributing to widespread environmental pollution (Priya et al., 2023).

Given their persistence and ubiquity, growing concerns have emerged regarding their effects on ecosystems and human health. These tiny particles can interfere with aquatic life and may also enter the human body through contaminated food or drinking water. Research has shown that microplastics can carry hazardous chemicals and even pathogens, potentially increasing associated health risks (Lusher et al., 2017). Traces of microplastics have now been identified in places as remote as the deep ocean and as close as bottled drinking water, demonstrating the extensive spread of microplastic pollution (Oßmann et al., 2018). Similar findings have also been reported in consumable salt products across Indonesia, indicating that microplastic contamination has extended to basic dietary sources (Amqam et al., 2024).

Many studies conducted globally have verified the widespread presence of microplastics in various water sources, including those intended for human use. A study conducted near the Tamangapa landfill in Makassar, for instance, discovered microplastic particles in every dug well sample examined – an alarming sign that even groundwater is not immune to plastic pollution

(Natsir et al., 2021). Likewise, bottled drinking water from different brands and countries has been found to contain microplastics, with some samples showing concentrations as high as 325 particles per liter (Lolodo and Nugraha, 2019; Tse et al., 2022; Zhang et al., 2020). These findings not only highlight the prevalence of environmental contamination but also raise legitimate concerns about the safety of widely consumed drinking water products (Geyer et al., 2024).

In areas such as Makassar, Indonesia, refillable plastic gallons are a common method of distributing drinking water. However, repeated use and frequent washing can gradually degrade the plastic, increasing the risk of microplastic contamination. A recent study on gallon water depots in Makassar detected microplastics in every sample tested, with concentrations of up to 0.8 particles per liter (Syarif et al., 2021). This risk is exacerbated by mechanical friction during the washing process, especially between the gallon walls and cleaning tools made of materials such as nylon or PVC. Over time, this friction can erode the container's surface, releasing microplastic particles into the water.

Beyond local observations, recent international studies have also highlighted microplastic contamination in both treated and untreated drinking water systems. For example, a 2023 study assessed microplastics in residential tap water, confirming the presence of particles such as cellulose and cellophane in all tested samples (Nor et al., 2023). Another 2023 study in Geneva, Switzerland, evaluated the effectiveness of drinking water treatment plants (DWTPs) in removing microplastics, reporting removal rates reaching up to 97%, although small amounts remained in treated water (Velasco et al., 2023).

Given the growing body of evidence linking plastic waste management practices to microplastic contamination, it is essential to investigate specific variables, such as washing frequency, and their impact on microplastic generation. Studies have indicated that increased washing frequency, particularly in refillable plastic containers, accelerates plastic degradation (Wang et al., 2018).

Polyethylene terephthalate (PET) is the most commonly used plastic for refillable gallon containers due to its lightweight, low cost, and transparency. However, PET has low resistance to heat and mechanical stress, making it prone to degradation from repeated use, sunlight exposure, or mechanical friction (Massahi et al., 2025). Unlike high-density polyethylene (HDPE) or polycarbonate (PC), PET more readily releases microplastic particles when subjected to repeated washing or abrasive contact. This characteristic raises concerns about the long-term safety of using PET gallons in refillable drinking water systems, particularly in tropical climates with high ambient temperatures.

Accordingly, this study investigates the presence and concentration of microplastics in refillable gallon drinking water sourced from local depots with varying washing frequencies. Unlike previous studies that primarily rely on passive sampling from bottled or tap water, this research adopts a controlled quasi-experimental design to replicate real-world washing scenarios. By identifying contributing factors – particularly those related to repeated mechanical abrasion and the material limitations of PET – it provides new evidence for a potentially overlooked contamination pathway. The findings may inform regulatory standards for refillable container hygiene and support a shift toward more durable and less degradable materials for public water consumption.

METHOD

Study design

This study employed a quasi-experimental, analytical observational design. This design was selected to facilitate comparative analysis between treatment groups without full randomization, focusing on controlled washing variations and their effects on microplastic presence. The study aimed to describe microplastic presence and examine trends associated with different washing frequencies.

Study subjects and sampling

The study was conducted in Makassar City. This study focused on water samples collected from refillable gallon containers at a local drinking water depot, where the containers underwent controlled washing treatments. These containers were made of PET, a polymer widely used for refillable drinking water containers in Indonesia. Each container was subjected to one of three washing protocols:

- Single wash (1×),
- Moderate wash (50×),
- Frequent wash (100×).

Each treatment was replicated three times to ensure the reliability of the data. A unique coding system was applied to label each test unit and minimize bias during the experimental process. The experimental approach followed standard protocols for evaluating water container sanitation and microplastic analysis (Li and Wu, 2019; Storey et al., 2011).

Data collection and processing

Primary data were obtained from laboratory testing to identify and quantify microplastic particles in each sample. Microplastic particles were identified and quantified using membrane filtration followed by visual microscopic observation. Secondary data, including literature and references related to microplastic contamination in drinking water, were also used to support the analysis.

All data underwent an initial cleaning process, including editing, entry, and validation, to ensure consistency and accuracy. The results were presented using both one-way and two-way tabulations to facilitate the descriptive interpretation of findings.

For statistical comparison of microplastic abundance across washing frequencies, nine observations ($N = 9$) were analyzed, corresponding to three replicates per treatment group. Normality (Shapiro–Wilk test) and homogeneity of variances (Levene's test) were confirmed ($p > 0.05$), justifying the use of one-way ANOVA for group comparisons

RESULT

Microplastics abundance

Table 1 shows the abundance of microplastics identified in drinking water samples from gallon washing treatments conducted at a depot in Makassar City. The average abundance of microplastics was highest in the 50× washing group (8.33 particles/L), followed by the 1× group (5.33 particles/L), and lowest in the 100× group (5.00 particles/L). These results suggest that moderate washing frequency (50×) may enhance microplastic release, possibly due to cumulative abrasion of the container surface over repeated mechanical contact.

Figure 1 presents the variability in microplastic abundance across washing frequency groups using a boxplot visualization. While some differences in particle concentration are visually apparent among treatments, the distributions exhibit overlapping ranges. Statistical analysis via one-way ANOVA revealed no significant differences between groups ($p = 0.435$), indicating that washing frequency did not have a statistically significant effect on microplastic abundance under the tested conditions.

Microplastic morphology and characteristics

Table 2 summarizes the characteristics of microplastic particles – including their shape, color, and size – identified in water samples from the gallon washing experiment.

The microplastic characteristics observed in the drinking water samples. Across all washing frequencies, fiber-shaped particles were predominant, accounting for 91.1% (51 of 56) of total microplastics, while fragments were relatively rare. The most frequently observed colors were transparent and red, particularly in the 1× and 50× groups, while black appeared more often in the 100× group. Particle sizes ranged from 0.064 mm to 1.944 mm, with the widest range observed in the single-wash samples.

DISCUSSION

Characteristics of identified microplastics

The findings of this study indicate that fiber-shaped microplastics dominate the drinking water samples from refillable gallon containers,

Table 1. Distribution of the abundance of microplastic drinking water from gallon washing experiments at a depot in Makassar City

Washing frequency	Replication 1 (particles/L)	Replication 2 (particles/L)	Replication 3 (particles/L)	Total (particles/L)	Average (particles/L)
1× (Single wash)	4	9	3	16	5.33
50× (Moderate wash)	8	12	5	25	8.33
100× (Frequent wash)	8	5	2	15	5.00

Note: There was no significant difference between the three groups based on the results of the ANOVA test ($p = 0.435$).

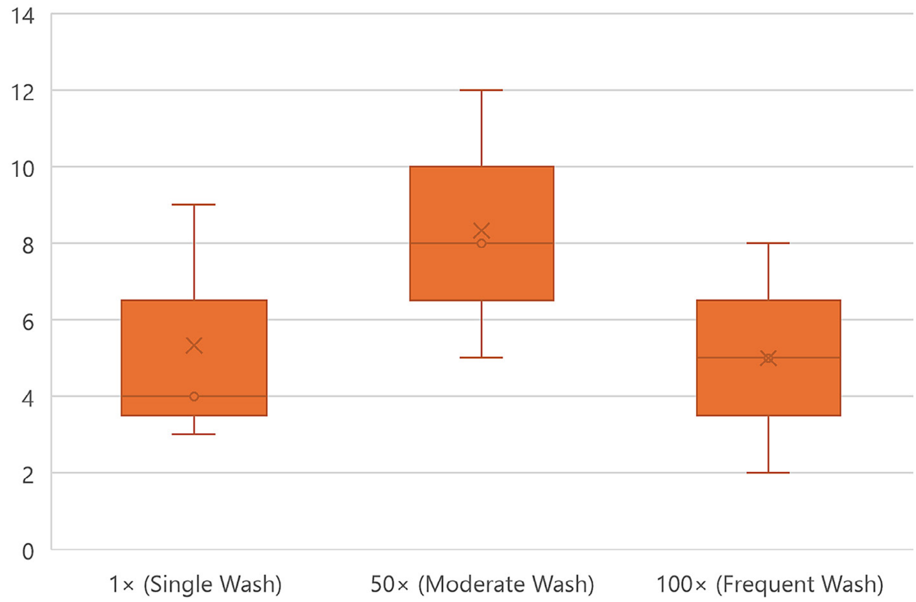

Figure 1. Boxplot of microplastic abundance in refilled drinking water by gallon washing frequency

Table 2. Distribution of microplastic shape, color, and size in drinking water from gallon washing experiments at a depot in Makassar City

Washing frequency	Shape		Total particles	Dominant colour (s)	Size range (mm)
	Fiber (n)	Fragment (n)			
1×	16	0	16	Transparent, Red	0.064 – 1.944
50×	22	3	25	Transparent, Red	0.114 – 1.565
100×	13	2	15	Transparent, Black	0.134 – 1.477
Total	51	5	56	–	–

accounting for 91.1% of the total identified particles. Fragment-shaped particles were found in limited quantities – only five out of a total of 56 microplastics. These findings are consistent with various global studies reporting that fibers are the most common form of microplastics in drinking water, most likely originating from the mechanical degradation of plastic materials such as gallon containers or cleaning tools made of nylon or polyester (Ramaremisa et al., 2024; Sabri et al., 2023; Sarlin et al., 2024).

The most frequently observed microplastic colors in this study were transparent and red in the 1× and 50× washing groups, while black particles were more prevalent in the 100× group. Color can provide important clues about the source and age of plastic particles. Transparent and red fibers were suspected to originate from pipes, plastic fittings, or detergent residues and cleaning tools that had contact with plastic surfaces (Maciel et al., 2022; Ramaremisa et al., 2024). Meanwhile, the appearance of black particles under intensive washing conditions may be associated with contamination from abrasive sponges or worn cleaning tools (Su et al., 2024).

The microplastic particles identified in this study ranged in size from 0.064 mm to 1.944 mm (64 to 1,944 micrometers), classifying them as medium to large in size. This finding is consistent with previous studies reporting that microplastic sizes in refillable drinking water typically fall below 2 mm (Acarer, 2023; Syarif et al., 2021; Wahyuni and Nurika, 2024).

Although no international standards currently regulate the safe size limits of microplastics in drinking water, several studies have shown that very small particles – particularly those under 5 micrometers – can penetrate the gastrointestinal lining and enter the circulatory system (Damaj et al., 2024; Garcia et al., 2023). Moreover, particles smaller than 150 micrometers have been reported to cross the intestinal mucosal barrier, potentially leading to systemic toxicity. While larger particles (> 150 μm) are generally not absorbed, they may still adhere to intestinal mucosa, triggering local inflammation and potentially affecting immune function (Amran et al., 2022; Mittal et al., 2023). Therefore, the presence of medium-sized microplastic particles (64–1.944 µm) observed in this study raises health concerns, particularly under long-term exposure through habitual consumption of refillable drinking water (Fröhlich, 2024).

The observed composition of microplastic colors and shapes reinforces the hypothesis that the primary source of contamination originates from surface abrasion of PET gallon containers due to repeated washing. The predominance of transparent fibers suggests they likely originate from the outer layer of the PET material. PET, the main polymer used in these containers, is known to be vulnerable to surface abrasion and microcrack formation under repeated mechanical stress. Under wet and frictional conditions – such as those occurring during depot cleaning processes – PET may gradually release microplastic fibers as a result of progressive degradation (Akyildiz et al., 2024; Liu et al., 2023). Although this study did not conduct polymer-specific chemical analysis, the observed fiber morphology and particle size distribution are consistent with early-stage PET degradation reported in previous literature. Additionally, the presence of red fibers in certain washing groups suggests possible contamination from cleaning tools, such as brushes or sponges made from nylon or polyester (Sarlin et al., 2024). Therefore, both the physical condition of the containers and the material composition of cleaning tools should be considered potential contributors to microplastic contamination in refillable drinking water.

Overall, the microplastic characteristics identified in this study – primarily fibrous in shape, transparent or red in color, and smaller than 2 mm in size – are consistent with global findings while also indicating a distinct contamination profile associated with refillable PET gallon containers. To improve the precision of source identification and better evaluate potential health risks, future studies should utilize spectroscopic or polymer-specific techniques such as FTIR or Raman spectroscopy.

Effect of washing frequency on microplastic abundance

The results of this study show that the highest average number of microplastics was found in the group subjected to 50 washing cycles, while the lowest count was recorded in the 100-wash group. Although statistical analysis using ANOVA did not reveal significant differences between groups ($p > 0.05$), the visual distribution pattern of microplastics indicates a non-linear trend – an increase in particle count during intermediate washing stages followed by a decline with further washing. This finding suggests that the relationship between washing frequency and microplastic release is not straightforward or proportional, but rather influenced by the changing physical condition of the gallon surface over time (Hu et al., 2022; Sun et al., 2022).

The increased number of microplastics observed in the 50-wash group can be attributed to the initial abrasion mechanism. At this stage, the relatively intact surface of the gallon container is more prone to particle release when subjected to repeated friction from cleaning tools. Light mechanical abrasion on plastic surfaces can result in significant microplastic release, particularly when the outer layer is still rich in loosely attached particles (Liu et al., 2023). This indicates that repeated washing does not necessarily reduce the risk of contamination; instead, it may exacerbate it at certain frequencies.

Although the number of microplastics showed a declining trend in the 100-wash group, this condition is likely due to surface wear on the gallon containers, where the outer layer prone to abrasion has been depleted, resulting in reduced particle release. Previous studies have shown that after repeated abrasive exposure, the number of microplastic particles released from plastic surfaces tends to decrease, as the surface becomes smoother or undergoes structural degradation (Huang et al., 2025). A similar phenomenon was observed in polymer plastic containers, where the highest microplastic release occurred in the initial stages, followed by a decline in subsequent exposure cycles (Hu et al., 2022).

These findings underscore the need to evaluate current gallon-washing practices, particularly because moderate washing frequencies were associated with the highest microplastic release. Refillable water depots should reassess the cleaning materials and techniques employed to ensure they are not excessively abrasive while maintaining hygiene standards. Optimizing cleaning protocols and conducting routine inspections of container wear may serve as effective preventive strategies to minimize microplastic contamination in drinking water.

Study limitations and implications

This study has several limitations that should be considered when interpreting the results. First, the limited sample size and number of replications (N = 9) may constrain the statistical power and generalizability of the findings. Additionally, all experiments were conducted at a single refillable water depot, which may not represent the variability in washing methods and operational conditions across other depots. Factors such as water pressure, temperature, and the type of cleaning tools used can significantly influence abrasion levels and microplastic release.

The microplastic identification method used in this study also has limitations. Light microscopy can detect particle shape and count, but it cannot identify polymer types or assess potential toxicity. Moreover, this method has limited sensitivity in detecting very small particles, particularly those under 20 micrometers, which are commonly found in bottled water and other environmental matrices (Schymanski et al., 2018).

To improve the reliability of microplastic identification, spectroscopic techniques such as Fourier-transform infrared (FTIR) and Raman spectroscopy are considered the gold standard in microplastic research. These methods can accurately identify polymer types and detect extremely small particles – down to the micron and even submicron scale (Käppler et al., 2015; Microspectroscopy et al., 2017; Müller et al., 2019). Future use of these methods will be essential for validating findings and deepening our understanding of microplastic hazards.

Despite its limitations, this study provides a valuable foundation for further research on microplastic release from refillable gallon containers. Its findings may also serve as preliminary input for the development of stricter regulations and technical guidelines for the management and cleaning of refillable water containers at depots.

CONCLUSIONS

This study demonstrates that refillable drinking water from repeatedly washed gallon containers contains microplastics predominantly in fiber form, transparent and red in color, and medium to large in size (0.064–1.944 mm). The highest number of microplastics was observed at the 50-wash frequency, while the lowest count occurred after 100 washes. Although differences between groups were not statistically significant, the distribution pattern revealed a non-linear trend likely influenced by the physical condition of the container surfaces undergoing abrasion and degradation with increased washing frequency.

These findings underscore the importance of evaluating washing practices for refillable water containers, particularly regarding the materials and cleaning tools used. Optimizing cleaning procedures and implementing routine monitoring of container wear should be considered preventive strategies to minimize microplastic release into drinking water. Further research with larger sample sizes and advanced identification techniques such as FTIR or Raman spectroscopy is strongly recommended to enhance the validity and depth of understanding regarding the sources and risks of microplastics in refillable drinking water.

REFERENCES

1. Acarer, S. (2023). Abundance and characteristics of microplastics in drinking water treatment plants, distribution systems, water from refill kiosks, tap waters and bottled waters. *The Science of the Total Environment*, 163866. https://doi.org/10.1016/j.scitotenv.2023.163866
2. Akyildiz, S. H., Fiore, S., Bruno, M., Sezgin, H., Yalcin-Enis, İ., Yalçın, B., Bellopede, R. (2024). Release of microplastic fibers from synthetic textiles during household washing. *Environmental Pollution*, 124455. https://doi.org/10.1016/j.envpol.2024.124455
3. Amqam, H., Natsir, M. F., Yusriani, Z. F. (2024). Microplastic contamination in Indonesian consumable salts. *Journal of Sea Research*, *198*, 102475. https://doi.org/10.1016/j.seares.2024.102475
4. Amran, N. H., Zaid, S. S. M., Mokhtar, M. H., Manaf, L. A., Othman, S. (2022). Exposure to Microplastics during Early Developmental Stage: Review of Current Evidence. *Toxics*, *10*(10). https://doi.org/10.3390/toxics10100597
5. Damaj, S., Trad, F., Goevert, D., Wilkesmann, J. (2024). Bridging the gaps between microplastics and human health. *Microplastics*. https://doi.org/10.3390/microplastics3010004
6. Fajaruddin Natsir, Muh., Selomo, M., Ibrahim, E., Arsin, A. A., Alni, N. C. (2021). Analysis on microplastics in dug wells around Tamangapa Landfills, Makassar City, Indonesia. *Gaceta Sanitaria*, *35*, S87–S89. https://doi.org/10.1016/j.gaceta.2020.12.024

7. Fröhlich, E. (2024). Local and systemic effects of microplastic particles through cell damage, release of chemicals and drugs, dysbiosis, and interference with the absorption of nutrients. *Journal of Toxicology and Environmental Health, Part B*, *27*, 315–344. https://doi.org/10.1080/10937404.2024.2406192
8. Garcia, M., Romero, A., Merkley, S. D., Meyer-Hagen, J. L., Forbes, C., Hayek, E., Sciezka, D. P., Templeton, R., Gonzalez-Estrella, J., Jin, Y., Gu, H., Benavidez, A. D., Hunter, R., Lucas, S. N., Herbert, G. W., Kim, K., Cui, J., Gullapalli, R. R., In, J. G., … Castillo, E. F. (2023). In vivo tissue distribution of microplastics and systemic metabolomic alterations after gastrointestinal exposure. *BioRxiv*. https://doi.org/10.1101/2023.06.02.542598
9. Geyer, R., Jambeck, J. R., Law, K. L. (2024). Production, use, and fate of all plastics ever made. *Science Advances*, *3*(7), e1700782. https://doi.org/10.1126/sciadv.1700782
10. Hu, J., Duan, Y., Zhong, H., Lin, Q.-B., Zhang, T., Zhao, C.-C., Chen, S., Dong, B., Li, D., Wang, J., Mo, M.-Z., Chen, J., Zheng, J. (2022). Analysis of microplastics released from plastic take-out food containers based on thermal properties and morphology study. *Food Additives & Contaminants: Part A*, *40*, 305–318. https://doi.org/10.1080/19440049.2022.2157894
11. Huang, Z., Xu, S., Pan, B., Zhang, J., Wang, K., Liu, H., Fan, Y. (2025). Quantification of microplastics released from plastic food containers during rinsing and migration by pyrolysis-gas chromatography/mass spectrometry. *Food Chemistry*, *472*, 142934. https://doi.org/10.1016/j.foodchem.2025.142934
12. Käppler, A., Windrich, F., Löder, M., Malanin, M., Fischer, D., Labrenz, M., Eichhorn, K., Voit, B. (2015). Identification of microplastics by FTIR and Raman microscopy: a novel silicon filter substrate opens the important spectral range below 1300 cm−1 for FTIR transmission measurements. *Analytical and Bioanalytical Chemistry*, *407*, 6791–6801. https://doi.org/10.1007/s00216-015-8850-8
13. Li, P., Wu, J. (2019). Drinking water quality and public health. *Exposure and Health*, *11*(2), 73–79. https://doi.org/10.1007/s12403-019-00299-8
14. Liu, G., Wang, K., Wang, L., Wu, M., Liu, H. (2023). The effect of mechanical action on the release of microplastic fibers during washing. *Textile Research Journal*, *94*, 740–749. https://doi.org/10.1177/00405175231207127
15. Lolodo, D., Nugraha, W. A. (2019). Mikroplastik pada bulu babi dari rataan terumbu Pulau Gili Labak Sumenep. *Jurnal Kelautan: Indonesian Journal of Marine Science and Technology*, *12*(2), 112–122. https://doi.org/10.21107/jk.v12i2.6267
16. Lusher, A., Hollman, P., Mendoza, J. (2017). *Microplastics in fisheries and aquaculture: Status of knowledge on their occurrence and implications for aquatic organisms and food safety*. FAO.
17. Maciel, H. C., Caetano, M., Schulz, U., Kieling, A. G. (2022). Quantifying shedding of microplastic fibers from textile washing. *Ciência e Natura*. https://doi.org/10.5902/2179460x68810
18. Massahi, T., Omer, A. K., Kiani, A., Soleimani, H., Fattahi, N., Sharafi, K. (2025). Assessing the effect of sunlight exposure and reuse of polyethylene terephthalate bottles on phthalate migration. *The Science of the Total Environment*, *962*, 178480. https://doi.org/10.1016/j.scitotenv.2025.178480
19. Microspectroscopy, R., Rocchia, M., Ruff, I., Vianello, A. (2017). *Microplastic identification and characterization by Raman imaging spectroscopy*.
20. Mittal, N., Tiwari, N., Singh, D., Tripathi, P., Sharma, S. (2023). Toxicological impacts of microplastics on human health: a bibliometric analysis. *Environmental Science and Pollution Research*, 1–13. https://doi.org/10.1007/s11356-023-30801-4
21. Mohd Nor, N. A. N., Shamsul Azahar, I. M., Saipolbahri, N., Subki, N. S. (2023). A Study on The Abundance of Microplastic Pollutant in Residential Tap Water. *BIO Web Conf.*, *73*. https://doi.org/10.1051/bioconf/20237305022
22. Müller, Y. K., Wernicke, T., Pittroff, M., Witzig, C. S., Storck, F., Klinger, J., Zumbülte, N. (2019). Microplastic analysis—are we measuring the same? Results on the first global comparative study for microplastic analysis in a water sample. *Analytical and Bioanalytical Chemistry*, *412*, 555–560. https://doi.org/10.1007/s00216-019-02311-1
23. Negrete Velasco, A., Ramseier Gentile, S., Zimmermann, S., Le Coustumer, P., Stoll, S. (2023). Contamination and removal efficiency of microplastics and synthetic fibres in a conventional drinking water treatment plant in Geneva, Switzerland. *Science of The Total Environment*, *880*, 163270. https://doi.org/10.1016/J.SCITOTENV.2023.163270
24. Oßmann, B. E., Sarau, G., Holtmannspötter, H., Pischetsrieder, M., Christiansen, S. H., Dicke, W. (2018). Small-sized microplastics and pigmented particles in bottled mineral water. *Water Research*, *141*, 307–316. https://doi.org/10.1016/J.WATRES.2018.05.027
25. Priya, A. K., Muruganandam, M., Imran, M., Gill, R., Vasudeva Reddy, M. R., Shkir, M., Sayed, M. A., AlAbdulaal, T. H., Algarni, H., Arif, M., Jha, N. K., Sehgal, S. S. (2023). A study on managing plastic waste to tackle the worldwide plastic contamination and environmental remediation. *Chemosphere*, *341*, 139979. https://doi.org/10.1016/J.CHEMOSPHERE.2023.139979
26. Ramaremisa, G., Tutu, H., Saad, D. (2024). Detection and characterisation of microplastics in tap water from Gauteng, South Africa.

Chemosphere, 141903. https://doi.org/10.1016/j.chemosphere.2024.141903

27. Sabri, R., Sultan, M., Al-Ahmady, K. (2023). Assessment of Microplastic Particles in Tap Water on The Right Side of Mosul City, Iraq. *Al-Rafidain Engineering Journal (AREJ)*. https://doi.org/10.33899/rengj.2023.140745.1257
28. Sarlin, P. J., Morris, S., Savitha, G., Gopan, A., Radhakrishnan, E. K. (2024). Occurrence and characterization of microplastics in bottled drinking water. *Discover Environment*. https://doi.org/10.1007/s44274-024-00129-y
29. Schymanski, D., Goldbeck, C., Humpf, H. U., Fürst, P. (2018). Analysis of microplastics in water by micro-Raman spectroscopy: Release of plastic particles from different packaging into mineral water. *Water Research*, *129*, 154–162. https://doi.org/10.1016/J.WATRES.2017.11.011
30. Storey, M. V., van der Gaag, B., Burns, B. P. (2011). Advances in on-line drinking water quality monitoring and early warning systems. *Water Research*, *45*(2), 741–747. https://doi.org/10.1016/J.WATRES.2010.08.049
31. Su, Y., Yang, C., Wang, S., Li, H., Wu, Y., Xing, B., Ji, R. (2024). Mechanochemical Formation of Poly(melamine-formaldehyde) Microplastic Fibers During Abrasion of Cleaning Sponges. *Environmental Science & Technology*. https://doi.org/10.1021/acs.est.4c00846
32. Sun, J., Zheng, H., Xiang, H., Fan, J., Jiang, H. (2022). The surface degradation and release of microplastics from plastic films studied by UV radiation and mechanical abrasion. *The Science of the Total Environment*, 156369. https://doi.org/10.2139/ssrn.4070228
33. Syarif, M., Daud, A., Natsir, Muh. F. (2021). Identifikasi keberadaan dan bentuk mikroplastik pada air minum isi ulang di kelurahan tamangapa kota makassar: identification of the existence and form of microplastic in refilled drinking water in Tamangapa Village, Makassar City. *Hasanuddin Journal of Public Health*, *2*(3), 346–354. https://doi.org/10.30597/hjph.v2i3.11971
34. Tse, Y.-T., Chan, S. M.-N., Sze, E. T.-P. (2022). Quantitative assessment of full size microplastics in bottled and tap water samples in Hong Kong. *International Journal of Environmental Research and Public Health*, *19*(20). https://doi.org/10.3390/ijerph192013432
35. Wahyuni, R. T., Nurika, G. (2024). Study of microplastic concentrations at the drinking water depot in Sumbersari Village, Jember Regency. *Jurnal Kesehatan Lingkungan: Jurnal Dan Aplikasi Teknik Kesehatan Lingkungan*. https://doi.org/10.31964/jkl.v21i1.857
36. Wang, F., Wong, C. S., Chen, D., Lu, X., Wang, F., Zeng, E. Y. (2018). Interaction of toxic chemicals with microplastics: A critical review. *Water Research*, *139*, 208–219. https://doi.org/10.1016/J.WATRES.2018.04.003
37. Zhang, Y., Diehl, A., Lewandowski, A., Gopalakrishnan, K., Baker, T. (2020). Removal efficiency of micro- and nanoplastics (180 nm–125 µm) during drinking water treatment. *Science of The Total Environment*, *720*, 137383. https://doi.org/10.1016/J.SCITOTENV.2020.137383