Microplastics in Water: Assessing the State of the Science



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NACWA

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Abbreviations and Acronyms

AI	artificial intelligence
AWWA	American Water Works Association
ARPA-H	Advanced Research Projects Agency for Health
BMP	best management practice
BPU	Board of Public Utilities (New Jersey)
DEP	Department of Environmental Protection (New Jersey)
CCL 6	Sixth Contaminant Candidate List
CRT	consolidated research topic
FTIR	Fourier-transform infrared
HHS	(United States Department of) Health and Human Services
HOC	hydrophobic organic chemical
HQI	hit quality index
ISO	International Organization for Standardization
ITRC	Interstate Technology & Regulatory Council
LDIR	laser direct infrared
LOD	limit of detection
LOQ	limit of quantification
MAG	microplastic analytical grade
MDA	minimum detectable amount
ML	machine learning
MP	microplastic(s)
NACWA	National Association of Clean Water Agencies
O-PTIR	optical-photothermal infrared
PA	polyamide
PE	polyethylene
PET	polyethylene terephthalate
POU	point of use
PP	polypropylene
PS	polystyrene
PVC	polyvinyl chloride
PVDF	polyvinylidene fluoride
Py-GC/MS	pyrolysis-gas chromatography/mass spectrometry
QA	quality assurance
QC	quality control
SB	Senate Bill
SCCWRP	Southern California Coastal Water Research Project
SEM	scanning electron microscopy
SOP	standard operating procedure
STOMP	Systematic Targeting of Microplastics
TED	thermal extraction desorption
TOC	total organic carbon
UCMR 6	Sixth Unregulated Contaminant Monitoring Rule
U.S. EPA	United States Environmental Protection Agency
WWTP	wastewater treatment plant

Executive Summary

Microplastics (MP) are rapidly becoming a widely discussed emerging contaminant, with a broad array of both research studies and mainstream media articles demonstrating occurrence throughout the environment, including water resources. As a result, the United States Environmental Protection Agency (U.S. EPA) included MP in the draft Sixth Contaminant Candidate List (CCL 6), published in the Federal Register on April 6, 2026, acknowledging that "there remain significant data gaps for microplastics that will require further research before the Agency can fully understand the risks associated with microplastics in drinking water." Thus, the purpose of this report is to document the current state of microplastics science in the context of water supplies, identifying and prioritizing key research needs to help direct funding to the areas most impactful for understanding risk. Subsequently, with the identified knowledge gaps sufficiently addressed, the research findings can appropriately inform public policy and regulatory determinations. In fulfillment of this purpose, state-of-the-science summaries were developed for MP in water supplies relative to each of seven topics: 1) occurrence; 2) sampling; 3) analysis; 4) treatment; 5) source control; 6) health effects; and 7) environmental impact. Based on these summaries, the following key points particularly applicable to water utilities were identified:

1. The highest priority topic areas for research funding were determined to be **health effects** and **analytical methods** (i.e., "analysis").
2. These priorities **align with the objectives of the Systematic Targeting of Microplastics (STOMP) initiative**, launched in April 2026 and funded by the United States Department of Health and Human Services (HHS) Advanced Research Projects Agency for Health (ARPA-H).
3. Given the challenges of detection and the greatest potential to cause adverse health effects, **a focus on nanoplastics (i.e., 1 - 1,000 nm in size) is critical** for every research topic area.
4. **Reducing analysis time and associated costs are essential** for enabling affordable water quality monitoring, particularly given the number of samples necessary to capture anticipated MP variability.
5. **A substantial investment in research funding is necessary prior to any comprehensive nationwide utility monitoring program** (e.g., the Unregulated Contaminant Monitoring Rule (UCMR)) in order to ensure accurate and fully representative data.

1 Introduction

1.1 Background

Microplastics (MP) are rapidly becoming a widely discussed emerging contaminant, with virtually ubiquitous occurrence in the environment, including water supplies. A rapidly proliferating number of MP studies and increased media attention have prompted both heightened utility customer awareness and regulatory attention at both the state and federal level. Accordingly, MP were included in the United States Environmental Protection Agency's (U.S. EPA) draft Sixth Contaminant Candidate List (CCL 6), published in the Federal Register on April 6, 2026, with language acknowledging that "there remain significant data gaps for microplastics that will require further research before the Agency can fully understand the risks associated with microplastics in drinking water." However, to-date there has been no concerted effort to capture the state-of-the-science with respect to MP in water supplies or articulate the wide array of specific research needs. Thus, the American Water Works Association (AWWA) and the National Association of Clean Water Agencies (NACWA) have jointly funded such an effort, with findings provided in this report.



1.2 Purpose and Objectives

In order to address the need for a resource that succinctly describes the current understanding of MP in water supplies, the associated challenges, and knowledge gaps, this report provides concise state-of-the-science summaries for seven topical areas: occurrence, sampling, analysis, treatment, source control, health effects, and environmental impact. Based on the findings of these topical summaries, key questions are also identified to inform timely research needs. Thus, the purpose of this report is to serve as a briefing document for stakeholders with the following specific objectives: 1) fostering a contemporary understanding of MP issues applicable to water supplies; 2) enabling the allocation of research funding to address the most critical questions and needs; and 3) informing appropriate MP policy and regulatory determinations. Accordingly, the report is written for a broad stakeholder audience, although some degree of general scientific background and understanding is necessarily assumed.

1.3 Research Approach

Literature reviews divided by topic area were conducted by MP subject matter experts to synthesize the respective state-of-the-science summaries and identify key questions associated with knowledge gaps. Primary sources targeted in the literature review include both peer-reviewed articles and research reports (e.g., from the Water Research Foundation), as well as materials issued by regulatory bodies and applicable standards published by recognized authorities (e.g., ASTM International (ASTM), the International Organization for Standardization (ISO), etc.). Given the rapid advancement of MP science, sources published since January 2024 were prioritized; however, older sources were also referenced for cases in which it was determined that the information remained valid and applicable.

The state-of-the-sciences summaries and associated key questions compiled in this report were reviewed by the Project Steering Committee before being presented for further review and comment in a stakeholder workshop. Participants in the workshop included representatives of AWWA, NACWA, state

and federal (U.S. EPA) regulators, water and wastewater utilities, and academic MP researchers. Feedback from these reviews was subsequently addressed (e.g., strategically adding/omitting content, consulting additional literature sources, revising key questions, etc.), with the revised content incorporated into this report.

1.4 Report Overview / Users Guide

1.4.1 Section Organization

The seven MP topic areas are discussed in respective sections comprising the core of the report, as follows:

- Section 3: Occurrence
- Section 4: Sampling
- Section 5: Analysis
- Section 6: Treatment
- Section 7: Source Control
- Section 8: Health Effects
- Section 9: Environmental Impact

Each of these sections includes four subsections. First, a brief synopsis of the topic is provided to serve as succinct high-level overview such that the reader can understand its importance and the interrelationships with other topic areas. The second subsections present the respective state-of-the-science summaries, each consisting of a concise 1-2 pages of discussion. References cited in the summaries are listed in the fourth subsections. Note that the associated references are purposefully included with each respective topic area section (vs. a consolidated section at the end of the report) to facilitate reader review of individual, self-contained topical discussions of interest.

Research needs are captured in the third subsections, listing the various key questions in a tabular format. The questions are grouped into categories based on broader themes labeled “consolidated research topics” (CRTs), and a shorthand CRT identifier is provided for reference. (For example: OCC-1 refers to the first CRT listed in the table for occurrence research needs.)

Preceding the topical discussions, Section 2 of the report provides an overview of the current MP regulatory landscape at both the state and federal level. Awareness of regulatory activity is valuable context for understanding some of the important drivers for MP research, as well as the need to address some of the key questions.

Section 10 discusses MP research priorities, recognizing that not all of the important studies can be funded simultaneously, and some must necessarily precede others. Thus, the seven topic areas are binned into highest, middle, and lowest priority categories, with accompanying explanation. Critical research focus areas are discussed in more detail for those topics in the highest priority bin, thus more fully conveying their importance and the associated rationale. The heightened significance of studying nanoplastics, in particular, across many topic areas, is also discussed. The final section of the report (Section 11) addresses the implications of the research summaries and identified key questions for the drinking water community.

1.4.2 Defining Microplastics

There is no formal scientific definition of "microplastics" based on any fundamental characteristics, nor even a uniform qualitative definition that is broadly recognized. Thus, as widely used in the literature, the term "microplastics" is applied in a descriptive sense, generally referring to very small plastic particulates. Notably, the State of California adopted a definition of "Microplastics in Drinking Water" in 2020, as shown below. Although there is no specific scientific basis for the maximum size of 5 mm, its formalization in California has prompted widespread informal adoption of this upper boundary in both peer-reviewed literature and mainstream media articles.

> **California Division of Drinking Water Definition of Microplastics**
>
> 'Microplastics in Drinking Water' are defined as solid polymeric material to which chemical additives or other substances may have been added, which are particles which have at least three dimensions that are greater than 1 nanometer and less than 5,000 micrometers. Polymers that are derived in nature that have not been chemically modified (other than by hydrolysis) are excluded.

No particular definition of MP was assumed in the context of this report, which inherently incorporates the varied definitions utilized by the authors of the respective studies referenced from the literature review. (Note that this inconsistency in the literature underscores a research need to develop a standardized definition of "microplastics," an issue that transcends all seven topic areas of this report.) However, as used in this report, the term "microplastic(s)" – shortened to "MP" – is considered to be essentially in alignment with the size range specified in the California definition: 1 nm - 5 mm. Accordingly, the term "nanoplastics" is used to refer specifically to the subset of MP with sizes between 1 - 1,000 nm.

The size of range associated with the California definition is demonstrated in a two-part illustration shown in Figures 1-1 and 1-2. Figure 1-1 shows the entire span of the definition in logarithmic scale, with colored bars depicting the scientifically recognized nano, micro, and milli ranges. This same span and size-associated color bars are shown in Figure 1-2, albeit on a linear (vs. logarithmic) scale from 0 to 5 mm. For context and comparison, Figure 1-2 also depicts the sizes of some commonly known items and their respective positions in the California microplastic size spectrum.

1.4.3 Important Notes

The topical state-of-the-science summaries are purposefully concise in order to facilitate the objectives identified in Section 1.2: 1) fostering understanding; 2) directing research funding; and 3) informing appropriate MP policy and regulatory determinations. The report is not intended to provide an extensive, in-depth discussion of all MP knowledge applicable to water supplies. Also, different MP subject matter experts may disagree on the extent to which some key questions identified in this report may already be adequately understood; however, such disagreement itself indicates a lack of consensus that supports the inclusion of such questions. In addition, it is widely understood that MP science is evolving quickly, such that some key questions identified in this report may already be under active investigation by researchers, potentially with pending publication of articles and/or reports discussing work that has been completed. Moreover, ongoing research may elucidate new key questions not yet envisioned at the time of this report, some of which could warrant high prioritization.

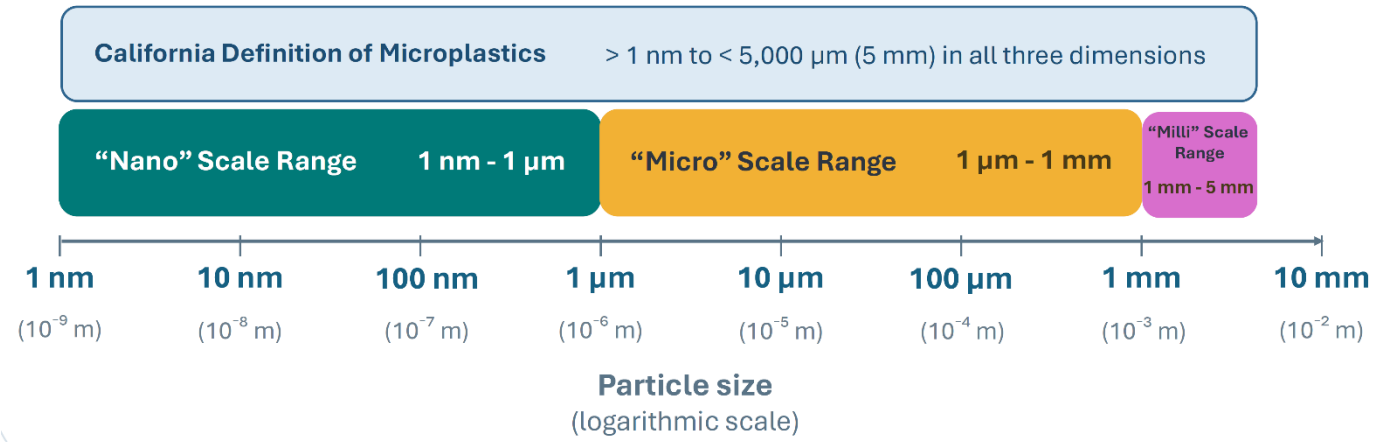


Figure 1-1: Microplastics size range per the California definition, expressed in logarithmic scale.

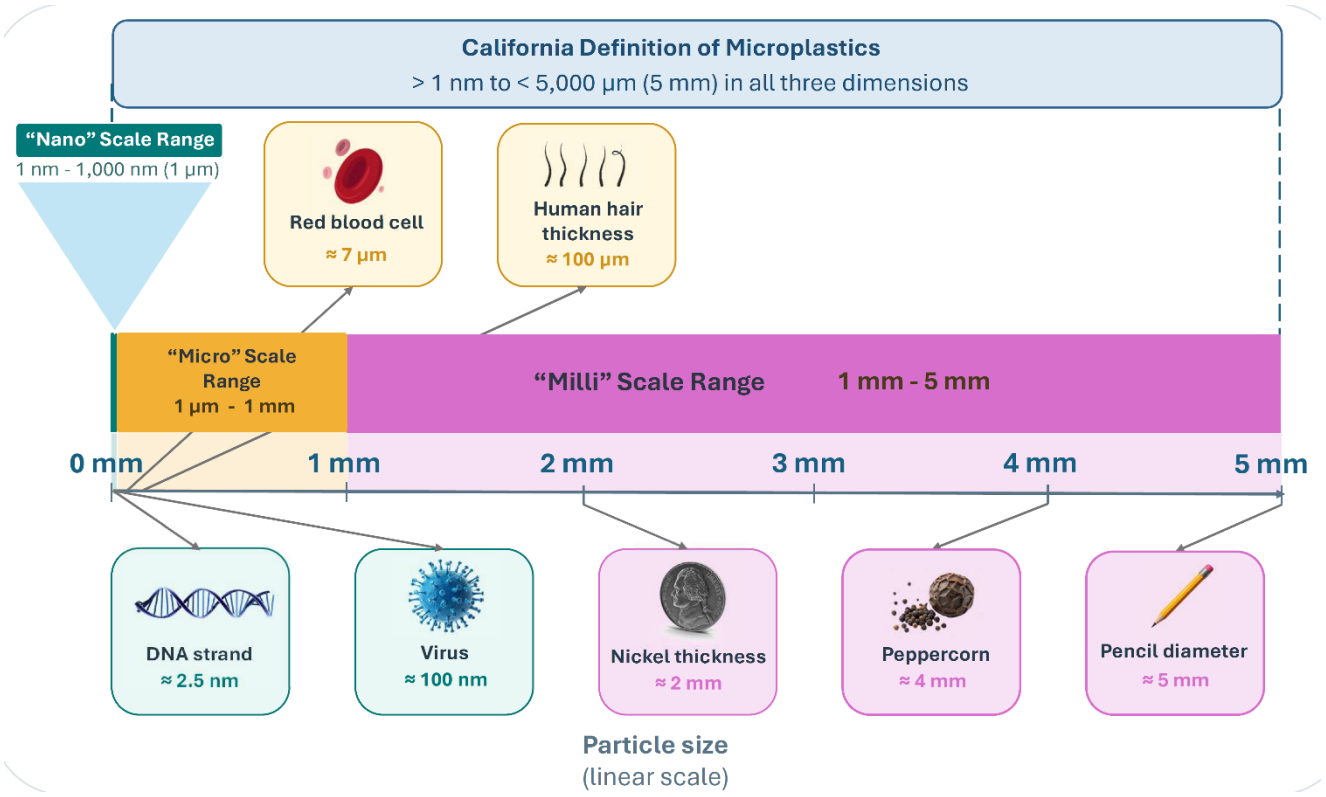


Figure 1-2: Microplastics size range per the California definition, expressed in linear scale.

2 Regulatory Landscape

2.1 Overview of Regulatory Activity

Currently, there are no federal or state regulatory criteria or standards for MP in any media (e.g., water, wastewater, air, or food). Although several states are exploring regulatory activity associated with MP in drinking water (e.g., monitoring programs), only California and New Jersey have enacted criteria and/or requirements for MP into law.

With the passage of Senate Bill (SB) 1422 "Microplastics in Drinking Water" in 2018, the State of California mandated not only the establishment of a statutory definition of MP, but also the development of standard analytical methods, the associated accreditation of laboratories, and a framework for four years of monitoring in drinking water supplies, explicitly requiring the public disclosure of monitoring results. In August 2022, the California State Water Resources Control Board released the "Policy Handbook Establishing a Standard Method of Testing and Reporting of Microplastics in Drinking Water," which indicated the state's intent to quantify MP in using either Fourier-transform infrared (FTIR) or Raman spectroscopy (i.e., approving both methods) and outlined a two-phase monitoring plan. While the first phase of monitoring targets source waters, the focus and scope of the subsequent second phase will be informed by the findings of the first (California State Water Resources Control Board 2022). Notably, the first phase has not yet been initiated, pending further advancements in sampling and analysis that are necessary to ensure meaningful data quality (as discussed in Sections 4 and 5 of this report).

In January 2024, the State of New Jersey enacted legislation with many similarities to that promulgated in California (consolidating provisions of Assembly Bill Nos. 4821 and 4823), that "Directs DEP (Department of Environmental Protection) to take certain actions concerning the identification and testing of microplastics in drinking water, and requires DEP and BPU (Board of Public Utilities) to study and promote the use of microplastics removal technologies." The required actions and studies, along with a resulting framework for four years of public water system monitoring (similar to California), must be completed by January 2027 (i.e. three years after the effective date of the legislation).

Although there is only formal regulatory activity pertaining to MPs in drinking water in California and New Jersey, other states are taking preliminary steps to explore more formal action. For example, in Michigan, two bills with provisions concerning the establishment of programs for monitoring MP in drinking water were introduced into the legislature in 2025 (Senate Bill Nos. 504 and 505), both of which would require sampling. However, the text of the bills only references the use of sampling methods consistent with the best practices of other organizations or agencies (with some examples provided in the discussion, including the state of California). Neither of these bills has been signed into Michigan law as of October 2026. In Virginia, two bills relating to the study of MP occurrence in public drinking water and the development of recommendations for the reduction of MP in drinking water (House Bills 1618 and 33) failed to pass in 2025.

On April 6, 2026, U.S. EPA published the draft CCL 6, citing MP as a priority contaminant group for potential future drinking water regulation under the Safe Drinking Water Act (SDWA) for the first time and potentially informing selection for future monitoring cycles under the Unregulated Contaminant Monitoring Rule (UCMR). Notably, MP were not included in the draft Sixth UCMR (UCMR 6), issued on June 26, 2026.

2.2 References

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Virginia House Bill 33. 2026. 2026 Regular Session, https://lis.virginia.gov/bill-details/20251/HB33/text/HB33

3 Occurrence

3.1 Brief Topical Synopsis

The occurrence of MP in water supplies is an important component of making appropriate regulatory policy decisions, whether in drinking in water (as is the primary focus of this report), wastewater, air, or other context. However, knowledge of occurrence is predicated on precise, accurate, reliable, and repeatable sampling and analytical methods.

3.2 State-of-the-Science

MP occurrence studies have been conducted globally across various matrices and have demonstrated the ubiquity of MP in air, water, sediments, soils, consumer products, and living organisms (Mendoza et al. 2021; Petersen and Hubbart 2021; Koelmans et al. 2019; Sun et al. 2019). MP can enter the environment via numerous vectors, including direct contaminant discharge (e.g., industrial accident, insufficient quality controls at plastics manufacturing facilities, etc.), effluents from wastewater treatment plants (WWTPs), stormwater systems, airborne deposition, and surface runoff. Rivers and streams may convey MP to lakes and oceans, which often function as MP sinks (Mendoza et al. 2021; ITRC 2023; Eastern Research Group, Inc. 2025).

The fate and transport of MP are influenced by their physical characteristics, as well as interactions with the environment, including particle mobility and transport processes (Mendoza et al. 2021). Hydrodynamic and atmospheric conditions often control the overall fate of MP. The size, density, and morphology (i.e., shape) of MP particles are additional factors that affect their rate of dispersion, resuspension, and sinking. In aquatic environments, MP can float long distances or travel through the water column to settle in sediments (Mendoza et al. 2021).

MP are comprised of two broad categories: primary and secondary. Primary MP are typically defined as those purposefully engineered for end-user consumer products (e.g., cosmetics or biomedical products) (U.S. EPA 2026; Song et al. 2024). Secondary MP are particulates that have fragmented from larger plastic materials (due to photodegradation, physical forces, or biological/chemical reactions). Examples of secondary MP sources include food wrapping, tires, and synthetic textiles, among many others (U.S. EPA 2026). MP can also further fragment over time, resulting in the production of a larger number of smaller particulates, thereby increasing the concentration (while conserving the total mass). Studies suggest that MP < 10 µm represent the largest fraction of MP in both raw and treated drinking water (Pivokonsky et al. 2018; Novotna et al. 2019). Note that the relative contributions of primary vs. secondary MP in the environment are generally unknown and difficult to assess.

Throughout the literature, MP occurrence is generally reported in terms of concentration (e.g., mass or count), physical characteristics (e.g., size or shape), and chemical characteristics (e.g., polymer type) (Eastern Research Group, Inc. 2025). Reported MP concentrations often vary widely, even within a given matrix type (e.g., water, wastewater soil, air, etc.). For example, MP have been observed in freshwater (the main source of human drinking water) around the world, including remote geographies, with reported concentrations ranging from very low to several thousand particles per liter (Shen et al. 2020; Petersen et al. 2021; Eastern Research Group, Inc. 2025). This wide variation observed in environmental samples is likely exacerbated by the wide range of sample collection and analysis methods employed, as well as the lack of a standardized reporting framework. MP concentrations in freshwater sources are typically elevated in urban locations relative to rural settings, and the characteristics of MP (i.e., size, shape, polymer type, etc.) are influenced by residential, commercial, and industrial activity within the area (Eastern Research Group, Inc. 2025; Koelmans et al. 2019).

There is a need for the development of higher-quality MP occurrence data across all matrices, with a notable gap in the literature related to groundwater sources (relative to other source water types). The development of high-quality data should include implementing both rigorous and consistently applied quality control (QC) and standardized protocols for sampling, sample preparation, analytical methods, data collection, data analysis, and data reporting criteria (Eastern Research Group, Inc. 2025). Such standardization of occurrence data would yield meaningful insight to help answer subsequent key questions. For example, improved confidence in occurrence data (via standardization) would facilitate understanding of relative exposure pathways (i.e., how MP occurrence in drinking water compares with other exposure routes such as air (inhalation) or food (ingestion)). It would also help assess contaminant co-occurrence with MP to inform more holistic toxicological assessments and treatment approaches, as well as the relative loading of various MP primary sources.

3.3 Research Needs

Key questions applicable to MP occurrence, as informed by the state-of-the-science assessment, are provided in Table 3-1, with the questions grouped CRTs.

Table 3-1: Consolidated Research Topics - Occurrence

ID	Consolidated Research Topic	Key Questions
OCC-1	Source Water Concentration Influences	How do source concentrations vary daily, seasonally, following storm events, and with respect to wind direction?
		How do source concentrations vary by depth in the water column?
		How do source concentrations vary by source water type (e.g., various types of surface waters and groundwater) and location (e.g., relative to urban centers, freeways/roads, etc.)?
		What are the critical point/non-point sources driving MP loading into source waters, and how do these vary seasonally/geographically?
OCC-2	Sharing Standardized Occurrence Data	What occurrence data (e.g., polymer type, size, concentration) should be part of standard reporting?
		What type of online data-sharing platform would be most beneficial for sharing occurrence data (including meta data) locally, regionally, and globally, considering ownership, quality assurance (QA) / QC protocols, contribution rules, storage, etc.?

ID	Consolidated Research Topic	Key Questions
OCC-3	Occurrence and Trends in Various Media and Matrices	Are there patterns in the dominant polymer type(s) and concentrations across water sources?
		How do micro- and nanoplastic concentrations compare in raw and treated waters?
		How does MP occurrence in drinking water compare with other potential sources such as air (inhalation) or food/beverages (ingestion)?
		How does MP occurrence compare in bottled water vs. tap water?
OCC-4	Occurrence in Distribution Systems	Do MP concentrations vary with respect to different locations in drinking water distribution systems? Do any spatial trends emerge after water flows out from a treatment facility?
		Does residential and/or utility-owned plastic piping contribute to MP occurrence? If so, how long does the plastic piping contribute to MP occurrence (i.e., only for a short time following installation, or continuously over the life of the material)?
		To what extent do changes in flow conditions trigger MP release in the distribution system/premise plumbing?
		To what extent do distribution system maintenance materials (e.g., crack-repair polymers, coatings, paint in tanks, etc.) contribute to MP?
		To what extent do distribution systems serve as sources/sinks of MP (e.g., storage tanks, piping, etc.)?

3.4 References

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4 Sampling

4.1 Brief Topical Synopsis

Sampling practices can exert a significant influence on analytical results, particularly given the numerous vectors for contamination by plastic materials. Even with proper QA/QC, sample equipment design and protocols can influence both the concentrations of MP and the attributes of the captured particulates. These influences, in turn, can affect the findings of occurrence and treatment studies, as well as the results of regulatory compliance monitoring (if/when applicable).

4.2 State-of-the-Science

There are two main approaches for MP sample collection: 1) collection of water in containers such as bottles (i.e., grab sampling); and 2) field filtration of water to collect particles of a given minimum size. Guidance provided by the ISO describes both approaches as valid and includes specific considerations with respect to sample volume, equipment, and inclusion of blanks for QA/QC (International Organization for Standardization 2025). For example, when collecting grab samples via bottles, volumes may be limited to a few liters; moreover, bottles, along with the inner surfaces of their lids, as well as any required pumps or tubing, should all be non-plastic. Similar recommendations are provided for filtration-based collection approaches, including the use of a series of filters of decreasing pore size, all comprised of metal. Note that the use of a plastic polymer that is uncommon in environmental samples may also be acceptable, as detectable concentrations of that polymer type can be deducted from the results. By contrast, ASTM prescribes the use of stainless-steel sieves arranged in a stack through which water is passed from a sampling tap via gravity (i.e., a non-pressurized system) (ASTM 2020). Limitations associated with the ASTM method include: 1) susceptibility to contamination by airborne MP due to not being fully enclosed; 2) breakthrough of retained particles as water flow is concentrated onto a small area of sieve surfaces; 3) limited total volume due to a lack of pressurization; and 4) difficulty in extracting particles retained on material surfaces via rinsing, which may serve as a source of contamination in subsequent samples collected using the same sieves (Almuhtaram et al. 2022).

Studies have assessed the use of enclosed in-line filtration-based sampling approaches vs. container-based sampling, in addition to the ASTM sieve-based method (Yuan et al., 2022; D'Ascanio et al., 2025). These studies highlighted substantial contamination when using container- or sieve-based sampling methods due to deposition by airborne MP, even when equipment is only briefly exposed to air. Therefore, enclosed, in-line filtration systems are recommended as current best practice for drinking water MP sample collection. Additional best practices to further mitigate sample contamination include preparation of sampling equipment in MP-free environments such as under a HEPA-filtered laminar flow hood, if available, or at a minimum, use of portable HEPA filters. In addition, sampling equipment (filter holders, tubing, valves, etc. – any surface exposed to the sample volume) should be ultrasonicated and rinsed thoroughly using microplastic analytical grade (MAG) water (as defined in the two California standard operating procedure (SOP) documents for extraction and analysis of MP particles); non-synthetic clothing should be worn by sampling personnel, potentially dyed with a characteristic color such that fibers can be readily identified; and field, matrix, trip, and/or procedural blanks should be prepared alongside samples, as appropriate (Wong et al. 2022b, 2022a; Munno et al. 2023; Lao et al. 2025; Al-Azzawi et al. 2022).

Recommendations for sample volume in the literature appear to be contradictory, ranging from 1 L to > 1,000 L (ASTM 2020; Coffin et al. 2022; ISO 2025; Cross et al. 2025). The underlying reason for these discrepancies is the documented variation of MP abundance with particle size, with concentrations

increasing logarithmically as size decreases (Feng et al. 2025; Cross et al. 2025; Kooi et al. 2021). Therefore, large volumes (1,000 L or more) may be required when considering a minimum particle size as high as 50 µm or larger (Koelmans et al. 2019), whereas a volume of ≤ 1 L may be sufficient for a minimum size of 1 µm and if only smaller particles are of interest (Coffin et al. 2022; Cross et al. 2025). Thus, large volumes are necessary to yield representative samples of larger particles, which occur at much lower concentrations; however, for smaller particles occurring in much higher numbers, smaller sample volumes may be appropriate. Consequently, the target sample volume may ultimately depend on the particle size(s) determined to be most toxicologically relevant. Other water quality and analytical factors may also greatly impact sample volume. For example, turbidity (including both organic and inorganic particulates) can impact filterability via clogging.

Analysis using spectroscopy-based techniques (such as those approved by the State of California – see Section 5 (Analysis) of this report) requires careful consideration of sample volume, since larger volumes result in a greater number of particles retained on the filter element (assuming the use of a field filtration technique). Thus, for the evaluation of a filter element (whether the entire filter area or specified sub-sampling area (e.g. 5% of the total), a greater number of particles increases the time required for analysis. Similarly, for a given limit on the analysis time (e.g., 2 days), a greater number of particles decreases the percentage of filter area that can be evaluated (Feng et al. 2025; SWCRB 2022). By contrast, larger sample volumes may be required for analysis by pyrolysis-gas chromatography/mass spectrometry (Py-GC/MS) in order to exceed minimum mass detection limits (Xu et al. 2024). Ultimately, sampling and analytical strategies should be based on characterizing MP attributes that drive potential human health risks, if/when such linkages are confidently established.

Most sampling campaigns in drinking water involving the collection of a single sample are only capable of representing snapshots of MP concentration at a particular time. Variability of results > 100% has been reported among multiple **source** water samples for the same site over 9-12 months (Johnson et al. 2020; Moses et al. 2023). By contrast, studies which examined **treated** water samples collected within 24 hours reported < 10% variability (Kirstein et al. 2021; Xu et al. 2024). (Note that these summaries of studies do not necessarily suggest whether such trends exist for source water samples collected over short intervals or for treated waters over longer periods). The spatial and temporal variability of MP raises questions regarding the representativeness of a single individual sample collected in an isolated event, particularly in source waters, which are directly subject to more variable influences (vs. treated waters). In order to establish baseline data regarding human exposure via drinking water, sampling frequency may be determined based on a preliminary understanding of variability in treated water, as well as a desired confidence level (i.e., reliability of results).

4.3 Research Needs

Key questions applicable to MP sampling, as informed by the state-of-the-science assessment, are provided in Table 4-1, with the questions grouped into CRTs.

Table 4-1: Consolidated Research Topics - Sampling

ID	Consolidated Research Topic	Key Questions
SAM-1	Certification	What QA/QC procedures or data are required for sampling to be considered valid?
SAM-2	Sample Representativeness	What sampling volume is appropriate, considering tradeoffs relating to specific methods of collection and analysis?
		What information is needed to pre-determine a target sampling volume?
		How many samples should be collected over what time frame to capture variability?
		What constitutes a "representative" sample?
SAM-3	Sampling Equipment	What characteristics of sampling equipment are important when considering routine monitoring of drinking water?

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5 Analysis

5.1 Brief Topical Synopsis

As with sampling, analytical methods are subject to numerous vectors for MP contamination, and the specific techniques and protocols utilized can likewise influence both the concentrations of MP and the associated attributes that can be identified and described (e.g., polymer type, size, mass concentration, morphology etc.). Thus, also like sampling, not only is QA/QC particularly important, but the various influences on the results can affect the findings of occurrence and treatment studies, as well as regulatory compliance monitoring (if/when applicable).

5.2 State-of-the-Science

There are two types of techniques for chemically identifying MP: 1) particle-based (or count-based); and 2) mass-based. Particle-based methods involve the use of combined microscopy-spectroscopy instruments such as Raman, FTIR, laser direct infrared (LDIR), and optical-photothermal infrared (O-PTIR) systems, which differentiate plastic particulates and enable them to be individually quantified. By contrast, mass-based methods employ mass spectrometry to quantify the mass of specific plastic polymers in a sample; because these are destructive methods, they do not allow for individual quantification of particles (Seeley and Lynch 2023; Yang et al. 2024). Low-cost surrogate methods exist for MP analysis using fluorescence microscopy for particles stained with dyes such as Nile red; however, these techniques may be applicable to only a limited number of polymer types (Aslam et al. 2025).

No reliable means of converting particle counts to mass or vice versa has been identified due to a wide array of variables, including particle shape, size, density, and polymer type (Kirstein et al. 2021; Primpke et al. 2020; Sefiloglu et al. 2024). Other analytical tools such as fluorescence microscopy, flow cytometry, stereomicroscopy, and scanning electron microscopy (SEM) can be used to determine particle characteristics such as size, concentration, and morphology; however, they do not allow identification of polymer types or differentiation of plastic vs. non-plastic particles. Thus, these methods are typically applied when the polymer type is known, such as in studies involving spiked fluorescently labelled MP to determine particle recovery (D'Ascanio et al. 2025).

Analysis using spectroscopy-based techniques generally involves concentrating microplastic particles on a 25-47 mm diameter filter composed of a material that is metal or a non-targeted polymer type and does not introduce interference to the characteristic particle spectra generated by the techniques. Spectra acquired from individual particles are subsequently compared to spectral libraries of known material types to confirm whether they are plastic. Spectroscopic techniques are generally capable of chemically identifying most polymers, although some specific types such as polyvinylidene difluoride (PVDF) or polyvinyl chloride (PVC), as well as environmental or modified polymer variants (such as polyethylene containing a dye additive), may be difficult to distinguish.

Current mass-based techniques such as py-GC/MS and thermal extraction desorption (TED)-GC/MS are limited to the identification of 5-12 polymer types based on available literature, depending on the sample preparation method and instrument settings utilized (Sorolla-Rosario et al. 2023; Hermabessiere et al. 2018; ASTM 2024; Seeley and Lynch 2023; Munno et al. 2020). For spectroscopy-based techniques, spectra-matching algorithms (i.e., between spectra generated from MP of unknown polymer type and reference spectra) can be used to generate comparison metrics such as hit quality index (HQI) (Clough et al. 2024). However, these metrics do not necessarily consider characteristic peak features ("fingerprint regions"), an omission which can result in incorrect matches. Thus, human expert verification of spectral matches is typically required. This process may be aided by the use of machine learning (ML) algorithms

to improve match accuracy (Clough et al. 2024; Eurofins 2025; Moore Institute 2025; Weber et al. 2023; Lim et al. 2024).

Current size-based limits of detection for spectroscopy-based techniques are ~10-20 µm for FTIR and LDIR, ~1 µm for Raman, and approximately 500 nm for O-PTIR (Yang et al. 2024; Parham et al. 2025; Macairan et al. 2025). The State of California has specified SOPs for Raman and FTIR spectroscopy that are applicable for MP > 20 and > 50 µm, respectively (Wong et al. 2022a; Wong et al. 2022b). These limits were selected based on the findings of an interlaboratory study conducted in 2021 by the Southern California Coastal Water Research Project (SCCWRP), which showed poor accuracy for smaller MP by participating labs (De Frond et al. 2022). While analytical capabilities among labs have subsequently improved, the State has not replicated the interlaboratory study to update the SOPs. TED- and py-GC/MS (i.e., mass-based techniques) theoretically have no lower size limit (i.e., resolution). However, it is important to recognize that mass decreases exponentially with particle size. Therefore, while nanoplastics (i.e., the subset of MP in the 0.001 - 1 µm size range, as shown in Figure 1-1) may be inherently incorporated during TED- or py-GC/MS analysis, it may be necessary to fractionate samples into a range of size bins (e.g., < 1 µm, 1-10 µm, 10-20 µm, and > 20 µm) prior to analysis to help ensure that their contribution to overall mass may be accurately quantified (Xu et al. 2024).

The time required for spectroscopy-based analyses depends on the instrument settings used, minimum particle size to be quantified, the size of filter area for analysis, and the total number of plastic and non-plastic particles present (Feng et al. 2025; Brandt et al. 2021). For example, sub-sampling of approximately 22% of a 25-mm diameter filter containing 60,000 to 180,000 particles ranging in size from 5-20 µm has been reported to take 4-8 days, even when using automated Raman spectroscopy tools for spectra acquisition and particle identification (Pittroff et al. 2021). (For example, although a custom-trained artificial intelligence (AI) agent can potentially improve both the speed and accuracy of matching Raman spectra to identify MP particulates and the associated polymer type, there is a still a physical limit to the speed at which the Raman laser can be aimed from particle to particle.) In another study, analysis of up to approximately 6% of a 47-mm diameter filter containing 200,000 to 250,000 particles > 2 µm was reported to take 2-3 days per sample (Balkenbusch et al. 2025). By contrast, analysis time for mass-based TED- and py-GC/MS is typically much more rapid, ranging from 20 to 120 min per sample, irrespective of the number of particles (Sorolla-Rosario et al. 2023; Hermabessiere et al. 2018; Gomiero et al. 2019; Dalmau-Soler et al. 2024).

Analysis is complicated by the fact that MP typically represent only a small fraction (e.g., ~1%) of the total particles present in drinking water (Brandt et al. 2021). Thus, for particle-based analytical methods, considerable time may be necessary to characterize and differentiate non-plastic particles. For mass-based methods, non-plastic organic materials may interfere with polymer detection during mass spectrometry, resulting in artificially high measurements. In order to overcome these challenges, laboratories apply sample preparation steps such as chemical to remove non-plastic organic particles (Feng et al. 2026; Rani et al. 2023; Cheng et al. 2025; ASTM 2020). Several studies of MP specifically in drinking water matrices have successfully minimized or eliminated such sample preparation steps in conjunction with mass-based analytical methods (Bonaccorso et al. 2025; Dalmau-Soler et al. 2025; Kirstein et al. 2021). However, whether using mass- or particle-based methods, the need to conduct one or more sample preparation steps, as well as the particular step(s) utilized, will vary with the water quality of the sample. Accordingly, systematic evaluations of digestion methods for both source and treated drinking water, as well as wastewater effluent, have been reported in the literature, and laboratories can strategically select the sample preparation steps appropriate for the water quality of the sample matrix (Lao et al. 2024; Cheng et al. 2025). Consequently, although the development of new sample preparation methods is not considered a significant knowledge gap, better defined linkages between specific sample characteristics (e.g., water quality and MP polymer type(s) and particle size(s)) and the most effective sample preparation techniques would improve data quality and reduce the time required for analysis.

Note that although density separation is also a commonly cited MP sample preparation step, such a step is more applicable for dense inorganic particulates; because these inorganic particles occur in much lower concentrations in drinking water and wastewater effluent (vs. environmental samples such as soil), no systematic evaluation of density separation methods has been reported for these matrices (Liu et al. 2022; Motiejauskaitė and Barčauskaitė 2025).

QA/QC practices during MP analysis involve defining accuracy, precision, and detection limits. Accuracy can be assessed by analyzing a spiked sample with a known concentration of MP comprised of a specific polymer type; the accuracy of the method is quantified by the ratio of the measured concentration to the known value. Precision is determined by the variability (i.e., relative standard deviation) in measurement of replicate spiked samples or by repeated measurement of environmental samples (D'Ascanio et al. 2025). For spectroscopy-based analyses, detection limits may be defined as a minimum detectable amount (MDA) of MP based on procedural blanks (Wong et al. 2022b, 2022a). Spiked samples can enable the determination of accuracy, precision, and MDA for specific polymer types, particle sizes, and morphologies, provided that those characteristics are defined for the spiked MP; thus, these spikes may indicate polymer-, size-, or shape-based limitations for a given method. Spiking may be performed using environmental matrices provided that spiked MP can be differentiated from background MP, such as by using fluorescently labeled particles (D'Ascanio et al. 2025; Gao et al. 2022). For TED- and py-GC/MS (mass-based methods), accuracy, precision, and limits of detection (LODs) and quantitation (LOQs) are determined using clean matrices spiked with MP, since py-GC/MS cannot distinguish spiked vs. background MP in environmental matrices on the basis of physical characteristics such as fluorescence, shape, or size. Clean matrices may be prepared by passing water through filters with pore sizes smaller than those to be used for sampling and analysis (e.g., 0.45 µm when using a 1 µm minimum size for sample collection). For both spectroscopy-based and mass-based methods, analysis of laboratory, field, trip, and/or procedural blanks (as applicable) that serve as negative controls is essential for characterizing background contamination that may occur during various stages of sample handling. An interlaboratory study involving 84 laboratories reported recoveries ranging from 45% to 129% for polyethylene (PE) and polypropylene (PP) particles 10-200 µm in size, indicating a need for standardization of both reference materials and analytical methods (Ciornii et al., 2025).

Due to the lack of standardization, the wide range of analytical practices that have been employed among studies of MP in drinking water make direct comparison of results challenging (Balkenbusch et al. 2025). As such, there is need for analytical methods validated across laboratories (whether mass- or particle-based) with appropriate QC data, accuracy, and precision that will allow for the reliable detection and analysis of MP characteristics of relevance to human health in drinking water (U.S. EPA 2026). Selection of a specific analytical method for potential routine monitoring depends on the most toxicologically relevant metric(s) to characterize human health risk. Pending the identification of such metrics, monitoring MP to provide baseline data regarding particle- and mass-based exposure may be beneficial (Coffin et al. 2022).

5.3 Research Needs

Key questions applicable to MP analysis, as informed by the state-of-the-science assessment, are provided in Table 5-1, with the questions grouped into CRTs.

Table 5-1: Consolidated Research Topics - Analysis

ID	Consolidated Research Topic	Key Questions
ANA-1	Data Quality and Reliability	What QA/QC procedures or data are required for analysis to be considered valid?
		How can MP be spiked into environmental matrices such that they can be distinguished from background MP when performing analysis using py-GC/MS?
		How can confidence in MP spectral identification be meaningfully improved?
		Can the thoroughness of spectral libraries be improved to ensure accurate matches?
		Can spectral libraries be standardized for Raman and IR-based spectroscopy to ensure both accuracy and consistency among diverse analytical laboratories?
		Under what conditions is human verification of spectral matches required?
ANA-2	Analytical Efficiency and Throughput	How can sample preparation steps (i.e., digestion of organics) be optimized based on water quality data?
		What are the analytical conditions that may decrease analytical time without compromising data quality?
		Can AI / ML tools improve sample analysis by reducing time, lowering costs, increasing filter sample area analyzed, and/or improving accuracy of detection?
ANA-3	Precursors to Routine Monitoring	Which analytical instruments and methods should be used for micro- and nanoplastic quantification in drinking water?
		How should the accuracy and precision of an analytical method be evaluated before a laboratory is accredited to perform MP analysis?
		What steps would be required to formally standardize a MP analytical method for drinking water?

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6 Treatment

6.1 Brief Topical Synopsis

An in-depth understanding of MP treatment efficacy is important for informing appropriate regulatory policy (if/when applicable). In addition, utility customers are also increasingly interested in the ability of treatment plants to remove MP from their drinking water supplies. However, establishing such an in-depth understanding is predicated on precise, accurate, reliable, and repeatable sampling and analytical methods.

6.2 State-of-the-Science

While drinking water treatment processes aim to provide clean, safe drinking water that protects public health in compliance with state and federal regulations, these technologies have not specifically been designed or optimized to target MP. MP removal via drinking water treatment reported in the literature ranges widely, with an array of studies reporting reductions between 13% and > 98% (Balkenbusch et al. 2025; Seay et al. 2025; Xu et al. 2024; Valdiviezo-Gonzales et al. 2026; Pivokonsky et al. 2018; Shen et al. 2020; Wang et al. 2020; Novotna et al. 2019). In addition to the potential variation associated with sampling and analysis (as discussed in Sections 4 and 5 of this report. respectively), this variability may be attributable to different treatment processes being assessed and the diverse physical properties of the MPs themselves (i.e., size, shape/morphology, polymer type, surface charge, degree of weathering, and other attributes).

For example, drinking water treatment processes such as coagulation and sedimentation (both designed to remove particulates), can achieve > 50%removal of MP larger than 10 µm, while smaller MP may more easily evade water treatment (Wang et al. 2020; Eastern Research Group, Inc. 2025). A similar pattern is observed for filtration processes, with studies suggesting that MPs < 50 µm predominate in the effluent of sand filtration, while larger particles are generally removed (Kankanige et al. 2021; Wang et al. 2020, Acarer 2023; Xu et al. 2024). Note that Balkenbusch et al. (2025) reported that removal of MP particles ≧ 2 µm was primarily achieved via granular media filtration at conventional treatment plants.

The relationship between MP characteristics and removal by various treatment strategies remains unclear and necessitates additional research (Pivokonsky et al. 2018; Shen et al. 2020; Wang et al. 2020; Novotna et al. 2019; Na et al. 2021). Even within a single unit process, there are many complexities that complicate the ability to understand MP removal, including variability with relevant unit process design criteria and operational parameters (e.g., media size, media type, flow rate, and hydraulic residence time, among others). Additional research is also needed to understand any impacts MP may have on the efficacy of drinking water treatment plant processes (Shen et al. 2020). Although several studies have noted the inhibition of wastewater processes by MP, the potential for similar impact in drinking water treatment plants has not been sufficiently studied (Liu et al. 2023; Pittura et al 2021). Note that direct comparison between studies of MP removal should be made carefully to differences in treatment technologies applied, MP sampling techniques, sample preparation techniques, analytical methods, and QA/QC practices, as well as potential differences related to spatial/temporal variations and sampling location (Novotna et al. 2019).

Several studies have explored potential correlations between the removal of MP and other commonly measured particulate water quality parameters in an effort to identify a suitable surrogate measurement for MP (Balkenbusch et al. 2025; Lapointe et al. 2020; Sarkar et al. 2021; Ma et al 2019). Most recently, Balkenbusch et al. (2025) reported no significant correlation with turbidity, particle counts, or total organic carbon (TOC), suggesting that no parameters routinely monitored in drinking water treatment

plants may be suitable surrogates. It is important to note that the full assessment of surrogate potential is challenging, given that MP are estimated to comprise only about 1% of total particles in water samples (Brandt et al. 2021). In addition, given the diversity of MP attributes, it is not known whether a correlation with turbidity or particle count data may exist for a specific MP polymer type, size fraction, morphology, etc. However, given the variability of MP characteristics, it is unlikely that surrogate measurements can accurately reflect MP removal across different size ranges, polymers, and particle shapes.

MP removal can be enhanced through advanced treatment processes such as membrane filtration; with respective nominal pore sizes of 100 and 10 nm, micro- and ultrafiltration act as sieves for all but the smallest MP particulates (Balkenbusch et al. 2025; Sun et al. 2019; Wang et al. 2020; Eastern Research Group, Inc. 2025). However, optimization of drinking water treatment to address MP must consider potential treatment capital and operation costs against clearly understood public health needs relative to the currently regulated contaminants for which plants are already designed (Eastern Research Group, Inc. 2025). To inform this assessment, additional research is needed to better understand not only treatment technologies in terms of feasibility, practicality, and effectiveness for MP removal, but also the human health impacts that could necessitate additional and/or further optimized treatment.

6.3 Research Needs

Key questions applicable to MP treatment, as informed by the state-of-the-science assessment, are provided in Table 6-1, with the questions grouped into CRTs.

Table 6-1: Consolidated Research Topics - Treatment

ID	Consolidated Research Topic	Key Questions
TRT-1	Quantifying MP Removal	What unit processes can effectively remove nanoplastics?
		How should “effective removal of MP” be defined / characterized, particularly given the inability to individually quantify a wide range of nanoplastics with existing analytical technology?
TRT-2	Understanding Variable Removal Efficiency	How does unit process removal vary with MP attributes, water quality, design criteria, and operational parameters?
		How does biofilm formation (e.g., on granular filter media) impact MP removal?
TRT-3	Treatment Technologies	What innovative technologies are on the horizon for the effective (and/or targeted) removal of MP from drinking water?
		Are there point-of-use (POU) devices that effectively remove MP? If so, what POUs are most appropriate for what kinds of MP?

ID	Consolidated Research Topic	Key Questions
TRT-4	Treatment Optimization	How can utilities optimize their existing treatment to improve the removal of MP?
		Which coagulants are more/less effective at removing MP? How is MP removal impacted by polymer addition (to facilitate coagulation)?
TRT-5	Treatment Systems as a Source/Vector for MP Contamination	To what extent is treatment plant infrastructure a vector for MP contamination?
		To what extent are polymeric membrane processes a source of MP?
		Are MP introduced into water via any of the typical chemicals/additives used during treatment?
		To what extent do treatment processes alter MP characteristics (surface properties, charge, etc.)?
TRT-6	Residuals Management	What are the appropriate means of disposing of concentrated MP particulates removed during treatment that would otherwise be recycled into the environment via land application or liquid residual discharges?
		What is the ultimate fate of MP removed during drinking water treatment?

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7 Source Control

7.1 Brief Topical Synopsis

Controlling MP at their source(s) may be an important part of minimizing human exposure and reducing the need for treatment processes to remove MP. However, as with treatment, an in-depth understanding of the ability of source control measures to reduce MP loading is predicated on precise, accurate, reliable, and repeatable sampling and analytical methods to characterize potential contamination vectors.

7.2 State-of-the-Science

Before the occurrence and transport of MP in the environment and sources of drinking water can be controlled, it is necessary to have a better understanding of potential MP sources and vectors for drinking water contamination (U.S. EPA, 2026; Fahrenfeld et al., 2019). In order to best focus source control efforts, sources of MP that are toxicologically relevant to human and ecological health, as well as limitations of conventional drinking water treatment processes for MP removal, also need to be better understood. Several sources have been investigated in the current literature, with WWTPs identified as significant contributors of MP to surface waters. Conventional wastewater treatment processes have been shown to be effective in removing MP, but wastewater effluent can still contribute substantial MP loading into receiving bodies (Zhuang et al. 2024; Acarer 2023; Kwon et al. 2022; Liu et al. 2021; Tang et al. 2021; Cristaldi et al. 2021; Iyare et al. 2020). Luo et al. (2023) found that the optimization of operational parameters for treatment processes at WWTPs, including the equalization tank and cyclic activated sludge system, could plausibly reduce the concentration of MP in the treated wastewater effluent by an order of magnitude, as a modeled relationship showed a reduction from 35 to 3 MP/L on average, considering a MP size range of 10 - 5,000 µm (Luo et al., 2023). However, such optimization must be balanced with regulatory and performance considerations (Luo et al., 2023).

For example, while larger MP (50 - 5,000 µm) were reported to be generally removed more effectively in an equalization tank, a decrease in the tank's surface overflow rate or increase in hydraulic retention time can enhance MP removal for all size classes within the range of 10 - 5,000 µm. However, these adjustments can decrease treatment plant capacity (Luo et al. 2023). By contrast, in a cyclic activated sludge system, smaller MP (10 - 200 µm) were reported to be more effectively removed than the larger sized particulates studied (200 - 5,000 µm); although a reduction in sludge wastage was shown to further improve MP removal for the < 200 µm size fraction, this change also increases the solids retention time, which can diminish the activity of bacteria and organic matter degradation (Luo et al. 2023). Therefore, it is possible that such optimization could adversely impact the removal efficacy for other wastewater contaminants; these diverse interrelationships and trade-offs are not yet well-understood. Moreover, more efficient removal of MP in wastewater treatment processes will increase concentrations in biosolids, potentially resulting in the re-release of MP into the environment and into the food chain via agricultural land application.

Stormwater runoff is another key source of MP loading in freshwater environments. It has been widely documented that best management practices (BMPs) and green infrastructure (i.e., bioretention cells, bioswales, permeable pavements, stormwater ponds, constructed wetlands, trash booms, etc.) can be effective tools for reducing MP discharge to surface water (University of Waterloo 2026; Ahmad et al. 2025; Wolfand et al. 2023). The broad array of stormwater management practices exhibits varying degrees of MP reduction, and the solutions can be optimized and/or combined for better removal (Ahmad et al. 2025; Wolfand et al. 2023). However, while many such practices may reduce MP discharge into receiving bodies, they ultimately concentrate and/or redistribute MP in the environment rather than

accomplishing full removal (e.g., retention in stormwater ponds, on the surface of permeable pavement, etc.). In addition to stormwater BMPs and green infrastructure, community-based practices such clean-up events can also reduce sources of secondary MP in urban runoff.

The relative loading of MP, as well as how various source control measures will impact loading, is not currently well-understood (Eastern Research Group, Inc. 2025). While source control measures for MP have not been broadly implemented, many abatement and control strategies have been suggested, including changes in consumer practices for laundry, enforcement of legislation for plastic pre-production industrial discharges, street sweepings, stormwater retention ponds and filters, change in maintenance and material for artificial turfs, and reduction in plastic use (Fältström & Anderberg 2020). However, such preventative actions may be difficult to implement as comprehensive programmatic solutions and/or would need to be combined with other measures to significantly impact MP discharge to the environment (Fältström & Anderberg 2020).

7.3 Research Needs

Key questions applicable to MP source control, as informed by the state-of-the-science assessment, are provided in Table 7-1, with the questions grouped into CRTs.

Table 7-1: Consolidated Research Topics – Source Control

ID	Consolidated Research Topic	Key Questions
SCT-1	Load Reduction	What control mechanisms create meaningful opportunities to reduce MP loading in watersheds?
		To what extent can effluent limitation guidelines effectively reduce environmental loading?
SCT-2	Quantifying Source Contributions	What are the relative contributions from various sources of MP loading (including WWTPs, stormwater runoff, airborne deposition, etc.) in drinking water sources?
		To what extent are WWTPs a source of MP loading into downstream drinking water treatment plants?

ID	Consolidated Research Topic	Key Questions
SCT-3	Source Control Management and Optimization	How can stormwater BMPs and green infrastructure be integrated and optimized for removal of MP in urban runoff?
		How can WWTP processes be optimized to better control MP loading to aquatic environments?
		How does optimization of wastewater treatment processes for the removal of MP impact the removal efficacy of other contaminants?
		How does optimization of wastewater treatment processes for the removal of MP impact biosolids concentrations and associated residuals management practices?
		What is the ultimate fate of MP removed during wastewater treatment?

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8 Health Effects

8.1 Brief Topical Synopsis

Human health effects are the most fundamental aspect of MP science in the context of water supplies, as they dictate the importance of regulation and treatment, as well as the need for precise, accurate, reliable, and repeatable sampling and analytical methods. In the absence of significant adverse health effects, the need to develop the most advanced, optimized sampling and analytical methods is non-essential; conversely, the demonstration of clear linkages between MP and adverse health effects makes such advanced methods critical.

8.2 State-of-the-Science

MP have been detected in a wide range of human organs and tissues, including the brain, liver, placenta, testes, lungs, kidneys, and fetuses, as well as in the blood, bile, and atherosclerotic plaque (Marfella et al. 2024; Nihart et al. 2025; Leslie et al. 2022; Dzierżyński et al. 2025; Horvatits et al. 2022; Zhu et al. 2023; Hu et al. 2024; Chwiej et al. 2025; Zhan et al. 2026; Zhang et al. 2026). These findings suggest that MP contamination is not only ubiquitous in the environment, but also in the human body. However, the presence of MP is not itself necessarily indicative of adverse health effects, and occurrence should not be conflated with risk or understood to imply toxicological impact. Several studies have linked MP exposure and adverse cardiovascular, neurological, inflammatory, and oxidative stress responses (Nihart et al. 2025; Liu et al. 2024; Marfella et al. 2024; Lee et al. 2024; Gosselink et al. 2025; Shi et al. 2022; Choi et al. 2021, 2020; Horvatits et al. 2022). However, definitive causative mechanisms have not been established (Prattichizzo et al. 2024). Human observational studies generally cannot be used to establish causation; instead, in vivo trials involving animals subjected to a range of controlled dosages are necessary to establish definitive dose-response relationships; such studies remain ongoing.

Among all MP characteristics, particle size is most likely associated with toxicity. In a study involving rodents, MP particle size (5 vs. 20 μm) strongly influenced fate and accumulation in tissues, including liver, kidney, and the intestinal system, with the smaller particles exerting the most significant oxidative stress and neurotoxicity responses (Deng et al. 2017). In addition, nanoplastics (< 1 μm) are more likely to exert stronger toxic effects compared to larger plastic particulates in the “micro” size range (> 1 μm) due to higher bioavailability, cellular uptake, and molecular reactivity (Tang 2025). As an example, exposure to < 1 μm polyamide (PA) fragments resulted in statistically significant toxic effects (cytotoxicity, inflammation) in cells lining the human airway (bronchial epithelial cells), whereas 1-5 and 5-10 μm PA fragments did not (Gosselink et al. 2025). Chemical composition of MP may also impact toxicity apart from the pure polymer type itself. For example, it has been shown that specific chemical (non-polymer) additives incorporated during manufacturing can drive toxicity in cell-based (in vitro) assays (Chen et al. 2022). However, studies that have systematically examined the effect of polymer additives in mammalian models are scarce in the literature. Similarly, ingested MP can serve as vectors for secondary contaminants sorbed on the particle surfaces, but the extent to which this exposure mechanism represents a significant risk factor will vary with properties of the contaminant, as well as MP polymer type, size, and residence time in the human body.

A critical limitation of the methodologies of existing in vivo toxicity trials involving mice and rats is that they typically employ MP dosages that may be orders of magnitude higher (billions of particles/L or mg/kg body weight concentrations) than those reported in drinking water exposure studies (tens or hundreds of particles/L, or ng/kg). This disparity raises questions regarding the environmental relevance of observed toxicological effects, thereby complicating risk assessment efforts. Another limitation is the

use of particles of a single polymer type, size, or morphology in contrast to the vast diversity of MP mixtures in drinking water and environmental matrices (Coffin et al. 2022; Liu at al. 2023; Prata 2023). Concerns over observational studies at unrealistically high exposure concentrations notwithstanding, such studies at environmentally relevant levels (particularly in treated drinking water) are more susceptible to being skewed by sample contamination if not properly controlled.

In animal models, micro- and nanoplastics are reported to cause toxicity through several primary mechanisms, with oxidative stress and inflammatory responses being most commonly reported throughout human organs and systems (Wang et al. 2025; Prattichizzo et al. 2024). Other reported toxicity mechanisms include endocrine disruption, immune dysregulation, and mitochondrial dysfunction. However, these were observed under conditions involving high dosages not representative of environmental exposure routes and/or using polymer types that have not been widely observed in human tissues (such as polystyrene (PS) and PP) (Prattichizzo et al. 2024). Thus, there is a need for in vivo studies that employ human-relevant MP dosages and polymer types (such as polyethylene terephthalate (PET), PA, PE, and PVC) under chronic exposure scenarios. Such studies will help define tolerable daily MP intakes beyond which adverse health effects may begin to occur. The relative source contribution of drinking water to this threshold in comparison to air, food, and beverages can then be assessed to determine whether it poses a potential health risk.

8.3 Research Needs

Key questions applicable to MP human health effects, as informed by the state-of-the-science assessment, are provided in Table 8-1, with the questions grouped into CRTs.

Table 8-1: Consolidated Research Topics – Health Effects

ID	Consolidated Research Topic	Key Questions
HFX-1	Understanding Toxicity Mechanisms	What (if any) adverse human health effects are clearly attributable to MP?
		Which MP attributes correlate to any adverse health effects?
		To what extent is secondary sorption of other drinking water contaminants a vector for human toxicity?
		To what extent do chemical additives contribute to toxicity in comparison to polymer type and particle size?
		For MP particles that have accumulated in human tissues, does their physical presence or chemical composition create a potential toxicity hazard?
		Do MP accumulate in human tissues indefinitely, or are they eliminated over time?

ID	Consolidated Research Topic	Key Questions
HFX-2	Fate and Transport in the Human Body	What are the estimated daily intakes and relative source contributions for MP in drinking water (in comparison to other sources such as air, food, and beverages)?
HFX-3	Defining Safe Exposure Thresholds Via Drinking Water	What MP exposure represents the point of departure for the onset of adverse effects in humans?

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9 Environmental Impact

9.1 Brief Topical Synopsis

Although the environmental impact of MP is an expansive subject extending far beyond the purview of water supply and treatment stakeholders, understanding some key aspects can inform residuals management practices with the goal of minimizing MP impact.

9.2 State-of-the-Science

MP can potentially have adverse impacts on aquatic biota through both physical and chemical interactions. The adverse impacts to aquatic biota may in turn potentially inform future discharge regulations. While various studies have shown adverse or toxic effects of MP to freshwater species, they have rarely shown such impacts at environmentally relevant concentrations (Triebskorn et al. 2019). In general, studies have reported nano-scale plastics particulates to be more toxic to aquatic species due to the ability to penetrate cells and tissues more easily (Wang et al. 2024; Triebskorn et al. 2019). In addition, nanoplastics have a high specific surface area that can increase their bioavailability and capacity to carry secondary contaminants (Wang et al. 2024; Triebskorn et al. 2019). As speculated by Wang et al. (2024), microplastics and nanoplastics could be considered as two different types of contaminants (and both distinct from macroplastics) due to their behavioral differences in aquatic environments. MP can also act as carriers for other contaminants, which could include heavy metals, hydrophobic persistent organic pollutants, pathogenic bacteria, and antibiotic-resistant bacteria, among others (Du et al. 2021). Moreover, many chemical additives are incorporated during the production of plastics (i.e., plasticizers, dyes, antioxidants, flame retardants, stabilizers, etc.), and these can gradually leach from MP when present in the environment, with subsequent transfer to aquatic organisms (Wang et al. 2024; Du et al. 2021). Physical impacts to aquatic species may also occur through ingesting MP, potentially leading to loss of nutrition, internal injury, intestinal blockage, starvation, and death (NOAA 2023).

Trophic transfer of MP along the food chain is also possible, with the extent related to residence time, accumulation, size, and shape of MP. Although MP with longer residence times may be more easily transferred, this process is not well-understood. There is also evidence for potential trophic-level transfer of secondary contaminants with MP, but bioaccumulation of such contaminants is likewise not well-understood for any vector media (i.e., MP or otherwise) (Du et al, 2021; Triebskorn et al. 2019; Koelmans et al., 2016). For example, although MP can act as a vector for hydrophobic organic chemicals (HOCs), it was determined that the fraction of total HOC sorbed to MP was small compared to other media in the ocean (Koelmans et al. 2016). In addition, different types of contaminants sorbed to MP may exhibit differing degrees of bioaccumulation (Diepens & Koelmans 2018).

9.3 Research Needs

Key questions applicable to the environmental impact of MP, as informed by the state-of-the-science assessment, are provided in Table 9-1, with the questions grouped into CRTs.

Table 9-1: Consolidated Research Topics – Environmental Impact

ID	Consolidated Research Topic	Key Questions
ENV-1	Understanding Causal Factors	Do MP or sorbed secondary contaminants represent a more significant vector for adverse environmental impact?
		What are the environmentally relevant concentrations and characteristics of MP that are toxic to freshwater species in aquatic ecosystems?

9.4 References

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10 Research Priorities

10.1 Priority Binning

Based on the findings of the literature review, as synthesized in the respective state-of-the-science summaries and associated key questions (as provided in Sections 3-9), each of the seven MP topic areas was binned in terms of its research priority, as shown in Figure 10-1.

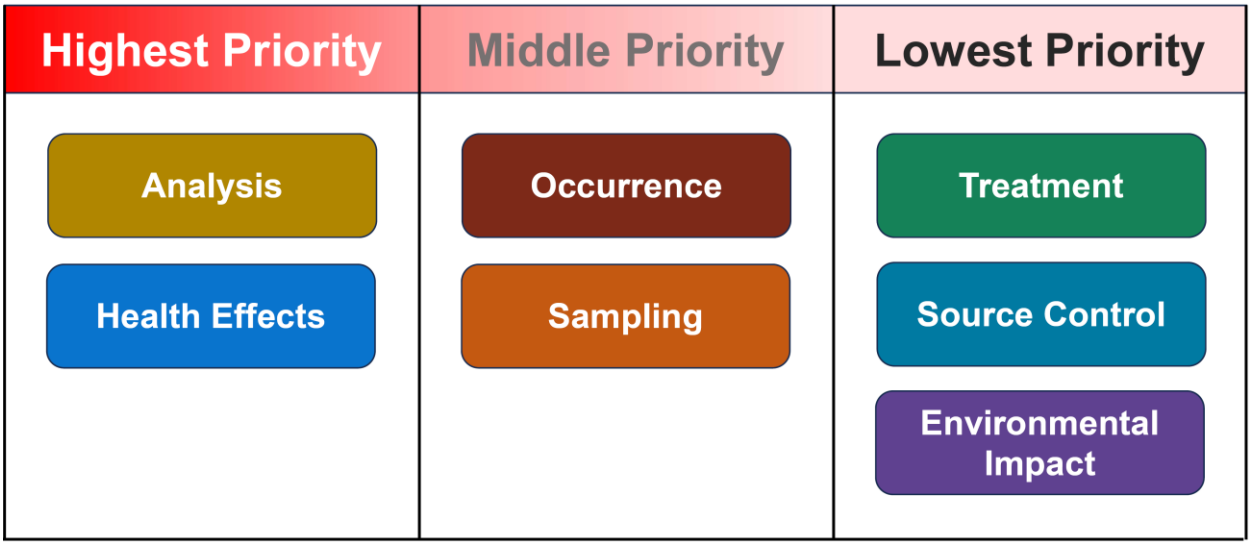


Figure 10-1: Research Priority Binning by Microplastics Topic Area

In assessing and assigning the binning priority shown in Figure 10-1, there are several important points that are critical for appropriate context. First, there are many interdependencies among the MP topic areas, CRTs, and individual key questions. For example, the value of an advanced analytical procedure that can individually quantify nanoplastic particulates is substantially diminished without full confidence that the associated sampling method can enable results that are completely representative of occurrence (including all targeted MP sizes, polymer types, morphologies, etc.). And without such an advanced analytical method to discretely quantify nanoplastics, treatment efficacy for those smallest particulates cannot be fully known. Thus, there is not a neat prioritization of MP research at either the topic, CRT, or key question levels.

Second, it is understood that not every CRT or key question within a topic area has equal priority, with some potentially higher or lower than their respective topical binning assignments in Figure 10-1. Moreover, research priorities can vary among different stakeholders. For example, some drinking water utilities may be more interested in MP treatment efficacy over environmental impact or source control. Similarly, these same utilities may might prioritize quantifying the MP removal capabilities of water treatment plants, even subject to the size constraints of current analytical methods, before developing new innovative techniques to individually quantify nanoplastics. By contrast, some wastewater utilities might prefer to prioritize an evaluation of source control measures before investing in research on treatment that might suggest costly upgrades are needed for MP removal.

Thus, the topical binning shown in Figure 10-1 should be understood as broadly representative prioritization that will yield the most substantial and expedient value for advancing MP science in the context of water supplies. Accordingly, analysis and health effects warrant the highest priority, given that advancements in these areas will not only better inform research into many of the other topic areas, but also most directly support regulatory determinations. Also, it is important to note that the designation of "lowest" priority for treatment, source control, and environmental impact is a relative assignment in comparison to the other topics, and it should not be interpreted as "low."

10.2 Nanoplastics Emphasis

The research findings indicated that for many aspects of the seven MP topic areas examined, nanoplastics (as a specific subset of the broadly encompassing "MP" category in the 1 - 1,000 nm size range – see Figure 1-1) are significantly less understood than plastic particulates > 1,000 nm (1 µm). A summary of some of the most critical challenges with respect to nanoplastics is provided in Table 10-1.

Table 10-1: Synopsis of Significant Nanoplastics Challenges by Topic Area

Topic Area	Nanoplastic Synopsis
Occurrence	Research suggests that the smallest plastic particulates occur in the greatest concentrations. However, nanoplastic occurrence is not well characterized. (See "Analysis" below)
Analysis	Current state-of-the-art methods cannot quantify individual nanoplastics with sizes below ~ 500 nm.
Sampling	Current best practices for sampling (i.e., field filtration) are not designed to capture most nanoplastics.
Health Effects	Effects of nanoplastics are more difficult to study, but ability to translocate in the human body (vs. larger plastics particulates) suggests the potential for more substantive impact.

Given their heightened significance, including the potential for more substantial occurrence and adverse health effects, "nanoplastics" may ultimately supplant the broader "microplastics" category as the more specific contaminant group of interest in water supplies. Accordingly, for all contemporary and future MP research, it is critical to emphasize the examination of nanoplastics to the extent technically feasible.

10.3 Critical Focus Areas

In the context of the two topic areas determined to be the highest priority for future MP research – **analysis** and **health effects** (as shown in Figure 10-1) – specific focus areas considered to be most critical were identified from the state-of-the-science assessments. These critical focus areas are summarized in Tables 10-2 and 10-3 for analysis and health effects, respectively.

Note that these two critical focus areas identified by this state-of-the-science assessment align with the United States Department of Health and Human Services (HHS) Advanced Research Projects Agency for Health (ARPA-H) program titled Systematic Targeting of Microplastics (STOMP), launched in April 2026. The STOMP program allocates $144 million to address issues in both analysis and health effects divided into three (3) Technical Areas, focusing on (respectively): 1) accurate, rapid, and low-cost identification of MP as small as 100 nm, particularly in biological samples; 2) bioaccumulation and health effects; and 3) removal of MP from the human body.

Table 10-2: Critical Research Focus Areas for Analysis

Focus Area	Description
Nanoplastics Detection	Count-based analytical techniques are needed to individually quantify nanoplastics as small as 1 - 10 nm in size.
Method Analysis Time	The implementation time associated with count-based analytical techniques can require as much as several days in extreme cases, depending on the water quality matrix, the number of particles present, the percent of the total sample filter area to be analyzed, and other factors. This analysis time must be reliably, consistently, and substantively reduced to a limited number of hours in order to enable enhanced occurrence and treatment studies requiring a much larger number of samples to generate more meaningful and representative data sets. More expedited analysis will also facilitate compliance monitoring (if/when applicable) by helping to avoid backlogged laboratory work limited by labor-intensive practices.
Cost	Although reducing the analysis time of count-based techniques will inherently reduce the associated costs, it is also important to identify other means of minimizing the expense of conducting MP analysis, **which may be very substantial** for count-based techniques used for individual quantification of particulates.
Standardization	In order to ensure the equitable comparison of data sets collected at different locations and times by different individuals, it is critical to have widely recognized and accepted standardized analytical techniques, including both implementation protocols and QA/QC practices. However, it is imperative that any standards for analytical methods encompass best practices not only capable of achieving precise, accurate, and reliable results both efficiently and affordably, but also which target microplastics identified as being the most toxicology relevant (e.g., specific sizes, shapes, polymer types, etc.). Such aspects of analytical methods remain areas of active research, precluding the ability to appropriately move forward with standardization at this time.

Table 10-3: Critical Research Focus Areas for Health Effects

Focus Area	Description
Stronger Linkages	Although numerous health effects studies have associated MP exposure with an array of adverse responses (e.g., cardiovascular, neurological, inflammatory, and oxidative stress), establishing stronger, more definitive linkages (or, conversely, confidently determining that the correlated health effects are not attributable to MP) would help inform an appropriate regulatory determination.
Causal Mechanisms	Even more significant than establishing stronger linkages between MP and adverse human health effects (as noted in the row above), identifying specific causal mechanisms (i.e., how MP interact with human physiology to yield given outcomes) would strongly inform the need for regulating MP in water supplies, as well as potentially an appropriate numerical standard.
MP Attribute Association	Understanding which MP attributes (e.g., size, polymer type, morphology, etc.) are associated with specific adverse health outcomes will inform not only appropriate regulation (if/when applicable), but also the targeted optimization of treatment processes for removing MP.
Impact of Plastic Additives	The potential for chemical additives in commercial plastic polymers to cause adverse health effects upon the ingestion of MP is not well-understood. However, this information could be critical not only for an appropriate regulatory determination, but also to implement more focused and targeted source control measures with the greatest potential to mitigate human exposure.
Relative Source Contribution	The relative source contribution of drinking water to overall human MP exposure is not well-understood. If MP are ultimately demonstrated to unequivocally cause adverse human health effects, the contribution of drinking water to overall toxicity is essential for making an appropriate regulatory determination.

10.4 Research Costs

This report focuses on characterizing the state of microplastics science in drinking water and identifying key questions / research gaps. Because these questions and gaps could be bundled in many variations for the purposes of developing specific research projects, depending on the particular interests and available funding from sponsoring agencies, the report has purposefully not attempted assign costs. However, independent of the manner in which research is ultimately conducted (i.e., more numerous projects with limited scope and budget vs. fewer, more expansive projects with more substantial funding), it is generally anticipated that tens of millions of dollars (at a minimum) will be required to adequately address all of identified questions and gaps. However, it is important to note that this investment of research funding will result in substantial long-term cost savings. For example, understanding specific health effects and causal mechanisms (if/as applicable) will prompt appropriate regulatory standards and targeted treatment to minimize exposure risk, thus precluding some associated health care costs. Similarly, understanding the most impactful monitoring program characteristics (if ultimately determined to be necessary) – sampling location(s) and frequencies – will prevent oversampling and associated costs, both in terms of labor and analytical work. Likewise, improving sampling and analytical method efficiency will also reduce costs, which may be very substantial in a scenario in which nationwide monitoring is required.

11 Implications

As demonstrated in the state-of-the-science summaries, the research needs for MP in water supplies are substantial across the seven topic areas assessed, both in terms of the number of Key Questions and their potential impact on public policy and regulatory determination. The research needs have practical impacts on water utilities, as well, with compounded challenges in both sampling and analysis inhibiting a full understanding of occurrence and treatment efficacy. Current best practices in both areas are more time- and labor-intensive than for any other water contaminant, resulting in significant costs and precluding the extensive sampling campaigns necessary to fully characterize MP variability in source and finished waters. Moreover, these same current best practices neither capture nor detect nanoplastics (i.e., 1 - 1,000 nm in size), the subset of microplastics suspected to occur in the greatest concentrations and carry the most potentially significant health risk. All of these challenges likewise complicate utility messaging to consumers. Thus, the inclusion of MP in CCL 6 is an important first step for highlighting both the importance of MP as an emerging contaminant and the need for a **substantial investment in research prior to any comprehensive nationwide utility monitoring program, such as the UMCR**. This investment is critical to ensure that monitoring is not only affordable for utilities and their ratepayers, but that it also generates accurate and fully representative data to instill consumer confidence and inform appropriate action by policymakers and regulators.