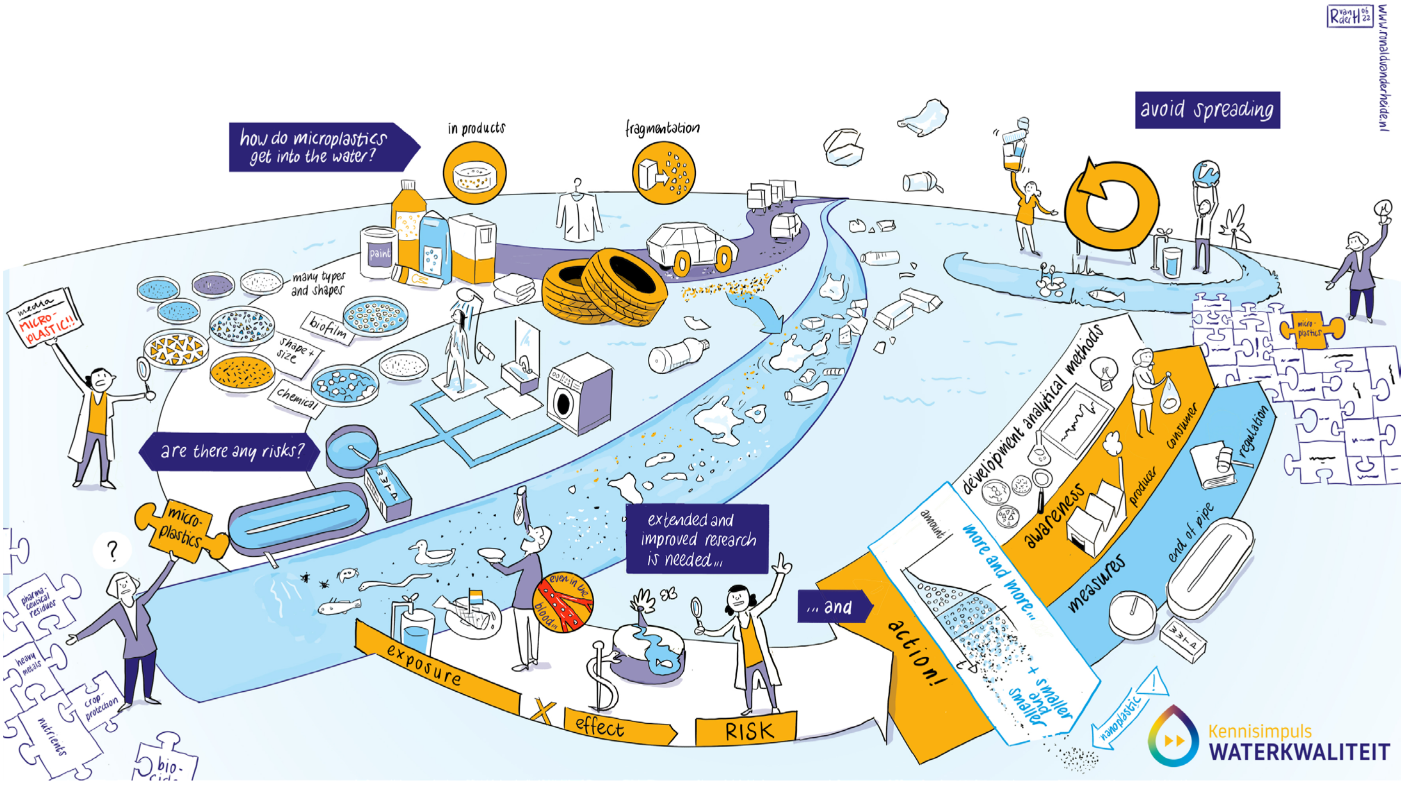
Factsheet

Global Water
Research Coalition

Microplastics in the Water Cycle



Recent research indicates that global plastic production is projected to increase from 464 million tonnes in 2020 to 884 million tonnes by 2050, with cumulative production since 2000 reaching up to 4,725 million tonnes. Consequently, environmental loads of microplastics are expected to rise (Dokl et al., 2024), intensifying microplastic pollution and increasing concentrations in drinking water source waters, particularly surface waters, due to ongoing emissions and incomplete removal across wastewater and environmental pathways. This factsheet summarises current regulatory approaches across selected regions and provides an overview of microplastic occurrence, analytical methods, and removal.

Definition

Microplastics (MP) are commonly defined as solid plastic or synthetic polymer particles that are insoluble in water and have a largest dimension between 1 µm and 5 mm (Frias and Nash [1]). However, the lower size limit of this definition remains subject to debate. In practice, higher lower-bound cut-offs (e.g. 10 or 20 µm) are frequently applied, reflecting the detection limits of many optical analytical techniques, and are therefore commonly adopted in the literature. Microplastics do not only vary in size, but also shape (particles, fibers, etc.), composition (type of polymer), color, and additives making each microplastic particle unique. Microplastics are commonly classified into two categories: primary and secondary microplastics [2]. Primary microplastics are intentionally manufactured at microscopic sizes and incorporated directly into products, such as cosmetics, or used as raw materials in plastic production (e.g. pre-production pellets). Secondary microplastics arise from the fragmentation, degradation, and abrasion of larger plastic items. Secondary microplastics are considered to be the dominant contributor to microplastic pollution.

Variability in size definitions, combined with the wide range of polymer types, complicates the reporting of microplastics data and significantly limits comparability between studies [3]. As a result, comparison studies and reported removal efficiencies should be interpreted with caution.

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Regulatory Environment

European Union: To address this problem a ISO norm was developed as well as a EU protocol how to sample, measure and report microplastics in drinking water. These documents describe which techniques should be used and how the acquired data must be presented. Furthermore, they define 10 priority polymers. Those are the polymers most used by industry and/or are present in the environment. A a total of 10 priority polymers is mentioned in ISO16094 and in the delegated act C(2024)1459 supplementing the Directive (EU) 2020/2184. They are: Polyethylene (PE), Polypropylene (PP), Polyethylene Terephthalate (PET), Polystyrene (PS), Polyvinylchloride (PVC), Polyamide (PA), Polyurethane (PU), Polymethylmethacrylate (PMMA), Polytetrafluoroethylene (PTFE), and Polycarbonate (PC). In addition to this, the delegated act also defines size classes. This means concentration of microplastics per size class need to be reported. This was done to improve the comparability between different datasets. On April 10, 2024, the European Commission also adopted the revision of the Urban Wastewater Treatment Directive (UWWTD), which mentions the monitoring of microplastics in sludge, particularly when used in agriculture for all municipalities with over 10,000 population equivalents (PE).

UK: The UK prohibited the manufacture and sale of rinse-off personal care products containing microbeads (<5mm) in 2018, however this does not exclude all intentionally added microplastics. There are currently no enforceable limits within drinking water, wastewater or biosolids in the UK, although the Department for Food and Rural Affairs (Defra) and other environmental regulators have been gathering evidence to assess the risks and possible regulatory approaches for microplastics, but no clear direction has yet been given.

USA: There are currently no legally enforceable standards at either the federal or state level that define acceptable levels of microplastics in environmental systems such as water, air, or soil. Definitions of microplastics also vary between governments and organisations, which makes regulation and global comparison difficult (ITRC, 2023). Although specific exposure limits do not exist, governments have introduced waste-reduction strategies, including restrictions on single-use plastics and laws banning microplastics in selected products. One example is the United States law that prohibited plastic microbeads in cosmetics. California has been one of the first jurisdictions to introduce formal monitoring of microplastics in water and marine environments. In 2022, the state released a policy framework to guide research and management actions for ocean pollution, which was updated again in 2025. California also introduced a standard testing method for microplastics in drinking water in 2022, using advanced laboratory techniques to detect particles. A two-stage monitoring program was established, beginning with source water testing, with later actions determined by the initial results.

Australia and New Zealand: Neither Australia nor New Zealand has established legally enforceable standards, numeric limits, or mandatory monitoring requirements for microplastics in drinking water.

The Australian Drinking Water Guidelines do not currently include microplastic criteria. Rather than setting enforceable limits, regulatory progress has focused on technical standardisation. Standards Australia has adopted AS ISO 24187 (aligned with ISO 24187:2023), which establishes principles for sampling, analysis, and reporting of microplastics in environmental matrices. This standard enables reporting by size class to improve data comparability and supports established analytical methods such as FTIR/Raman spectroscopy and pyrolysis-GC/MS for polymer identification and particle characterisation. However, it does not specify priority polymers or drinking water thresholds. Testing capability is developing across the country, with NATA-accredited laboratories now offering microplastics testing for drinking water. Some jurisdictions have conducted environmental microplastics surveys, including a New South Wales waterways study. Source reduction measures currently in place include microbeads phase-outs, bans in several jurisdictions, and national plastics reduction measures targeting microplastic releases such as microfibre shedding from textiles.

Following drinking water reforms in 2021, microplastics remain outside the scope of New Zealand's Drinking Water Standards. Taumata Arowai, the water services regulator, does not require microplastics testing and maintains no national dataset on microplastics or nanoplastics in drinking water. New Zealand's approach has emphasised prevention through source reduction, including a nationwide microbeads ban implemented in 2018 and broader single-use plastics restrictions. Ongoing research is being conducted to inform potential future regulatory pathways.

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Singapore: While Singapore does not currently have specific regulations on microplastics, it addresses the issue through a holistic waste management framework and upstream plastic controls. In 2022, Singapore launched a National Action Strategy on Marine Litter (NASML) which aims to reduce land-based litter and intensify research into the impact of microplastics on the marine environment. Larger Singapore companies have to report their packaging data and develop 3R (Reduce, Reuse, Recycle) plans. PUB, Singapore's National Water Agency, has further improved the removal rate of microplastics from wastewater before it is discharged using membrane bioreactor technology. Lastly, Singapore's National Environment Agency and PUB maintain a network of litter traps in drains and use specialized craft to remove floating debris from reservoirs and coastal waters to prevent land-based plastic from reaching the ocean.

Occurance, source and removal

Microplastics have been detected in freshwater, groundwater, raw and treated drinking water, raw and treated wastewater, and bottled water, at various levels. By far the lowest level are usually found in drinking water. As mentioned before, comparison of these numbers is yet difficult due to the lack of standardised measurements and reporting. However, the presence of microplastics in the matrices is certain. Rivers and streams act as major transport pathways, conveying microplastics to lakes and oceans, which function as long-term sinks for these particles. At the same time, rivers and lakes serve as important sources of drinking water in many countries, creating a direct link between environmental contamination and human exposure.

Table 1. Potential of different pipe material to leach/release Microplastics.

Pipe material	Potential to release MPs	Reference
PVC (polyvinyl chloride)	Possible (plastic polymer; ageing/scouring shown to release MPs)	Liu H., Zhao M., Jiang F. (2025). Aging of PVC pipes induces release of microplastics: Insight into the role of the hydrophilicity of pipe inner surface. Process Safety and Environmental Protection, 200, 107409. https://doi.org/10.1016/j.psep.2025.107409
PE (polyethylene)	Possible (plastic polymer; ageing/scouring shown to release MPs)	Świetlik J., Magnucka M. (2025). Aging of drinking water transmission pipes during long-term operation as a potential source of nano- and microplastics. International Journal of Hygiene and Environmental Health, 263, 114467. https://doi.org/10.1016/j.ijheh.2024.114467
PPR (polypropylene random copolymer)	Possible (plastic polymer; ageing/scouring shown to release MPs)	Xiu J., Geng B., Liu M., Han X., Zhang D., Bai X. (2026). Biofilm induced microplastics and microbial metabolites release from Polypropylene Random pipes in drinking water distribution systems. Water Research, 288, 124626. https://doi.org/10.1016/j.watres.2025.124626
Galvanized steel	N/A – non-plastic	World Health Organization (2019). Microplastics in drinking-water. (Defines microplastics as plastic particles; metals are not plastics.) https://www.who.int/publications/i/item/9789241516198

DCIP (ductile cast iron pipe)	Possible (polymer lining could shed plastic particles if degraded/abraded; evidence base is much stronger for chemical leaching than for MPs)) / Unlikely (cement-mortar lined)	For cement-mortar lined (Unlikely): DIPRA (2023, rev. May 2023). Cement-Mortar Linings for Ductile Iron Pipe. https://dipra.org/wp-content/uploads/2025/02/Cement_Mortar_Linings_for_Ductile_Iron_Pipe__English.pdf For polymer linings context (Possible): Rajasärkkä J. et al. (2016). Drinking water contaminants from epoxy resin-coated pipes: A field study. Water Research, 103, 120–128. https://doi.org/10.1016/j.watres.2016.07.025
Stainless steel	N/A (non-plastic; used as a comparison material in pipe MP-release work)	Sheng K., Yang Z., Tang Y., Zhang Y. (2024). Release of microplastics from pipe materials and their impact on stagnant water (includes stainless steel as comparison). Journal of Water Process Engineering. https://doi.org/10.1016/j.jwpe.2024.106872
Copper	N/A – non-plastic	World Health Organization (2019). Microplastics in drinking-water. (Microplastics are plastic particles; copper is a metal.) https://www.who.int/publications/i/item/9789241516198
PE-RT (polyethylene of raised temperature resistance)	**Unlikely (based on tested conditions)** (no MPs above detection limit reported in the conference paper's test rig studies)	Sejersen P., Debever L. (2023). Microplastics and Plastic Pipes (conference paper reporting no MPs above detection limit for PE-RT under tested conditions). Proceedings of the 21st Plastic Pipes Conference (PPXXI). https://pipa.com.au/wp-content/uploads/2025/09/ID05-Microplastics-and-Plastic-Pipes.pdf
GRP (glass reinforced plastic)	Possible in principle, but pipe-specific evidence is limited (composite with polymer resin matrix; can fragment into polymer-containing particles)	Lekshmi N.M., Kumar S.S., Ashraf P.M., Nehala S.P., Edwin L., Turner A. (2023). Occurrence and characteristics of fibreglass-reinforced plastics and microplastics on a beach impacted by abandoned fishing boats. Marine Pollution Bulletin, 192, 114980. https://doi.org/10.1016/j.marpolbul.2023.114980
FRP (fiber-reinforced plastic)	Possible in principle, but pipe-specific evidence is limited	Galgani F., Shim W.J., Bessa F., Piermarini R., Buitrago N.R., Topouzelis K., Gilardi K. (2025). A comprehensive analysis of the scrapping and abandonment of fiber-reinforced polymer vessels at sea. Marine Pollution Bulletin, 220, 118378. https://doi.org/10.1016/j.marpolbul.2025.118378

A significant proportion of microplastics enter the system from people's use of everyday products that release microplastics into the sewage system. The microplastics are then released into the environment through wastewater treatment plants, which are often unable to completely remove these particles. Another major source of microplastics is traffic. As tyres abrade during driving, secondary microplastics are generated and subsequently dispersed either through the air or into surface waters. These particles may enter aquatic systems directly, via road runoff into roadside ditches, or indirectly through sewer systems and wastewater treatment plants.

Overall, microplastics represent a highly diverse group of complex and persistent pollutants that enter ecosystems through a wide range of human and industrial activities. Beyond tyre wear, virtually any plastic or polymer-based material can contribute to microplastic pollution. Notable sources include paints, synthetic textiles, and packaging materials such as plastic bottles.

Wastewater and sewage treatment plants can substantially reduce microplastic concentrations in effluents. Although wastewater treatment processes were not originally designed to target microplastics, they are effective at partitioning these particles from the water phase into solids, achieving removal efficiencies ranging from approximately 80% to 99.9% in wastewater treatment plants (WWTPs) (Harley-Nyang et al., 2023). The majority of microplastics are removed during the pre-treatment and primary treatment stages. Nevertheless, even the remaining fraction—often around 1%—can represent a considerable number of particles due to the large volumes of wastewater treated. Because microplastics are persistent, they accumulate in the environment over time and have been detected in marine and freshwater systems, soils, the atmosphere, and living organisms, highlighting their ubiquitous presence.

During wastewater treatment, a substantial fraction of microplastics is retained in sewage sludge (raw or treated), which is commonly applied to land as biosolids. As a result, biosolids application constitutes one of several potential pathways for the transfer of microplastics to terrestrial environments. Understanding the relative contribution of different sources and monitoring their long-term impacts on soil health remains an important area for ongoing research and adaptive management practices. Regarding drinking water, studies have shown high removal of microplastics up to 99% and the consequence only low concentrations of microplastics have been found in drinking water, if any. However, the lack of standardized protocols for sampling, analysis and reporting, uncertainty regarding the most important characteristics from an exposure and toxicity standpoint, and the diversity of microplastics make their analysis and comparison difficult, time consuming and expensive.

Sampling and Measurement

Detecting microplastics (MPs) in water systems requires standardized analytical methods per ISO 5667-27:2025.

ISO 5667-27:2025 plays a **foundational, enabling role** for microplastics monitoring — not by defining limits or polymers, but by standardising **how samples are taken** so results are credible and comparable.

ISO 5667-27:2025 is part of the ISO 5667 Water quality — Sampling series and provides **specific guidance for sampling water intended for microplastics analysis**, including drinking water, raw water, and treated wastewater.

Key techniques include FTIR microscopy for particles >10 µm, micro-Raman spectroscopy around 1µm and SEM/EDS for particles as small as 0.2 µm, pyrolysis-GC/MS for polymer identification, and Nile Red fluorescence staining for preliminary screening. Filter membrane pore size determines the smallest detectable particle size and should align with monitoring goals.. Analysis of microplastics comprises of three steps. Sampling, sample preparation, and measurement. Sampling is usually achieved by filtering large volumes of water through a cascade of filters. In the next step samples need to be treated before they can be analysed by most analytical tools that are available. In the last step the sample is analysed.

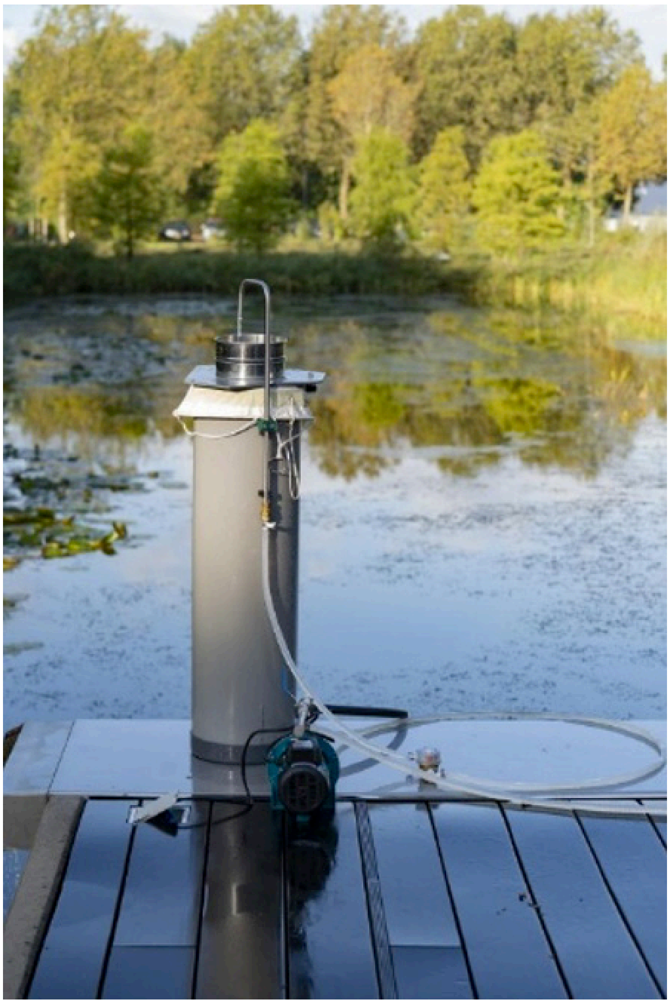

Figure 1: Example of a filter cascade.

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To analyze microplastics, various analytical methods are employed, each with their own advantages and limitations. Optical microscopy is a common initial technique, capable of detecting particles a few hundred micrometers in size, though it does not provide information about the polymer type. To identify the chemical composition of microplastics, spectroscopic methods such as Fourier-transform infrared (FT-IR), laser direct infrared imaging (LDIR), and Raman spectroscopy are used in combination with microscopy. These allow for simultaneous analysis of particle size, shape, and composition, with Raman spectroscopy capable of detecting particles as small as 1 µm, and FT-IR and LDIR detecting down to about 20 µm. For larger particles (>500 µm), attenuated total reflection infrared spectroscopy (ATR-IR) is commonly used. Additionally, thermal analysis techniques like thermogravimetric analysis (TGA) or pyrolysis coupled with gas chromatography-mass spectrometry (GC/MS) can detect even smaller particles (<1 µm), though these are destructive and do not provide size data. However, these methods can provides information on the mass concentration of MP in a specific matrix.

Table 2. Comparison of techniques

		Particle number	Particle size	Colour	Morphology	Chemical composition	Mass concentration	Microplastics	Nanoplastics
Microscopy-based techniques *	Optical microscopy	✓	✓	✓	✓			✓	
	Fluorescence microscopy	✓	✓		✓			✓	
	Electron microscopy	✓	✓		✓			✓	✓
	Atomic force microscopy	✓	✓		✓			✓	✓
Microscopy-based vibrational spectroscopy techniques *	Micro–Fourier-transform infrared spectroscopy (micro-FTIR)	✓	✓	✓		✓		✓	
	Micro-Raman spectroscopy	✓	✓	✓		✓		✓	
	Quantum cascade laser spectroscopy (QCL-IR) e.g. laser direct infrared spectroscopy (LDIR)	✓	✓	✓		✓		✓	
Thermal degradation techniques +	Pyrolysis gas chromatography–mass spectrometry (Py-GCMS)					✓	✓	✓	✓
	Thermal desorption gas chromatography–mass spectrometry (TD-GCMS)					✓	✓	✓	✓

* Particle counting methods

\+ Mass concentration methods

Conclusion

The water sector is actively contributing to the development and validation of analytical, measurement, and monitoring methods for microplastics, while also supporting ongoing ecotoxicological research to improve understanding of the potential risks microplastics may pose to human health and the environment.

Effective management will require a whole-systems approach that is multidisciplinary, cross-sectoral, and coordinated across jurisdictions and requires improved understanding of measurement methods, sources, pathways, fate, and potential risks to humans and ecosystems, including the effects of chronic exposure and interactions with other contaminants. Prevention efforts should focus on risk-based interventions at identified hotspots and strengthened upstream waste and materials management to reduce microplastic emissions at their source.

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