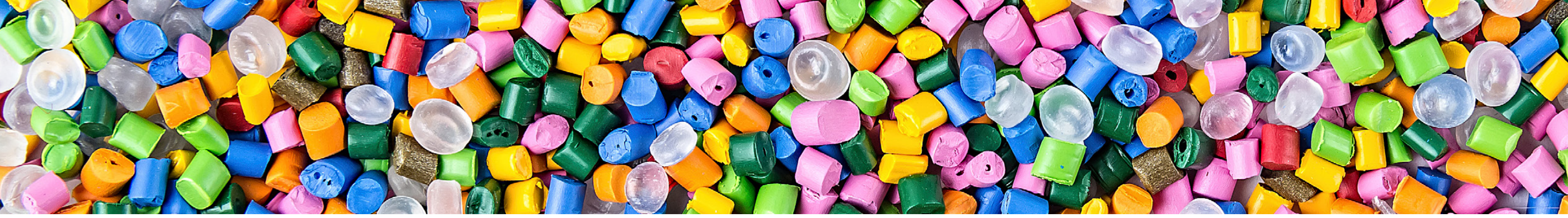


THE Water Research FOUNDATION

Microplastics in Water

What Are Microplastics?

Microplastics (MPs) are plastic particles under 5 mm in size (but seldom sampled <0.3 mm). They enter the environment through human use. Some plastics are manufactured as MPs; however, larger plastic debris can degrade into micro-sized particles over time with exposure to sun and water. The appearance and shape of MPs vary widely, making it difficult to quantify and separate MPs from natural particles. Beauty products with microbeads, synthetic clothing, plastic bags, polystyrene foam, and disposable plastic items can all contribute to microplastic pollution. There are 13 types of MPs—polyethylene, polypropylene, and polystyrene are the most common. There are three primary categories of MPs:

- Microfibers, usually the most common type of microplastics, are derived from synthetic textiles and slough off during daily use and machine washing of clothing (e.g., fleece jackets). Most microfibers released into water are between 0.1–0.8 mm in size. (Hernandez et al. 2017).
- Fragments form as a result of physical breakage of macroplastics.
- Microbeads are common in personal care products.

How Bad Is the Problem and What Can We Do About It?

- The worst MP concentration recorded is 32 per 1,000 liters (Baldwin et al. 2016). Similar-sized algae are thousands to tens of millions per liter higher in concentration (7 to 10 orders of magnitude). This concentration makes ingestion by zooplankton or fish larvae unlikely.
- Lab work using concentrations 2 to 10 orders of magnitude higher than the worst environmental levels shows adverse effects.
- Microplastics have been found to adsorb and transport ambient pollutants such as PCBs (coolants), PBDEs (flame retardants), and other persistent organic pollutants.

Can Microplastics Introduce Compounds of Interest and Pathogens to Aquatic Organisms?

Microfibers have been found in fish and marine animals. However, more research is needed on the toxicology of MPs, including microfibers, and the overall relevance for freshwater resources, drinking water, and human health. There have been no studies to investigate the possible role of MPs on increasing exposure to pathogens. Since biofilms form on most surfaces in shallow waters, it is likely that pathogens are a component of the biofilms in human-dominated watersheds. The increased availability of nutrients on the particles would increase survival of pathogens, just as in sediments (Burton et al. 1987). This should not pose ecological or human health issues due to low concentrations in comparison to natural sediment particles.

How Are Microplastics Monitored?

The numbers and types of MPs measured vary by method, and often two analytical methods are needed. Monitoring for different types of plastic materials requires advanced instrumentation that is not readily available. This instrumentation may include 1) Raman micro-spectroscopy, 2) Fourier transform infrared spectroscopy (FTIR), 3) focal plane array-based reflection FTIR, 4) combining atomic force microscopy-infrared spectroscopy, 5) field flow fractionation, or 6) optical microscopy. Each method has its own unique strengths and limitations. A few limited studies have tried to quantify the various types of MPs occurring in marine and freshwaters; however, none have allowed for site-specific generalizations. It is difficult to compare MP studies due to lack of standardized methods.

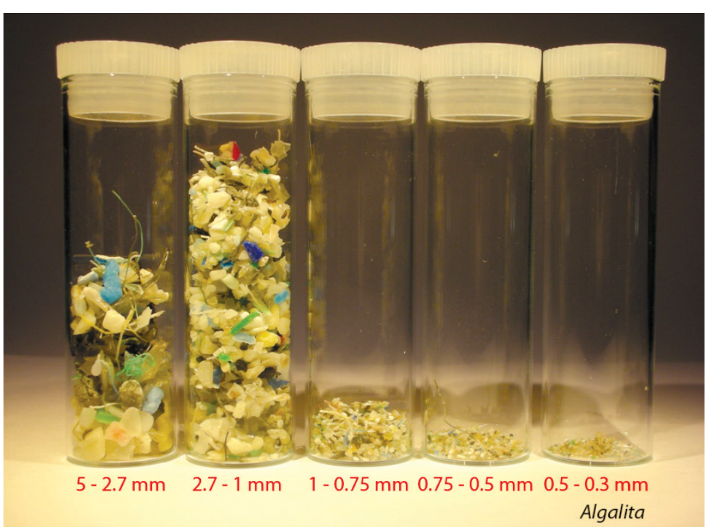
What About Microplastics in Treated Municipal Wastewater and Drinking Water?

Municipal wastewater treatment plants (WWTPs) and water resource recovery facilities (WRRFs) are the largest sources of MPs into aquatic systems in the United States, and likely all developed countries (McCormick et al. 2014). Mason et al. (2016) reported widespread MP pollution from WWTP/WRRF effluents, sampling 17 facilities in the

United States. The average discharge was 0.05 ± 0.024 MPs per liter effluent, with a daily discharge of over four million per facility per day. They estimated 3 to 23 billion MPs are released each day by municipal WWTP/WRRFs into U.S. waters. This estimate is less than those cited in prior studies done by Rochman et al. (2015).

The ability to remove microplastics from water depends on the particle size. A European study found that 90–99% of microplastics was removed in WWTPs/WRRFs, but removal efficiency of smaller particles (20–300 µm) was lower (Browne et al. 2011). A second study found 98% removal of microplastics, though the remaining amount of microplastics discharged to receiving waters was still estimated at 65 million per day (or 0.25 microplastics/L) (Murphy et al. 2016). This demonstrates that when dealing with large volumes of effluent, even a modest concentration of MPs being released per liter of effluent could result in significant amounts of microplastics entering the environment. During conventional wastewater treatment, microplastics are mainly retained by sedimentation. Other research has shown removal by membrane filtration. Larger particles, as investigated in many studies, should presumably be retained during membrane filtration, media filtration, bank filtration, or underground passage (Storck et al. 2015).

Limited research has been conducted on MPs in drinking water. Water suppliers using surface water supplies impacted by upstream wastewater discharges may have MPs in their raw water prior to treatment, and possibly in their treated water. The traditional size class of 300–500 µm would not be expected to make it through a modern-day drinking water treatment plant that has filtration.



Size distribution of plastics from a typical Manta trawl

What Research Has Been Completed?

- The publication of peer-reviewed papers on MPs in scientific journals has increased in recent years (Connors et al. 2017, Lusher et al. 2017). There have also been several beneficial government reports, critical reviews, and perspectives (e.g., Duis and Coors 2016, Hidalgo-Ruz et al. 2012, Lenz et al. 2016, NOAA 2013, NOAA 2015, Rochman et al. 2016, Shim et al. 2017, EPA 2016, and Wagner et al. 2014).
- In 2017, the Water Environment & Reuse Foundation (now The Water Research Foundation) published *White Paper – Microplastics in Aquatic Systems: An Assessment of Risk* (Burton 2017). The white paper explored the risks of MPs to aquatic systems and identified knowledge gaps by conducting a critical review of the peer-reviewed literature focusing on risk-associated issues.

White Paper – Microplastics in Aquatic Systems: An Assessment of Risk

Burton 2017 focused on MPs in the environment and wastewater effluents. The recommendations of recent U.S. Environmental Protection Agency (EPA), National Oceanic and Atmospheric Administration (NOAA), and critical reviews on research needs were considered. The white paper provides a balance between what is known and where there are gaps in assessing the risk of MPs in the aquatic environment.

Critical Questions

The white paper sought to address the following risk-associated issues to identify knowledge gaps:

- What are the levels of MPs in WWTP/WRRF effluents (i.e., secondary and tertiary, range and percentile distributions)?
- What is the distribution of MP types and sizes associated with urban WWTP/WRRF effluents? Fibers may be more common in freshwater fish than other MPs—why? What are their sources? Are they an ecological concern?
- How does removal efficiency vary between wastewater treatment processes?
- Could MP concentrations in sediments near WWTP/WRRF outfalls be a concern to benthic biota?
- Are adverse effects on aquatic biota possible at concentrations found in worst-case scenarios?
- Can metals and trace organic compounds adsorbed to MPs be of concern, given their concentrations in nature and chemical uptake rates?

White Paper Findings

- Macroplastics, perhaps not microplastics, cause physical harm to fish-eating birds, aquatic mammals and reptiles, and fish.
- MPs adsorb some toxic chemicals, but are not an exposure route of significance for aquatic birds or aquatic organisms, as compared to prey consumption.
- It is questionable whether existing aquatic toxicity tests assess the potential physical impacts of MPs.
- Research indicates that the occurrence of MPs in the environment has not been shown to cause adverse effects to aquatic wildlife.
- Improved MP exposure models for effluent discharges into receiving waters are needed to predict whether MPs may be a stressor of concern.
- MP levels are more likely to be elevated near urban centers and in depositional sediments near municipal WWTP/WRRF outfalls.
- No standard methods exist for sampling and quantifying MPs, making it difficult to compare studies or reliably predict exposure, effects, hazards, or risks.
- MP concentrations in waters containing the highest number of particles are below 10 particles per 1,000 liters, resulting in very low potential for exposure and uptake by biota.
- Benthic macroinvertebrates in sediments near WWTP/WRRF outfalls are the most likely receptors to be exposed to potentially adverse levels of MPs.
- WWTPs/WRRFs remove the majority of MPs, with most being captured in sludge. The white paper suggests a need to conduct realistic exposures to determine ecological risks.
- Filtration is an optimal treatment for removing MPs from wastewater effluents and intake waters.
- The predominant sources of microfibers are likely clothes washing (>1,900 fibers/garment/wash, Browne et al. 2011) and antifouling boat paints.
- Microbeads have been banned in the United States, but MPs will likely not decrease due to sources of fibers and fragments.
- Several government agencies have identified knowledge gaps and research needs similar to those identified by the white paper.
- There is a need for a widespread education program geared towards the public and regulators.

Research Gaps and Next Steps

- A new study by Orb Media, found microfibers in 83% of 159 tap water samples from around the world and in 94% of the U.S. tap waters sampled (Tyree and Morrison 2017). However, this study is only a snapshot, and further research on the occurrence and toxicological relevance of MPs is needed.
- Measurement methods for MPs vary significantly, and there is no universal protocol for sample preparation, which can make results hard to compare. Standard methods for collecting, identifying, analyzing, and determining toxicity and bioaccumulation are needed.
- More research is also needed on the removal of MPs and microfibers by various water treatment processes, particularly for sizes smaller than 300 µm.
- A strategic research plan is needed to address critical knowledge gaps within the next five years. This plan should be conducted in concert with interested federal/national agencies (e.g., EPA, Environment and Climate Change Canada, NOAA, European Chemicals Agency, and Commonwealth Scientific and Industrial Research Organization) and with standards-setting organizations (e.g., American Society for Testing and Materials, International Organization for Standardization, and Organization for Economic Co-Operation and Development). Some of the knowledge gaps are currently being addressed by these agencies and individual researchers, so the strategic plan should describe a process for engaging key parties and stakeholders.

The Water Research Foundation is engaged in multiple partnerships to further the understanding of MPs. WRF is partnering with the Global Water Research Coalition to co-fund an interlaboratory comparison of microplastic analytical techniques. In addition, in collaboration with the National Science Foundation, WRF will be supporting Dr. Belinda Strum at the University of Kansas with her microplastics research titled *Determining the Fate and Major Removal Mechanisms of Microplastics in Water and Resource Recovery Facilities*. This research project will further investigate the fate of microplastics across WRRFs, including both liquid discharge and biosolids land application. In preliminary studies, the researchers have found that the majority of microplastics are entrained or adsorbed into activated sludge; therefore, they hypothesize that the sludge structure and extracellular polymeric substance content are controlling variables to microplastic removal.

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