State of New Jersey
DEPARTMENT OF ENVIRONMENTAL PROTECTION
OFFICE OF THE COMMISSIONER
401 East State Street
P.O. Box 402, Mail Code 401-07
Trenton, New Jersey 08625-0402
Tel. (609) 292-2885 • Fax (609) 292-7695
www.nj.gov/dep

Mikie Sherrill
Governor

Dr. Dale G. Caldwell
Lt. Governor

Ed Potosnak
Acting Commissioner

April 21, 2026

Dear Members of the Senate Environment and Energy Committee, Assembly Environment and Solid Waste Committee, and Members of the Legislature,

In 2024, New Jersey enacted P.L.2023, c.279, requiring the New Jersey Department of Environmental Protection (NJDEP), in partnership with the New Jersey Drinking Water Quality Institute (DWQI), to assess the feasibility of establishing a maximum contaminant level or other standard for the entire class, or subclasses, of PFAS in drinking water. Additionally, NJDEP was charged with assessing treatment technologies that may be effective in removing PFAS from drinking water and wastewater.

The attached report provides the assessments required by P.L.2023, c.279, based on evaluation of relevant information including peer-reviewed publications and documents from government agencies, with input from the DWQI.

New Jersey is Leading the Nation in Addressing PFAS:

New Jersey is leading the nation in addressing PFAS contamination. NJDEP established the first-ever MCL for any PFAS in the United States when it adopted a standard for PFNA in 2018, followed by MCLs for PFOA and PFOS in 2020. As of December 2025, NJDEP has approved 116 permits in 84 different public water systems for permanent treatment to remove PFAS, with 56 plants having completed installation as of April 2025.

This report represents NJDEP's ongoing commitment to evaluating advanced and innovative approaches to address this critical environmental and public health challenge. NJDEP remains dedicated to staying at the forefront of evolving analytical methods and treatment technologies and will continue to assess emerging strategies for more comprehensive regulation and removal of PFAS.

Key Findings on Regulation Feasibility:

While addressing the entire class of per- and polyfluoroalkyl substances (PFAS) in drinking water is a worthwhile goal, establishing a drinking water standard for PFAS as an entire class is not currently feasible due to analytical and treatment constraints. Specifically, available analytical methods for estimating total PFAS lack the sensitivity and specificity needed for regulatory compliance monitoring, and treatment approaches to remove all PFAS require further development.

However, it is feasible to establish drinking water standards for subclasses or mixtures of PFAS selected based on common health effects, detection with the same analytical method, or other considerations. Several factors should be carefully evaluated before establishing such standards, including whether health-based drinking water concentrations are above analytical detection limits; availability of toxicological data; treatment technology requirements; and occurrence information for PFAS in New Jersey drinking water. The report recommends that the feasibility of regulating the entire class be periodically reevaluated as analytical methods and treatment technologies continue to advance.

Key Findings on Treatment Technologies:

Granular activated carbon (GAC) and ion exchange (IX) resins are the most utilized and effective technologies for removing a wide range of PFAS from both drinking water and wastewater. As of April 2025, at least 27 New Jersey public water treatment plants have installed GAC and at least 29 have installed IX resins for PFAS removal. Other adsorbent technologies have been approved by NJDEP and are being tested in pilot-scale studies at New Jersey facilities.

Additional technologies, including membrane-based approaches (reverse osmosis and nanofiltration) and emerging destruction-based technologies, show promise but face current limitations related to cost, practicality, or stage of development. The report emphasizes that every site requires careful consideration and design unique to its goals and constraints, and that comprehensive PFAS removal may require more than one treatment technology in a treatment train.

Conclusion:

Thank you for your continued interest and partnership to address PFAS. We welcome any questions you may have regarding the findings and recommendations contained in this assessment.

Sincerely,

Ed Potosnak
Acting Commissioner

Assessments of Feasibility of Regulation of Per- and Polyfluoroalkyl Substances (PFAS) in Drinking Water as the Entire Class or as Certain Subclasses or Mixtures *and* Treatment Technologies for Removal of PFAS from Drinking Water or Wastewater in Response to P.L.2023, c.279.

Prepared by:

New Jersey Department of Environmental Protection

Prepared for:

Senate Environment and Energy Committee

Assembly Environment and Solid Waste Committee

Members of the Legislature

March 2026

Mikie Sherrill, Governor
State of New Jersey

Dr. Dale G. Caldwell, Lt. Governor
State of New Jersey

Ed Potosnak, Acting Commissioner
Department of Environmental Protection

Visit the DEP website:
https://dep.nj.gov/

Acknowledgements

Gloria Post, Ph.D., D.A.B.T. (NJDEP Office of the Commissioner) was the primary author of the first sections of this report. Camila Llerena-Olivera, Ph.D. (NJDEP Division of Science and Research) was the primary author of the final section on treatment technologies for removal of PFAS from drinking water and wastewater, with extensive input from Filina Poonolly and Cory Stevenson (NJDEP Division of Water Supply and Geoscience). The thorough reviews and helpful comments provided by Jessie Gleason (NJ Department of Health and NJ Drinking Water Quality Institute) on the first section of this report, and by Sandra Goodrow, Ph.D. (NJDEP Contaminated Site Remediation & Redevelopment), Lori Lester, Ph.D. and Nick Procopio, Ph.D. (NJDEP Division of Science and Research), and Katrina Angarone (NJDEP Office of the Commissioner) on the entire report are gratefully acknowledged.

Preface

The goal of this report is to provide the assessments required by New Jersey P.L.2023, c.279, as follows:

> To assess “the feasibility of establishing a ... maximum contaminant level [MCL] or other standard for the entire class, or for certain subclasses or mixtures, of … perfluoroalkyl and polyfluoroalkyl substances [PFAS] in drinking water, rather than for each individual substance.”
>
> To assess “treatment technologies that may be effective in removing perfluoroalkyl and polyfluoroalkyl substances from drinking water or wastewater.”

The information presented and the studies cited in the report, including reports from federal and state agencies as well as from the peer-reviewed scientific literature, are intended to illustrate key points

Table of Contents

Executive Summary

Key Findings

- Addressing the entire class of per- and polyfluoroalkyl substances (PFAS) in drinking water is a worthwhile goal. However, establishing a drinking water standard for PFAS as an entire class is not currently feasible because of analytical and treatment constraints, as discussed below and in more detail in the accompanying report and supporting Appendix.

- It is feasible to establish a drinking water standard for a subclass/mixture of PFAS selected on the basis of common health effects, detection with the same analytical method, or other considerations. Several factors should be considered in determining whether a standard for a subclass/mixture should be established, as described below and in more detail in the accompanying report and supporting Appendix.

- It is not feasible to establish a drinking water standard for a subclass/mixture based on removal by a specific treatment technology, and such an approach is more relevant to addressing PFAS as the entire class.

- Regarding treatment technologies:
  - Granular activated carbon and ion exchange resins are the most utilized technologies for both water and wastewater treatment. They are effective at removing a wide range of PFAS beyond the three long-chain PFAS with New Jersey Maximum Contaminant Levels (MCLs; drinking water standards).
  - Other adsorbent technologies have been approved by the New Jersey Department of Environmental Protection (NJDEP) and/or are being tested at New Jersey drinking water treatment plants.
  - Each technology has its own advantages and challenges.
  - Every site and plant requires careful consideration and design unique to its goals and constraints.

Background

Per- and polyfluoroalkyl substances (PFAS) overview

On January 16, 2024, New Jersey enacted P.L.2023, c.279 which requires the New Jersey Department of Environmental Protection (NJDEP), in consultation with the New Jersey Drinking Water Quality Institute (DWQI), to conduct “an assessment of the feasibility of establishing a maximum contaminant level [MCL] or other standard for the entire class, or for certain subclasses or mixtures, of PFAS in drinking water, rather than for each individual substance” and to assess “treatment technologies that may be effective in removing perfluoroalkyl and polyfluoroalkyl substances from drinking water or wastewater." This report provides the assessments required by P.L.2023, c. 279, based on evaluation of relevant information including peer-reviewed publications and documents from government agencies. Input from the DWQI has been incorporated.

Per- and polyfluoroalkyl substances (PFAS) are a large class of thousands of synthetic organic compounds that contain one or more totally fluorinated carbon atoms. Due to their chemical structures, PFAS repel both water and oil and are resistant to high temperatures and chemical reactions. Because of these useful properties, PFAS have been produced and used since the 1950s for many purposes including in consumer products (e.g., stain-resistant coatings for upholstery and carpeting, waterproof cosmetics, water-resistant breathable outdoor clothing, greaseproof food packaging), in aqueous film forming foams (AFFF) used for fighting petroleum fires, and as processing aids in the production of fluoropolymers used in non-stick cookware and other products.

Large amounts of PFAS have been released to the environment, and PFAS are detected in surface water, groundwater, finished drinking water, and other environmental media in New Jersey, throughout the U.S., and worldwide. Sources of PFAS in the environment include industrial facilities where they are made or used, release of AFFF during training or firefighting, leachate from landfills where industrial waste or consumer products containing PFAS are disposed, and, relevant to this report, industrial and domestic wastewater treatment plant (WWTP) effluent and land application of biosolids (sludge) from WWTPs. Once released to the environment, PFAS persist indefinitely due to the strength of their carbon-fluorine bonds, and they are thus known as "forever chemicals." PFAS are not effectively removed from drinking water or wastewater by conventional treatment methods, and specific treatment technologies effective for PFAS removal are discussed in this report.

PFAS are of particular concern as drinking water contaminants for numerous reasons, including those discussed below.

- As mentioned above, PFAS do not degrade in the environment. Additionally, they are highly water-soluble. In contrast, other well-known persistent, bioaccumulative, and toxic (PBT) organic pollutants (e.g., dioxins and polychlorinated biphenyls) are found primarily in soils, sediments, and lipids in fish, meat, and dairy products. As such, drinking water is an important exposure source for PFAS but not for other well-known PBT contaminants.

- Everyone is exposed to PFAS from common sources such as food and consumer products, and certain PFAS are detected in the blood of almost all U.S. residents. However, exposures to PFAS from levels often found in drinking water are greater than typical exposures from common sources, and consumption of contaminated drinking water increases the levels of certain PFAS in blood. Because the PFAS that are detected in blood are excreted very slowly, the elevated blood levels persist for many years after exposure to contaminated drinking water ends.

- Human health effects of some PFAS are associated even with the blood levels in the general population that result from exposures to common sources. It is therefore important to minimize additional exposure to PFAS from contaminated drinking water.
- Notably, infants are particularly susceptible to the adverse effects of certain PFAS, and PFAS exposures to infants from contaminated water are higher than in older individuals. This is particularly true for breastfed infants whose mothers drink contaminated water, and it is also the case for infants who consume formula prepared with contaminated water.

NJDEP began to evaluate PFAS when they were first reported in New Jersey waters over 20 years ago. At that time, PFAS were not widely recognized as important environmental contaminants, but NJDEP scientists soon realized that they are different from other contaminants and that their presence in drinking water is a cause for concern. Since that time, PFAS have become a high priority environmental issue throughout the U.S. and the world, and information on their sources, occurrence, environmental fate and transport, and health effects has increased exponentially.

NJDEP conducted the first U.S. statewide occurrence studies of PFAS in public water systems in 2006 and 2009. In these studies, perfluorooctanoic acid (PFOA) was detected (above the reporting level of 4-5 nanograms per liter (ng/L or parts per trillion) in raw or treated water of about 60% of the 54 public water systems tested, and perfluorooctane sulfonate (PFOS) was found in about 30% of the systems. In the 2009 study, perfluorononanoic acid (PFNA), a PFAS which was not well known at the time, was found in a supply well of a New Jersey public water system at 96 ng/L, the highest level that had been reported in drinking water worldwide at that time, and an industrial source was later identified.

In 2007, NJDEP developed guidance for chronic (lifetime) exposure to PFOA in drinking water of 40 ng/L based on the health effects information that was then available. This guidance value was much lower than other PFOA drinking water guidelines at the time, but it is similar to the drinking water guidelines that were later established by USEPA and several other states.

Subsequently, NJDEP established drinking water standards (Maximum Contaminant Levels; MCLs) for three PFAS - PFNA (13 ng/L) in 2018, and PFOA (14 ng/L) and PFOS (13 ng/L) in 2020. These MCLs were recommended to NJDEP by the New Jersey Drinking Water Quality Institute (DWQI), an advisory body established in amendments to the New Jersey Safe Drinking Water Act (N.J.S.A. 58:12A- 20) in 1984. It is notable that NJDEP's MCL for PFNA that was adopted in 2018 was the first MCL for any PFAS in the United States.

In 2024, USEPA established lower federal MCLs for PFOA and PFOS of 4 ng/L, which is the lowest concentration that could be reliably measured in drinking water. The USEPA MCLs consider recent epidemiology studies demonstrating health effects in humans at very low PFAS exposures. USEPA also established MCLs for the total concentration of four other PFAS (PFNA, perfluorohexane sulfonate [PFHxS], perfluorobutane sulfonate [PFBS], hexafluoropropylene oxide dimer acid [HFPO-DA, GenX]) in 2024.

Since NJDEP adopted its PFAS MCLs in 2018-2020, many New Jersey public water systems have taken action to address PFAS. Specifically, NJDEP had approved 116 permits in 84 different public water systems for permanent treatment to remove PFAS as of December 2025. Of these approved permits, 56 New Jersey drinking water treatment plants had installed treatment to remove PFAS to concentrations below the New Jersey MCLs as of April 2025.

Definition of PFAS

PFAS are defined in New Jersey P.L.2023, c.279 as "any member of the class of fluorinated organic chemicals containing at least one fully fluorinated carbon atom." This is an inclusive definition which is consistent with definitions adopted by numerous other authoritative organizations (e.g., Organisation for Economic Co-operation and Development, at least 23 other states, and Congress in the National Defense Authorization Act). PFAS can generally be subdivided by the number of carbon atoms in their carbon chains (long-chain, short-chain, ultrashort-chain). New Jersey's PFAS definition includes ultrashort chain PFAS such as trifluoroacetic acid (TFA), which has only one fully fluorinated carbon.

Assessment of Feasibility of Regulation of PFAS in Drinking Water as the Entire Class or as Certain Subclasses or Mixtures

The New Jersey MCLs for PFOA, PFOS, and PFNA are based on the concentrations of the individual compounds. The recommendation of chemical-specific MCLs for these PFAS is consistent with the approach generally used by the DWQI for other contaminants.

This section of the report provides an assessment of the feasibility of regulating PFAS in drinking water as the entire class or as certain subclasses or mixtures. In this assessment, "feasibility" refers to scientific, technical, and regulatory considerations relevant to this evaluation; costs were not considered. This section of the report also discusses previous NJDEP, DWQI, and NJDEP Science Advisory Board evaluations relevant to this topic, as well as federal, state, and international drinking water guidelines for multiple PFAS.

A key concept for this assessment is that considerations for regulating PFAS as the **entire class** (i.e., any chemical included in the definition of PFAS) are different from considerations for regulating a **certain PFAS subclass or mixture** (i.e., the combined concentrations of more than one specific PFAS).

PFAS as the entire class

Actions to address the entire class of PFAS (i.e., all of the thousands of chemicals defined as PFAS) are primarily based on their common property of extreme environmental persistence (i.e., they do not break down) and concerns that they will thus eventually reach unacceptable levels in the environment. These approaches are not based on the exposure levels at which health effects may occur, and they do not assume that all PFAS cause the same types of health effects or that they are all equally toxic.

Importantly, most actions that address PFAS as the entire class have focused on products that contain intentionally added PFAS, such as the recently enacted New Jersey P.L.2025, c.202 which prohibits the sale of cosmetics, carpet and fabric treatments, and food packaging containing intentionally added PFAS. Considerations for addressing PFAS as an entire class in drinking water are different than for products, and no state has regulated the entire class of PFAS in drinking water. Specifically, regulation of the intentional use of PFAS in products relies on information provided by the companies that make and sell the products, and it does not require analysis of the products for PFAS. In contrast, regulation of PFAS as an entire class in drinking water requires a treatment technology or technologies that can remove all PFAS that may be present and an analytical method or methods that can determine whether any PFAS are present after treatment.

Analytical methods for estimation of total PFAS have been developed. These methods measure the total concentration of organic fluorine and do not identify or measure individual PFAS. However, these methods are not highly sensitive, and they are not specific to PFAS because they detect other compounds that contain organic fluorine.

Additionally, analytical methods used for regulatory compliance with New Jersey MCLs must be promulgated for drinking water analysis through federal (USEPA) or state (NJDEP) rulemaking. Importantly, neither USEPA nor New Jersey has established an analytical method that can be used in regulation of total PFAS in drinking water.

Furthermore, because the PFAS class includes compounds with diverse chemical structures, effective removal of the entire class from drinking water would likely require the strategic use of multiple treatment technologies in a chain, and such treatment approaches have not yet been fully evaluated.

The California State Water Resources Control Board is currently investigating potential “broad spectrum” approaches for PFAS analysis and “treatment-based regulation for entire class of PFAS” in drinking water, in response to the requirements of California legislation. The results of the California efforts and other relevant investigations may provide approaches for future regulation of the entire class of PFAS in drinking water.

Certain PFAS subclasses or mixtures

A drinking water standard for a PFAS subclass or mixture is based on the combined concentrations of more than one individual PFAS. The individual PFAS included in the regulated subclass/mixture may be selected based on common health effects, detection with the same analytical method, or for another reason.

In general, it is feasible to establish an MCL or drinking water guideline for a PFAS subclass. For example, several states have established MCLs of 20 to 30 ng/L for the total concentration of four to six long chain PFAS based on the assumption that they are all equally toxic, and USEPA has established an MCL for the total concentration of four PFAS based on a Hazard Index which weights each included PFAS based on its toxicological potency. Additionally, Health Canada recently established a non-enforceable drinking water objective of 30 ng/L for the total concentration of 25 PFAS included in a specific analytical method, USEPA Method 533.

However, the factors discussed below should be considered in determining whether an MCL for a PFAS subclass/mixture should be established in New Jersey:

- Newer toxicity factors developed by USEPA and several states for five long-chain PFAS (PFOA, PFOS, PFNA, PFHxS, perfluorodecanoic acid [PFDA]), most of which occur in New Jersey drinking water, are based on human epidemiology data. These newer toxicity factors are much more stringent than the toxicity factors based on animal toxicology data used in earlier federal and state drinking water standards and guidance. Health-based drinking water concentrations for long-chain PFAS based on the newer toxicity factors are below practical quantitation levels (PQLs), the lowest concentrations that can be reliably measured in drinking water.

  When a contaminant's health-based drinking water concentrations is below its PQL, the MCL is set at the PQL, and any detection of the contaminant will exceed the MCL for just the individual contaminant. Additionally, when an MCL for a PFAS mixture is based on the health-based levels of the individual PFAS, it is not appropriate to include a PFAS for which the MCL is set at the analytical PQL rather than the health-based level. Therefore, it is not appropriate or meaningful to include such a PFAS in an MCL for multiple PFAS.

  Relevant to this point, the USEPA Maximum Contaminant Level Goals (health-based concentrations) for PFOA and PFOS are below their PQLs, and the USEPA MCLs for these two PFAS are thus set at their PQLs (4 ng/L). For this reason, USEPA did not include PFOA and PFOS in its MCL for a mixture of four other PFAS.

  Additionally, the MCLs of 20 to 30 ng/L for the total concentration of five or six long-chain PFAS established by several states mentioned above are based on the older toxicity factors using animal toxicology data. These MCLs may need reevaluation in light of the recent USEPA MCLs for PFOA and PFOS, which are set at their PQLs and the recent stringent USEPA toxicity factors using human data for several other long-chain PFAS.

It is emphasized that these considerations do not preclude development of a drinking water standard for mixtures of other PFAS with health-based drinking water concentrations above their PQLs.

- An analytical method that is approved for regulation in drinking water (compliance with New Jersey MCLs) must be available for any PFAS included in a regulated PFAS subclass. Such methods must be promulgated for drinking water analysis through federal (USEPA) or state (NJDEP) rulemaking. Currently, two USEPA analytical methods which include 29 PFAS altogether are approved for MCL compliance.
- The toxicological information needed for development of toxicity factors for use in an MCL for a PFAS subclass based on health effects is not available for many PFAS, including some PFAS that are found in drinking water. Approaches for developing toxicity factors for contaminants that lack traditional toxicology data are under development. If such approaches are incorporated into New Jersey guidance for toxicity factor development, they may potentially be used in the future.
- In an MCL based on the total concentration of the PFAS detected with the same analytical method, all included PFAS are weighted equally regardless of differences in their toxicological potencies. The numerical value of such an MCL is therefore a policy decision. Additionally, as above, it is not appropriate or meaningful to include a PFAS with a health-based concentration below its PQL in such an MCL.
- The treatment technologies most frequently used to remove PFAS from drinking water (granular activated carbon and ion exchange resins) can remove many different PFAS. However, breakthrough times and removal efficiencies vary among PFAS, and regulation of a PFAS subclass could potentially require multiple treatment technologies. Additionally, the treatment technology or technologies used by a specific public water system would depend on which of the regulated PFAS are detected there as well as other site-specific considerations.
- Occurrence information for PFAS in New Jersey drinking water should be considered in determining whether an MCL for a PFAS subclass should be established. Specifically, occurrence data should be evaluated to determine whether unregulated PFAS are present at frequencies and concentrations of potential concern.

  The USEPA Unregulated Contaminant Monitoring Rule 5 (UCMR5) monitored all U.S. public water systems serving more than 3300 people, and a subset of smaller systems in 2023-2025 for the 29 PFAS in included in the two USEPA methods approved for drinking water analysis. As such, UCMR5 data is a valuable source of occurrence information for PFAS with methods that can be used for MCL compliance monitoring.

- Analytical methods other than those approved for regulatory use can identify many PFAS not included in the two methods approved for MCL compliance. Monitoring studies using these methods are important for identifying currently unregulated PFAS that occur in New Jersey drinking water. Other targeted analytical methods for drinking analysis available from commercial laboratories include a much larger number of PFAS analytes than the 29 PFAS detected in the two approved methods. Furthermore, studies using non-targeted analysis (NTA) identified previously unknown PFAS in New Jersey waters, and additional such studies may identify other PFAS not included in targeted methods. Detection of unregulated PFAS at frequencies and levels of concern with these methods may indicate the need for development of information required for future regulation, such as health-based concentrations, approved analytical methods, and evaluation of treatment removal.

Conclusions and recommendations

PFAS as entire class

NJDEP, in consultation with the DWQI, recognizes that addressing the entire class of PFAS in drinking water is a worthwhile goal, but concludes that establishing a drinking water standard for PFAS as an entire class is not currently feasible because of the analytical and treatment constraints discussed above. Specifically, available analytical methods for estimation of PFAS as the entire class lack sensitivity and specificity and are not approved for MCL compliance monitoring. Additionally, treatment technologies to remove all PFAS that may be present in drinking water need further development, and multiple sequential technologies are likely required. Efforts to develop analytical and treatment approaches that may inform regulation of the entire class are currently underway, including California's current work towards "develop[ing] a treatment-based regulation for the entire class of PFAS." It is recommended that the feasibility of regulating the entire class of PFAS in drinking water be reevaluated annually as these and other relevant efforts progress.

Certain PFAS subclasses or mixtures

NJDEP, in consultation with the DWQI, further concludes that it is feasible to establish a drinking water standard for a subclass/mixture of PFAS selected on the basis of common health effects, detection with the same analytical method, or other considerations. In contrast, it is not feasible to establish a drinking water standard for a subclass/mixture based on removal by a specific treatment technology, and such an approach is more relevant to addressing PFAS as the entire class.

Several factors should be considered in determining whether an MCL for a subclass/mixture should be established:

- It is not appropriate or meaningful to include PFAS with health-based drinking water concentrations below their analytical PQLs in an MCL for multiple PFAS.

- The toxicological information needed for development of an MCL for a PFAS subclass based on health effects is not available for some PFAS found in drinking water. Approaches for developing toxicity factors for contaminants that lack traditional toxicology data are under development and may potentially be used in the future.
- The numerical value of an MCL based on the total concentration of PFAS detected with the same analytical method is a policy decision.
- Regulation of a PFAS subclass could potentially require the simultaneous use of multiple treatment technologies. The treatment technology or technologies used by a specific public water system would depend on which regulated PFAS are detected and other site-specific considerations.
- Occurrence information for PFAS in New Jersey drinking water should be considered in determining whether an MCL for a PFAS subclass should be established. Specifically, frequencies and concentrations of unregulated PFAS, and co-occurrence with PFAS that are already regulated should be considered.
- Monitoring studies using targeted and non-targeted analytical methods that are not approved for regulatory use are important for identifying currently unregulated PFAS that occur in New Jersey drinking water. Detection of unregulated PFAS with these methods may indicate the need for development of health effects information, approved analytical methods, and evaluation of treatment removal needed for future regulation.

Assessment of Treatment Technologies for Removal of PFAS from Drinking Water and Wastewater

New Jersey P.L.2023, c.279 requires the New Jersey Department of Environmental Protection (NJDEP), in consultation with the NJ Drinking Water Quality Institute (DWQI), to perform an assessment of “treatment technologies that may be effective in removing perfluoroalkyl and polyfluoroalkyl substances from drinking water or wastewater.” Conventional drinking water and wastewater treatment technologies (e.g., bar screens, grit removal, clarifiers, filtration, aeration) are generally not effective for the removal of PFAS, and specific treatment technologies are needed. As discussed above, NJDEP established a Maximum Contaminant Level (MCL) of 13 nanograms per liter (ng/L) for PFNA in 2018, and MCLs of 14 ng/L for PFOA and 13 ng/L for PFOS in 2020.

To comply with these MCLs, numerous New Jersey public water systems have installed or plan to install treatment technologies to remove PFAS. Specifically, NJDEP had approved 116 permits in 84 different public water systems, including community and non-community water systems[1], for permanent treatment to remove PFAS as of December 2025. Of the approved permits, 56 New Jersey drinking water treatment plants had installed treatment to remove PFAS to concentrations below the New Jersey MCLs as of April 2025. In addition to the permits that have been approved for permanent treatment, other permit applications for PFAS treatment are under review, and additional permits for temporary treatment (e.g., pilot scale) have also been approved by NJDEP. This section of the attached report provides a brief overview of the available technologies that can be used to remove PFAS from drinking water and/or wastewater based both on information from the published literature and the knowledge about treatment removal of PFAS that NJDEP has acquired since its PFAS MCLs were established.

Three major categories of technology - adsorption, membranes, and destruction – that are used for the removal of PFAS from drinking water and/or wastewater are discussed below. Although cost was excluded as a key performance indicator in this assessment, cost may be a limiting factor when designing or implementing treatment for PFAS removal and is mentioned where relevant. For wastewater, treatment of effluent was the focus of this assessment, and treatment of wastewater byproducts such as activated sludge and biosolids to remove PFAS was not evaluated.

Adsorption-based technologies are frequently used to remove PFAS from drinking water and are also used for PFAS removal from industrial wastewater. In contrast, no publicly owned treatment plants (POTWs; i.e., sewer plants that treat municipal and/or industrial wastewater) in New Jersey currently use adsorbents to treat their wastewater for PFAS, and no POTWs that do so elsewhere in the U.S. were identified. Two adsorption technologies, granular activated carbon (GAC) and ion exchange (IX) resins, are the most frequently used approaches for removal of PFAS, and other adsorption technologies such as powdered activated carbon (PAC) are being explored. As of April 2025, at least 27 New Jersey public water treatment plants had installed GAC and at least 29 plants had installed IX resins for PFAS removal from drinking water. Additionally, emerging adsorbents made from plant-based materials or surface modified clay may be used for removal of PFAS from drinking water and/or wastewater in the future, and some of these are currently being tested at the pilot-scale in some New Jersey drinking water systems. Other adsorption-based processes such as foam fractionation could be applied for wastewater treatment in the future as well.

---

[1] Treatment for PFAS at some non-community public water systems may have been approved at the county level and are not included in the numbers above.

Although many PFAS that may be present in drinking water can be removed by adsorption technologies, differences in removal efficiencies among PFAS must be considered to ensure adequate removal of all PFAS of interest. Both GAC and IX resins are less efficient for removal of short-chain PFAS than long-chain PFAS, and they are also less efficient for PFAS that are carboxylates than those that are sulfonates. Adsorbent materials containing concentrated PFAS must be disposed of at end of use, and disposal options include destruction via incineration at facilities approved to handle PFAS materials and disposal at landfills approved to handle PFAS materials. However, an increasing number of landfills will not accept solids with PFAS contamination.

Membrane-based technologies including reverse osmosis (RO) and nanofiltration (NF) are also effective for removal of PFAS from water, and differences in removal efficiencies among different types of PFAS are less prominent for membrane technologies than for other technologies such as GAC. In these technologies, the PFAS that are removed are highly concentrated, and the liquid “concentrate” (i.e., reject water) must be disposed. RO and NF have been successfully used to remove multiple types of PFAS at drinking water treatment plants. However, widespread application of membrane-based technologies for PFAS removal at drinking water treatment plants is currently limited by cost and other factors, and these technologies are currently not practical for removal of PFAS from wastewater.

Destruction-based technologies could serve as the ideal approach to ending the release and recirculation of PFAS through the environment. A few examples of emerging destruction-based technologies applicable for PFAS removal include electrochemical oxidation, supercritical water oxidation, and plasma. These approaches are currently in the lab-scale or pilot-scale phase, and they cannot yet be widely used for treatment of drinking water or wastewater.

Ultra-short chain PFAS are a rising concern for treatment facilities. IX resins and RO could be possible technologies that can reduce these types of PFAS. However, more research is needed to understand ultra-short chain removal and optimization of available technologies. To guarantee a comprehensive removal of PFAS with varying sizes, more than one treatment technology should be included in the treatment train.

Finally, it should be noted that although a variety of PFAS treatment technologies are currently available or under development, removing PFAS from drinking water or wastewater can be a complicated process. Water quality goals (e.g., target concentration of specific PFAS parameters, pH, water temperature, etc.) and site-specific constraints (e.g., cost, space, sewer availability) differ widely among treatment facilities, and installation of treatment technology for removal of

PFAS could require significant allocation of resources. Therefore, any treatment technique for PFAS should be carefully designed and tailored to the specific facility where it will be used.

Introduction

On January 16, 2024, New Jersey enacted P.L.2023, c.279[2] which requires NJDEP, in consultation with the New Jersey Drinking Water Quality Institute (DWQI), an advisory body established in the New Jersey Safe Drinking Water Act, to conduct "an assessment of the feasibility of establishing a maximum contaminant level [MCL] or other standard for the entire class, or for certain subclasses or mixtures, of PFAS in drinking water, rather than for each individual substance" and to assess "treatment technologies that may be effective in removing perfluoroalkyl and polyfluoroalkyl substances from drinking water or wastewater."

This report provides the assessments required by P.L.2023, c. 279, based on evaluation of relevant information including peer-reviewed publications and documents from government agencies, and Appendix A provides additional detail on the topics discussed herein.

Per- and polyfluoroalkyl substances (PFAS) are a large class of thousands of synthetic organic compounds that contain one or more totally fluorinated carbon atoms. Due to their chemical structures, PFAS repel both water and oil and are resistant to high temperatures and chemical reactions. Because of these useful properties, PFAS have been produced and used since the 1950s for many purposes including in consumer products (e.g., stain-resistant coatings for upholstery and carpeting, waterproof cosmetics, water-resistant breathable outdoor clothing, greaseproof food packaging), in aqueous film forming foams (AFFF) used for fighting petroleum fires, and as processing aids (i.e., surfactants) in the production of fluoropolymers used in non-stick cookware and other products (ITRC, 2026, Section 2).

Large amounts of PFAS have been released to the environment, and PFAS have been detected in surface water, groundwater, finished drinking water, and other environmental media in New Jersey, throughout the U.S., and worldwide. Sources of PFAS in the environment include industrial facilities where they are made or used, release of AFFF during training or firefighting, industrial and domestic wastewater treatment plant (WWTP) effluent, land application of biosolids (sludge) from WWTPs, and leachate from industrial waste or consumer products disposed of in landfills (ITRC, 2026, Section 2).

PFAS are of particular concern as drinking water contaminants for several important reasons. They are known as "forever chemicals" because they persist indefinitely in the environment,

---

[2] From P.L.2023, c.279: "The Department of Environmental Protection, in consultation with the Drinking Water Quality Institute established pursuant to section 10 of P.L.1983, c.443 (C.58:12A -20), shall conduct a study on the regulation of perfluoroalkyl and polyfluoroalkyl substances in drinking water. The study shall include an assessment of the feasibility of establishing a maximum contaminant level or other standard for the entire class, or for certain subclasses or mixtures, of perfluoroalkyl and polyfluoroalkyl substances in drinking water, rather than for each individual substance. The study shall also include an assessment of treatment technologies that may be effective in removing perfluoroalkyl and polyfluoroalkyl substances from drinking water or wastewater." A written report is due to the Senate Environment and Energy Committee and the Assembly Environment and Solid Waste Committee, or their successors, and the Legislature no later than 24 months after the effective date of the law.

due to the strength of their carbon-fluorine bonds. Additionally, they are highly water-soluble, in contrast to other well-known persistent, bioaccumulative, and toxic (PBT) organic pollutants (e.g., dioxins and polychlorinated biphenyls) which distribute primarily to soils and sediments (Post et al., 2017).

Everyone is exposed to PFAS from common sources such as food and consumer products, and certain PFAS are detected in the blood serum of almost all U.S. residents. However, exposures from low PFAS levels often found in drinking water are greater than typical exposures from common sources such as food and consumer products, and consumption of contaminated drinking water increases the levels of these PFAS in blood serum over time. The PFAS commonly detected in blood serum are excreted very slowly, and the elevated blood serum levels persist for many years after exposure to contaminated drinking water ends. Because human health effects of some PFAS are associated even with exposure levels that are prevalent in the general population, it is important to minimize additional exposure from contaminated drinking. Notably, infants are particularly susceptible to the adverse effects of certain PFAS, and PFAS exposures to infants from contaminated water are higher than in older individuals. This is particularly true for breastfed infants whose mothers drink contaminated water, and it is also the case for infants who consume formula prepared with contaminated water (Post et al., 2017; NJDOH, 2024).

The New Jersey Department of Environmental Protection (NJDEP) began to evaluate PFAS when they were first reported in New Jersey waters over 20 years ago. At that time, PFAS were not widely recognized as important environmental contaminants, but NJDEP scientists soon realized that they are different from other contaminants and that their presence in drinking water is a cause for concern. Since that time, PFAS have become a high priority environmental issue throughout the U.S. and the world, and information on their sources, occurrence, environmental fate and transport, and health effects has increased exponentially (NJDEP, 2026).

NJDEP conducted the first U.S. statewide occurrence studies of PFAS in public water systems in 2006 and 2009. In these studies, perfluorooctanoic acid (PFOA) was detected (above the reporting level of 4-5 ng/L) in raw or treated water of about 60% of the 54 public water systems tested, and perfluorooctane sulfonate (PFOS) was found in about 30%. In the 2009 study, perfluorononanoic acid (PFNA), a PFAS which was not well known at the time, was found in a New Jersey public water system at 96 ng/L, the highest level that had been reported in drinking water worldwide at the time (Post et al., 2013), and an industrial source was later identified (NJDEP, 2007; Post et al., 2013; NJDEP, 2014).

In 2007, NJDEP developed guidance for chronic (lifetime) exposure to PFOA in drinking water of 40 ng/L based on the health effects information that was then available. This guidance value was much lower than other PFOA drinking water guidelines at the time, but it is similar to the drinking water guidelines that were later established by USEPA and several other states. Subsequently, NJDEP established drinking water standards (Maximum Contaminant Levels;

MCLs), recommended by the DWQI, for PFNA (13 ng/L) in 2018 and PFOA (14 ng/L) and PFOS (13 ng/L) in 2020. It is notable that NJDEP's MCL for PFNA that was adopted in 2018 was the first MCL for any PFAS in the United States (NJDEP, 2026).

In 2024, USEPA (2024a) established lower federal MCLs for PFOA and PFOS of 4 ng/L, which is the lowest concentration that could be reliably measured in drinking water. These USEPA MCLs consider recent epidemiology studies demonstrating human health effects at very low exposure levels. USEPA also established MCLs for the total concentration of four other PFAS (PFNA, perfluorohexane sulfonate [PFHxS], perfluorobutane sulfonate [PFBS], hexafluoropropylene oxide dimer acid [HFPO-DA, GenX]) in 2024.

Since NJDEP adopted its PFAS MCLs in 2018-2020, many New Jersey public water systems have taken action to address PFAS. Specifically, NJDEP had approved 116 permits in 84 different public water systems for permanent treatment to remove PFAS as of December 2025. Of these approved permits, 56 New Jersey drinking water treatment plants had installed treatment to remove PFAS to concentrations below the New Jersey MCLs as of April 2025.

Definition of PFAS

PFAS are defined in P.L.2023, c.279 as "any member of the class of fluorinated organic chemicals containing at least one fully fluorinated carbon atom." This is an inclusive definition which is identical or consistent with the definitions adopted by the Organisation for Economic Co-operation and Development (OECD), at least 23 other states, and Congress in the National Defense Authorization Act. Importantly, this definition includes ultrashort chain PFAS such as trifluoroacetic acid (TFA), which has only one fully fluorinated carbon. In contrast, several USEPA programs[3] and at least one state (Delaware) have adopted less inclusive definitions that are generally supported by industrial stakeholders (Safer States, 2024; OECD, 2021; DE House of Representatives, 2021).

Perfluoroalkyl acids (PFAAs) are a well-known PFAS subgroup that consist of a fully fluorinated carbon chain and negatively charged carboxylate or sulfonate group. PFAAs can be subdivided by chain length (long-chain, short-chain, ultrashort-chain); this terminology has also been used

---

[3] USEPA Office of Water defines PFAS as "chemicals that contain at least one of these three structures…: 1. R-(CF2)-CF(R')R", where both the CF2 and CF moieties are saturated carbons, and none of the R groups can be hydrogen; 2. R-CF20CF2-R', where both the CF2 moieties are saturated carbons, and none of the R groups can be hydrogen; CF3C(CF3)RR', where all the carbons are saturated, and none of the R groups can be hydrogen." (USEPA, 2022a).

The USEPA Office of Chemical Safety and Pollution Prevention definition is similar but slightly different: "…including at least one of these three structures: R-(CF2)-CF(R')R", where both the CF2 and CF moieties are saturated carbons; R–CF2OCF2-R', where R and R' can either be F, O, or saturated carbons; and CF3C(CF3)R'R", where R' and R" can either be F or saturated carbons. (USEPA, 2023). This definition is used in TSCA's National Testing Strategy for PFAS (USEPA, 2021).

for PFAS with other structures. Long-chain PFAAs are defined as perfluorocarboxylic acids (PFCAs) with 8 or more carbons (i.e., perfluorooctanoic acid [PFOA] and longer) and perfluorosulfonic acids (PFSAs) with 6 or more carbons (i.e., perfluorohexane sulfonic acid [PFHxS] and longer) (USEPA, 2009). Short-chain PFAAs are PFCAs with 4 to 7 carbons and PFSAs with 4 or 5 carbons (ITRC, 2026, Section 2.2). Ultrashort-chain PFAS are PFCAs with 2 or 3 carbons and PFSAs with 1, 2, or 3 carbons. Carbon chain length is relevant to the health effects, analytical methods, and treatment removal discussed below.

Assessment of Feasibility of Regulation of PFAS in Drinking Water as the Entire Class or as Certain Subclasses or Mixtures

The current New Jersey Maximum Contaminant Levels (MCLs) for three PFAS (PFOA, perfluorooctane sulfonate [PFOS], perfluorononanoic acid [PFNA]) are based on the concentrations of the individual compounds.[4] New Jersey P.L.2023, c.279 requires the New Jersey Department of Environmental Protection (NJDEP), in consultation with the NJ Drinking Water Quality Institute (DWQI), to conduct an "assessment of the feasibility of establishing a ... maximum contaminant level [MCL] or other standard for the entire class, or for certain subclasses or mixtures, of … perfluoroalkyl and polyfluoroalkyl substances [PFAS] in drinking water, rather than for each individual substance."

This section of the report provides an assessment of the feasibility of regulating PFAS in drinking water as the entire class or as certain subclasses or mixtures. In this assessment, "feasibility" refers to scientific, technical, and regulatory considerations relevant to this evaluation; costs were not considered. This section also discusses previous NJDEP, DWQI, and NJDEP Science Advisory Board evaluations relevant to this topic, as well as federal, state, and international drinking water guidelines for multiple PFAS. Comments and input provided by the New Jersey Drinking Water Quality Institute (DWQI) and its subcommittees are incorporated into this section. Additional detail is provided in Appendix A for all topics discussed herein.

Information on treatment removal of PFAS from drinking water that is relevant to regulating PFAS as the entire class or as certain subclasses/mixtures is included in this section. A more comprehensive review of treatment technologies for PFAS in drinking water and wastewater is provided in the assessment of this topic in the next section of this report.

---

[4] These DWQI recommendations of these MCLs and the accompanying technical support documents are posted on the DWQI website at https://www.nj.gov/dep/watersupply/g_boards_dwqi.html

Previous DWQI, NJDEP, and NJDEP Science Advisory Board evaluations relevant to regulation of multiple PFAS in drinking water

DWQI consideration of multiple PFAS in drinking water

The DWQI Health Effects Subcommittee has previously evaluated toxicological interactions of co-occurring PFAS. The potential for toxicological interactions (i.e., additive toxicity) in PFAS mixtures was recognized in the DWQI Health Effects Subcommittee's support documents for the health basis of the individual MCLs for PFOA, PFOS, and PFNA in 2015-2018. These support documents are posted at the link in footnote 3 above.

More recently, the NJDEP Commissioner requested that the DWQI evaluate the current New Jersey MCLs for PFOA and PFOS. In its response to this request (DWQI, 2022), the Health Effects Subcommittee concluded that it is appropriate and health protective to assume dose additivity for mixtures of PFAS. It also noted that if MCLs for PFOA and PFOS considered these toxicological interactions, they would be more stringent than the current NJ MCLs for these two PFAS.

However, as discussed below, health-based drinking water concentrations for long-chain PFAS (e.g., PFOA, PFOS) based on more recent toxicity factors are below their analytical Practical Quantitation Levels (PQLs), the lowest concentration that can be reliably measured in drinking water. In such cases, the MCL for the individual compound is set at its PQL, and it is not appropriate or meaningful to include such PFAS in an MCL for multiple PFAS.

NJDEP (2004) discussion paper on approaches for reducing unregulated synthetic organic contaminants (SOCs) from public drinking water supplies

NJDEP (2004) developed a discussion paper on approaches for reducing unregulated synthetic organic contaminants (SOCs) in public water systems in response to research studies which found that multiple unregulated SOCs co-occur in New Jersey public drinking water systems. Some of the SOCs detected in these studies are considered to be contaminants of emerging concern (CECs) based on knowledge of their occurrence and/or potential toxicity, while little or nothing is known about many other SOCs that were detected. Although this paper was written prior to awareness of PFAS in New Jersey waters, many of the concepts that are discussed appear relevant to the assessment of the feasibility of regulating PFAS in drinking water as a class or as certain subclasses or mixtures.

In the discussion paper, the provision for regulating contaminants through a "treatment technique" in the NJ Safe Drinking Water Act was interpreted as allowing establishment of a New Jersey regulation that requires drinking water systems vulnerable to SOC contamination to install treatment, specifically granular activated carbon (GAC). This strategy was stated to "represent a proactive approach to protecting public health in the absence of little or no definitive scientific information on the contaminants being detected" based on the assumption that "the contaminants may have adverse effects on human health."

In considering the potential application of this approach to regulating PFAS as a class or as certain subclasses or mixtures, both the contaminant(s) used as an indicator of a public water system's vulnerability to PFAS contamination and the analyte(s) used as marker(s) for the effectiveness of PFAS treatment removal would need to be selected. Additionally, the NJDEP (2004) interpretation of the New Jersey Safe Drinking Water Act as allowing establishment of a New Jersey regulation that requires drinking water systems vulnerable to SOC contamination to install treatment would likely require a legal review and opinion.

NJDEP Science Advisory Board (2020) Report

The topic addressed by the NJDEP Science Advisory Board (2020) report "Approaches for Addressing Drinking Water and Wastewater Contaminants of Emerging Concern (CECs) in a Broader Context: Identification, Ranking and Treatment Removal" was designated a priority issue by NJDEP (NJDEP SAB, 2020). This report responded to charge questions from NJDEP related to addressing drinking water contaminants as groups rather than individually and reviewed health effects/risk assessment, analytical, and treatment removal information relevant to this topic. It is noted that some of the approaches discussed by NJDEP SAB (2020) might require legal review to determine if they could be implemented under current New Jersey legislation and/or regulations.

General considerations for regulating PFAS as the entire class or as certain subclasses or mixtures

A key concept for this assessment is that considerations for regulating PFAS as the **entire class** (i.e., any chemical included in the definition of PFAS) are different from considerations for regulating a **certain PFAS subclass or mixture** (i.e., the combined concentrations of more than one specific PFAS).

PFAS as the entire class

Concerns about the entire class of PFAS are primarily based on their common property of extreme environmental persistence (i.e., they do not break down) and concerns that they will thus eventually reach unacceptable levels in the environment (Cousins et al., 2020). It is not assumed that all PFAS are equally toxic, and approaches to address the entire PFAS class are not based on risk assessment (i.e., the level of exposure at which health effects may occur).

Importantly, most actions that address PFAS as the entire class have focused on products that contain intentionally added PFAS, such as the recently enacted New Jersey P.L.2025, c.202 which prohibits the sale of cosmetics, carpet and fabric treatments, and food packaging containing intentionally added PFAS. Considerations for addressing PFAS as an entire class in drinking water are different than for products. Specifically, regulation of the intentional use of PFAS in products relies on information provided by the companies that make and sell the products, and it does not require analysis of the products for PFAS. In contrast, regulation of PFAS as an entire class in drinking water requires a treatment technology or technologies that can remove all PFAS that may be present and an analytical method or methods that can determine whether any PFAS are present after treatment.

Analytical methods have been developed for estimation of total PFAS (ITRC, 2026, Section 11.2; USEPA, 2024e; McDonough et al., 2019). These methods measure the total concentration of organic fluorine and do not identify or measure individual PFAS. However, these methods are not highly sensitive, and they are not specific to PFAS because they detect other compounds that contain organic fluorine. Additionally, analytical methods approved for regulatory compliance with New Jersey MCLs must be promulgated for drinking water analysis through federal (USEPA) or state (NJDEP) rulemaking. Importantly, neither USEPA or New Jersey has established an analytical method that can be used in regulation of total PFAS in drinking water.

Furthermore, because the PFAS class includes compounds with diverse chemical structures, effective removal of the entire class from drinking water would likely require the strategic use of multiple treatment technologies in a chain, and such treatment approaches have not yet been fully evaluated. Relevant to this topic, the California State Water Resources Control Board is currently investigating a "broad spectrum" analytical approach and "treatment-based regulation for entire class of PFAS" as required by legislation (CA Assembly, 2022).

It is noted that two states, Vermont (VT ANR, 2020) and Hawaii (HIDOH, 2024) have evaluated regulation of PFAS as a class in drinking water, and neither state decided to move forward with this approach. Additionally, the USEPA Drinking Water Contaminant Candidate List 5 (CCL5; USEPA, 2022) includes "PFAS as a group" but explains that this "does not necessarily mean that EPA will make subsequent regulatory decisions for the entire group."

Certain subclasses or mixtures of PFAS

A drinking water standard for a PFAS subclass or mixture is based on the combined concentrations of more than one individual PFAS. PFAS included in such an MCL must be detected in an analytical method approved for MCL compliance and be removed by an available treatment technology. The individual PFAS included in the regulated subclass/mixture may be selected based on common health effects, or detection with the same analytical method. Additionally, occurrence of such PFAS in New Jersey drinking water, such as data from the USEPA Unregulated Contaminant Monitoring Rule 5 (USEPA, 2026), should be considered in determining whether such an MCL should be established. Specifically, frequency, concentrations, and co-occurrence with PFAS that are already regulated should be considered.

General approaches for regulating a PFAS subclass/mixture

1. Two general approaches have been used for developing drinking water guidelines (standards or guidance values) for a PFAS subclass/mixture. These approaches are

discussed in detail in ITRC (2026, Sections 1.4.5, 7.1.5, 7.1.7) and Appendix A to this report. The approaches are:

Total concentration: Some drinking water guidelines are based on the total concentration (i.e., sum) of the individual PFAS that are included, without use of chemical-specific values for each of these PFAS. In this approach, the concentration of each individual PFAS that is included is weighted equally.

Additive toxicity, but toxicological potencies differ: Some drinking water guidelines assume that toxicity of the specific PFAS that are included is additive, but that their potency (dose at which toxicity occurs) varies. In this approach, the concentrations of the individual PFAS are weighted differently to account for their differing toxicological potencies. Specific approaches of this type are further discussed in the section on regulation based on health effects below.

Key issue: Inclusion of long-chain PFAS in standard for subclass/mixture

Newer toxicity factors developed by USEPA and several states for long-chain PFAS (PFOA, PFOS, PFHxS, PFDA, final; PFNA, draft)[5], some of which commonly occur in New Jersey drinking water, are based on human epidemiology data. These newer toxicity factors are much more stringent than the toxicity factors based on animal toxicology data used in earlier federal and state drinking water standards and guidance. Health-based drinking water concentrations based on these newer toxicity factors are below analytical practical quantitation levels (PQLs; the lowest level that can be reliably measured in drinking water) (Appendix A; USEPA, 2026).

It is not appropriate or meaningful to include a PFAS with a health-based drinking water concentration below its PQL in a drinking water standard for multiple PFAS. This is because the MCL for the individual PFAS is set at its PQL, and any detection of the individual PFAS therefore exceeds the drinking water standard. Additionally, for an MCL for a PFAS mixture based on the health-based concentrations (i.e., MCLGs) of the individual PFAS (e.g., Hazard Index, see below), it is not appropriate to include PFAS with MCLs set at their analytical PQLs rather than their health-based concentrations. This issue was acknowledged by USEPA (2024a) in its explanation of why PFOA and PFOS, whose health-based drinking water concentrations (Maximum Contaminant Level Goals; MCLGs) are below their PQLs, were not included in the USEPA MCL for a mixture of four other PFAS.

It is emphasized that the considerations discussed above do not preclude development of a drinking water standard for mixtures of other PFAS with health-based drinking water concentrations above their PQLs and which are detected in analytical methods approved for MCL compliance monitoring. However, occurrence data (frequency, concentrations, co-occurrence with regulated PFAS), such as data from the USEPA Unregulated Contaminant

---

[5] Citations for these assessments are found in Table 3 of Appendix A.

Monitoring Rule 5 (UCMR5; USEPA, 2026), should be considered in determining such an MCL should be established.

Regulation of entire class or a subclass/mixture based on health effects

PFAS as the entire class

As discussed above, efforts to address all PFAS as a class are based primarily on environmental persistence as a common property. These approaches are not based on risk assessment (e.g., the level of exposure at which health effects may occur) and do not assume that all PFAS are equally toxic.

Interim guidance developed by Hawaii Department of Health (HIDOH, 2024) includes a screening approach to estimate the human health risk of all PFAS in environmental samples. However, this approach uses analytical methods that are not approved for drinking water and provide uncertain estimates of the concentration of total PFAS. Additionally, the HIDOH approaches for risk assessment of total PFAS are highly uncertain, and HIDOH has not stated that it plans to use this approach for PFAS in drinking water.

Certain subclasses or mixtures of PFAS

General considerations

In general, it is feasible to establish an MCL for a PFAS subclass based on common health effects. However, the factors discussed below should be considered in determining whether such an MCL standard should be established.

Many of the PFAS with the toxicological information needed for a health-based standard are included in the analytical methods approved for MCL compliance monitoring (USEPA Methods 533 and/or 537.1). Considerations for treatment removal of PFAS from drinking water are reviewed in the next section of this report. In summary, PFAS included in the USEPA methods are generally removed by the same treatment technologies (e.g., granular activated carbon; ion exchange resins), although removal efficiencies vary among the individual PFAS. However, depending on which PFAS are included, a drinking water standard for a PFAS subclass/mixture could potentially require multiple analytical methods and/or multiple treatment technologies. These factors should be considered in developing a regulation for a subclass/mixture of PFAS based on health effects.

Additionally, as above, it is not appropriate or meaningful to include a long-chain PFAS with a health-based drinking water concentration below its PQL in a drinking water standard for multiple PFAS. As above, occurrence data for the PFAS to be included in the subclass should be considered when deciding whether such an MCL should be established.

Total concentration

Health-based drinking water guidelines using the total concentration (also called "simple additive") approach are based on the sum of the concentrations (i.e., the total concentration) of the specific PFAS that are included. In this approach, it is assumed that the included PFAS are all equally potent (cause toxicity at the same dose) and that their toxicity is additive (ITRC, 2026, Section 7.1.5).

Several states have established MCLs or guidance of 20 to 30 ng/L for the total concentration of four to six long chain PFAS (PFOA, PFOS, PFNA, and PFHxS, plus PFHpA and/or PFDA) based on assumed toxicological similarity (Appendix A). However, these MCLs are not applicable if recent more stringent toxicity factors that result in drinking water concentrations below PQLs are considered. At least one state, Massachusetts, is considering reevaluating its MCL for the total concentration of six long chain PFAS in view of this issue.

Additive toxicity, but with differing toxicological potencies

Health-based drinking water standards for a PFAS subgroup/mixture can also use approaches in which the concentrations of the individual PFAS are weighted differently to account for their differing toxicological potencies (doses at which toxicity occurs). Such approaches, including Hazard Index and Relative Potency Factors, require chemical-specific toxicity values for each included PFAS. While the format of the equations and the calculations for these approaches differ, all of these methods assume dose additivity (Appendix A and ITRC, 2026, Section 7.1.5)

The MCL for a mixture of four PFAS (PFNA, PFHxS, PFBS, GenX) finalized by USEPA (2024a) is based on a general Hazard Index. In this approach, the toxicity factors (Reference Doses) for the individual PFAS are based on non-cancer effects in different target organs (e.g., thyroid, liver, developmental). This approach is more scientifically uncertain than the target organ-specific Hazard Index (below). While the general Hazard Index was used for the USEPA MCL, USEPA risk assessment guidance, the USEPA Science Advisory Board PFAS Review Panel, and the New Jersey DWQI Health Effects Subcommittee (DWQI, 2025) recommend that this approach be used for screening.

A target organ-specific Hazard Index evaluates risks of multiple chemicals with toxicity factors (e.g., Reference Doses) based on adverse effects in the same target organ. It is less uncertain than a general Hazard Index. Minnesota Department of Health (MDH, 2020) uses such an approach to evaluate risks of co-occurring contaminants in groundwater.

A Relative Potency Factor approach for mixtures of PFAS, analogous to the toxicity equivalency factor (TEF) approach used for dioxins, has been proposed by scientists from RIVM (Netherlands National Institute for Public Health and the Environment; Bil et al., 2021). This approach is based on the relative potency of each PFAS compared to an index compound (e.g., PFOA) for a specific toxicological effect (e.g., increased relative liver weight in male rats). Among several issues noted with this approach, only PFAS with information on relative liver weight can be included and other toxicological effects of certain PFAS that are more sensitive (occur at lower doses) than increased relative liver weight are not considered.

Consideration of PFAS that lack toxicity data

Mammalian toxicology data (e.g., repeated dose studies of systemic and/or developmental effects) that can be used to develop a toxicity factor (Reference Dose) and health-based water concentration are not available for many PFAS, including some PFAS that are detected in New Jersey drinking water. An example of a PFAS that lacks such toxicity data is perfluoropentanoic acid, which is the most frequently detected PFAS in UCMR5 as of January 2026, and additional PFAS that lack toxicity data may be identified in New Jersey drinking water in the future. Potential approaches for evaluating toxicity of such compounds include quantitative structure-activity relationship (QSAR) evaluations, "read across" from structurally related PFAS that have toxicity data, use of high throughput testing data (e.g., results of *in vitro* assays in cultured cells), use of data for transcriptomic (gene expression) changes after short term dosing of laboratory animals, and standardized approaches for development of toxicity factors for chemicals lacking a full toxicity dataset (Appendix A).

Specifically, USEPA has developed the EPA Transcriptomic Assessment Product (ETAP; USEPA, 2024d). ETAP can rapidly provide transcriptomic reference values (TRVs), which are intended to provide reliable estimates of chronic Reference Doses, from transcriptomic (gene expression) changes in a standardized short-term (5 day) *in vivo* rat study. More recently, USEPA has developed the Database-Calibrated Assessment Process (DCAP) (USEPA, 2025; Harrill et al., 2026), a standardized approach to generate Calibrated Toxicity Values (CTVs) for non-cancer effects information in the USEPA Toxicity Values Database

If it is determined in the future that approaches such as ETAP and DCAP are sufficiently predictive of human health effects, it may be feasible to use them as the basis of a health-based drinking water standard for a certain PFAS subclass that includes PFAS which lack repeated dose mammalian toxicology data.

Regulation of entire class or a subclass/mixture based on detection with same analytical method(s)

Analytical methods approved for NJDEP MCL compliance monitoring must be promulgated for drinking water analysis by USEPA through federal rulemaking or validated for drinking water analysis by NJDEP and promulgated by NJDEP through rulemaking. While NJDEP could potentially validate and promulgate a method for use in MCL compliance as an Alternate Test Procedure as described in N.J.S.A. 7:18, Section 2:20 (https://dep.nj.gov/wp-content/uploads/rules/rules/njac7_18.pdf), an approved reference method that has been developed elsewhere must be available. For this reason, methods for compliance with MCLs established by NJDEP have typically been developed and validated by USEPA or a similar reference setting body such as Standard Methods for the Examination of Water and Wastewater or ASTM International.

PFAS as the entire class

Available data indicate that targeted analytical methods may not account for a considerable portion of the PFAS present in drinking water. Methods that provide estimates of aggregate PFAS include the total oxidizable precursor (TOP) assay, which estimates the concentration of PFAS precursors that can potentially transform to perfluoroalkyl acids (PFAAs; e.g., PFOA and PFOS), and total organic fluorine methods (sometimes called "total" PFAS methods) such as adsorbable organic fluorine (AOF) and extractable organic fluorine (EOF) (Appendix A; ITRC, 2026, Section 11.2; USEPA, 2024e; McDonough et al., 2019). It is noted that these methods are much less sensitive than targeted PFAS methods. Additionally, these methods are not specific to PFAS because fluorinated organic compounds other than PFAS (e.g., some fluorinated pharmaceuticals and pesticides) contribute to the organic fluorine measured in drinking water with AOF and EOF. Also, the adsorption or extraction steps in these methods may not capture all of the organic fluorine that is present.

At this time, neither USEPA nor New Jersey has approved an analytical method for estimation of aggregate PFAS in drinking water for MCL compliance monitoring. As such, methods such as TOP, EOF, and AOF cannot currently be used as the basis of a regulatory standard for PFAS in drinking water. It is noted that USEPA (2024f) has finalized has not yet promulgated, Method 1621 for estimation of total PFAS for analysis of wastewater, but not drinking water. The California State Water Resources Control Board (CA Water Board, 2024a; CA Water Board 2024b). The CA Water is currently investigating potential "broad spectrum" analytical approaches including Method 1621 for measurement of PFAS in drinking water, in response to a legislative requirement (CA Assembly, 2022).

Certain subclasses or mixtures of PFAS

Analytical methods for individual PFAS include targeted analytical methods and non-targeted analysis. The USEPA has finalized and approved two targeted analytical methods, EPA Method 533 and Method 537.1 (USEPA, 2026), for PFAS in drinking water. As mentioned above, only methods promulgated for drinking water analysis by USEPA or NJDEP can be used for MCL compliance purposes, while other methods (e.g., non-targeted analysis) can be used for informational purposes.

A drinking water standard could potentially be based on the subclass of PFAS that is detected with one or more targeted analytical methods, and Health Canada (2024) has established a non-enforceable drinking water objective for the 25 PFAS included in USEPA Method 533. The numerical value for the total concentration of PFAS in such a standard is a policy decision.

Additionally, multiple treatment technologies could potentially be needed to remove all of the included PFAS to levels that comply with the standard.

Although they are not approved for use in MCL compliance, analytical methods other than the two USEPA methods approved for regulatory use can identify many PFAS not included in the two approved USEPA methods. Monitoring studies using these methods are important for identifying currently unregulated PFAS that occur in New Jersey drinking water. Specifically, additional targeted analytical methods for drinking analysis that are available from commercial laboratories include a much larger number of PFAS analytes than the 29 PFAS detected in the two approved methods (Pelch et al., 2023). Furthermore, studies using non-targeted analysis (NTA) have identified previously unknown PFAS in New Jersey waters (Washington et al., 2020; McCord et al., 2020)., and future studies using NTA may identify other PFAS not included in targeted methods. Detection of unregulated PFAS at frequencies and levels of concern with these methods may indicate the need for development of information required for future regulation, such as health-based concentrations, approved analytical methods, and evaluation of treatment removal.

Treatment removal considerations for regulation of PFAS as entire class or subclass/mixture

Treatment removal considerations relevant to regulation of PFAS in drinking water as the entire class or as certain subclasses/mixtures are discussed in this section of the report. A comprehensive review of treatment removal technologies for removal of PFAS from drinking water and wastewater is provided in the assessment of this topic in next section of this report.

Granular activated carbon (GAC) and ion exchange (IX) resins are the treatment technologies most frequently used to remove PFAS by New Jersey public water systems. These and other treatment technologies can remove many individual PFAS with varying efficiencies, as breakthrough times and removal efficiencies vary among PFAS and are affected by chain length and chemical structure. For example, both GAC and IX resins generally have shorter breakthrough times (when media exceeds its capacity to remove PFAS) for short-chain perfluoroalkyl acids (PFAAs) than long-chain PFAAs. These differences would need to be considered in a drinking water standard for multiple PFAS based on their removal by a specific treatment technology to ensure adequate removal of all PFAS of concern (next section of this report and Appendix A; ITRC, 2026, Section 12.2.1).

High-pressure membranes such as reverse osmosis (RO) and nanofiltration (NF) have also been shown to be effective for PFAS removal from drinking water (next section of this report and Appendix A), and RO is used to remove PFAS in point of use devices for residential drinking water (NSF, 2026). However, widespread application of RO for PFAS removal at drinking water treatment plants is currently limited by factors such as cost and disposal of the PFAS reject water containing concentrated PFAS created after RO treatment. In addition, more research is needed on full-scale application of NF (next section of this report and Appendix A).

PFAS as the entire class

A treatment-based standard for the entire class of PFAS would require an analytical method that can determine whether all PFAS have been removed from the drinking water. As discussed above, analytical methods intended to measure PFAS as the entire class are not currently available for use drinking water regulation (i.e., MCL compliance). Further, it appears unlikely that a completely inclusive treatment removal approach can be developed because of the structural diversity of the vast number of members of the PFAS class. Instead, multiple technologies would likely need to be used strategically in a chain to effectively remove the entire class of PFAS, and such approaches have not been fully evaluated (next section of this report and Appendix A). It is noted that California legislation (CA Assembly, 2022) provides funding to "develop a treatment-based regulation for the entire class of PFAS" and that the state of California is currently in the process of evaluating this issue.

Certain subclasses or mixtures of PFAS

A drinking water standard could for a subclass consisting of those PFAS that are removed by a specific treatment technology would require that all PFAS removed by the method can be monitored with targeted analytical method(s) approved for MCL compliance. However, the identities of all PFAS removed by a specific treatment technology are not known, and all PFAS removed by a specific technology are not detected in targeted analytical methods. As such, this approach is not feasible for a PFAS subclass, and it is more relevant to treatment removal approaches for addressing PFAS as the entire class, discussed above.

Additional considerations for a standard based on a specific treatment technology include the need to consider the differences in removal efficiency of the included PFAS, which may be impacted by variability within the available treatment technologies, relative concentrations of other types of PFAS in the source water, other water quality parameters, and/or site-specific constraints (see next section of this report and NJDEP, 2026).

As mentioned above, regulation of a PFAS subclass selected based on common health effects, inclusion in the same analytical method, or for another reason could potentially require multiple treatment technologies. In such cases, the treatment technology/technologies used by a specific public water system would depend on which of the regulated PFAS are detected there as well as other site-specific considerations.

Conclusions and recommendations for regulation of PFAS in drinking water as entire class or as certain subclasses or mixtures

NJDEP, in consultation with the DWQI, recognizes that addressing the entire class of PFAS is a worthwhile goal but concludes that establishing a drinking water standard for PFAS as an entire class is not currently feasible because of the analytical and treatment constraints discussed above. Specifically, available analytical methods for estimation of total PFAS lack sensitivity and are not specific to PFAS, and methods for determination of total PFAS in drinking water have not been promulgated by USEPA or NJDEP. Additionally, multiple sequential treatment methods would likely be necessary to treat PFAS as an entire class. Efforts to develop the analytical methods and treatment removal approaches that may potentially make it possible to regulate the entire class of PFAS in drinking water are currently underway. These efforts include California's work towards developing a "broad spectrum" analytical approach for PFAS and a "treatment-based regulation for the entire class of PFAS." It is recommended that the possibility of regulation of the entire class of PFAS in drinking water be reevaluated annually as these and other relevant efforts progress.

NJDEP, in consultation with the DWQI, further concludes that it is feasible to establish a drinking water standard for a subclass/mixture of PFAS selected on the basis of common health effects, detection with the same analytical method, or other considerations, with the caveats discussed above. Specifically, it is not appropriate or meaningful to include a PFAS with a health-based concentrations below its PQL in such an MCL. Additionally, many PFAS lack the toxicity data required for development of the health-based drinking water concentration needed for inclusion in a subclass based on health effects. Furthermore, each PFAS included in a subclass must be detected with an analytical method approved for MCL compliance and removed by an available treatment technology, and this is not the case for many PFAS. For a subclass of PFAS with approved methods and available treatment technologies, multiple analytical methods and sequential technologies may be required to address all included PFAS. Finally, the numerical drinking water standard for a subclass of PFAS selected based on detection with the same analytical method is a policy decision.

Occurrence information for PFAS in New Jersey drinking water should be considered in determining whether an MCL for a PFAS subclass is needed. Specifically, occurrence data should be evaluated to determine whether unregulated PFAS are present at frequencies and concentrations of potential concern. The USEPA Unregulated Contaminant Monitoring Rule 5 (UCMR5) monitored all U.S. public water systems serving more than 3300 people, and a subset of smaller systems, in 2023-2025 for the 29 PFAS in included in the two USEPA methods approved for drinking water analysis. As such, UCMR5 data is a valuable source of occurrence information for PFAS with methods approved for MCL compliance monitoring.

Other analytical methods can identify many PFAS not included in the two methods approved for MCL compliance, and monitoring studies using these methods are important for identifying currently unregulated PFAS that occur in New Jersey drinking water. Additional targeted analytical methods for drinking water analysis available from commercial laboratories include a much larger number of PFAS analytes than the 29 PFAS detected in the two approved methods. Furthermore, studies using non-targeted analysis (NTA) have identified previously unknown PFAS in New Jersey waters, and future studies using NTA may identify other PFAS not included in targeted methods. Detection of unregulated PFAS at frequencies and levels of concern with these methods may indicate the need for development of information required for future regulation such as health-based concentrations, approved analytical methods, and evaluation of treatment removal.

NJDEP, in consultation with the DWQI, further concludes that regulation of a PFAS subclass selected based on removal by a specific treatment technology is not feasible. The identities of all PFAS removed by a specific treatment technology are not known, and all PFAS removed by a specific technology are not detected in targeted analytical methods. As such, this approach is more relevant to treatment removal approaches for addressing PFAS as the entire class because, as discussed above, identification of all PFAS present and removed is not required. Additionally, the treatment technology or technologies that are most appropriate for use by a specific public water system depends on which of the regulated PFAS are detected there as well as other site-specific considerations.

The table below provides a summary of considerations and conclusions for regulation of PFAS as the entire class or as certain subclasses or mixtures in drinking water.

	*Considerations for Drinking Water Standards**	
	PFAS as entire class	PFAS as certain subclasses or mixtures
General considerations for all categories below	• Regulation of PFAS as entire class in drinking water is a worthwhile goal, but it is not feasible at this time. • Reconsideration is recommended when California evaluations (see below) are completed.	• Feasible, with caveats discussed. • Not appropriate to include long-chain PFAS with health-based level below PQL. • Occurrence of unregulated PFAS in NJ drinking water should be considered in deciding if an MCL is needed. • Sources of occurrence data include USEPA UCMR5 for 29 PFAS with approved analytical methods; studies with other targeted methods or non-targeted analysis for additional PFAS.
Standard based on same health effect(s)	• Similar toxicity of all PFAS not assumed, and approach not based on human health risk assessment. • Primary basis is common property of extreme environmental persistence.	• Toxicology data to develop health-based concentration is needed for each PFAS included in subclass; many PFAS lack such information. • Approved analytical method and a treatment removal technology must be available for each included PFAS; multiple analytical methods and sequential treatment technologies may be needed.
Standard based on inclusion in same analytical method	• Approved methods for regulation of total PFAS in drinking water not currently available. • Current methods for estimating total PFAS lack sensitivity and specificity. • California is developing broad-spectrum analytical approach for PFAS in drinking water; unclear if will be used for regulation.	• Feasible for PFAS detected in analytical method approved for MCL compliance; many PFAS are not detected in these methods. • Treatment removal technology must be available for each included PFAS; multiple sequential technologies may be needed. • Development of health-based concentration for each included PFAS is not required. • Numerical standard for total concentration of included PFAS is a policy decision; does not consider differences in toxicological potency among PFAS.
Standard based on removal by a specific treatment technology	• Would likely require multiple concurrent treatment methods. • Requires use of analytical method for total PFAS to evaluate treatment removal. • California evaluation of "treatment-based [drinking water] regulation" for PFAS as a class is in progress. Recommend future reevaluation of this issue based on this effort.	• Not feasible for subclass of specific PFAS. • All PFAS removed by a specific technology are not known and/or not detected with targeted analytical methods. • As such, this approach is more relevant to addressing PFAS as entire class, since identification of all PFAS present in source water and removed by treatment is not required.

*Costs were not considered in this evaluation.

Federal, state, and international guidelines for PFAS as a class or as certain subclasses or mixtures

The Interstate Technology & Regulatory Council (ITRC) maintains a comprehensive table (PFAS Water and Soil Values Table– Excel file) of current state, federal and international guidelines (standards and guidance values) for PFAS in water and soil. The table is updated approximately every two months and can be accessed at https://pfas-1.itrcweb.org/fact-sheets/.

Additionally, ECOS (2025) provides a recent summary of state drinking water guidelines for individual and grouped PFAS, including the rationales provided by states for their approaches.

Information on key federal, state, and international guidelines is summarized below:

USEPA

USEPA (2024a) finalized MCLs for five individual PFAS (PFOA, PFOS, PFNA, PFHxS, GenX [HFPO-DA]) and an MCL of a Hazard Index of 1 for non-cancer effects of a mixture of four PFAS (PFNA, PFHxS, GenX, PFBS) in 2024.

PFOA and PFOS were classified as likely human carcinogens, and their Maximum Contaminant Levels Goals (MCLGs; health-based levels) were set at zero in accordance with USEPA policy for likely human carcinogens. Therefore, the enforceable MCLs for PFOA and PFOS were set at their PQLs (4.0 ng/L) because they are higher than the MCLGs.

The USEPA (2024b,c) Office of Water toxicity assessments of PFOA and PFOS also include Reference Doses for non-cancer effects based on human data that are several hundred-fold lower than the earlier USEPA Reference Doses based on animal data. These new Reference Doses result in health-based drinking water concentrations far below the PFOA and PFOS PQLs of 4.0 ng/L. USEPA (2024a) explained that it would not be appropriate or meaningful to include PFOA or PFOS in the MCL for non-cancer effects of a PFAS mixture because any detection (defined as the PQL for regulatory purposes) would result in an MCL exceedance.

The Reference Doses for PFNA and PFHxS used for the USEPA (2024a) MCLs are based on animal toxicology data.[6] However, the USEPA Integrated Risk Information System (IRIS) program has developed a final Reference Doses for PFHxS and a draft Reference Dose for PFNA using human data, with bases similar to the USEPA Office of Water Reference Doses for PFOA and PFOS that also use human data (mentioned above). These PFHxS and PFNA Reference Doses are several hundred-fold lower than the Reference Doses based on animal data used for the PFHxS and PFNA MCLs (Table 4 of Appendix A).

---

[6] The References Doses used for the USEPA (2024a) PFNA and PFHxS MCLs come from Agency for Toxicity Substances and Disease Registry (ATSDR) Minimal Risk Levels (MRLs) for these PFAS. MRLs are developed to protect for non-carcinogenic effects through a similar process as is used for Reference Doses.

The USEPA (2024a) MCL for a PFAS mixture did not use the IRIS Reference Doses based on human data because they were not final at the time the MCLs were finalized. As is the case for PFOA and PFOS, health-based drinking water concentrations for PFNA and PFHxS using these new Reference Doses would be far below their PQLs. Therefore, it would not be appropriate or meaningful to include PFNA and PFHxS in an MCL for a PFAS mixture based on these much lower Reference Doses after they are finalized. This is because any detection would result in an MCL exceedance. Additionally, for an MCL for a PFAS mixture that is based on the health-based concentrations (i.e., MCLGs) of the individual PFAS (e.g., Hazard Index), it is not appropriate to include PFAS with MCLs set at their analytical PQLs rather than the

U.S. states

New Jersey and several other states (e.g., CA, IL, MI, MN, NH, NY, WA) have developed chemical-specific drinking water guidelines for PFOA, PFOS, PFNA, PFHxS, and/or GenX (ECOS, 2025; ITRC PFAS Water and Soil Values Table– Excel file at https://pfas-1.itrcweb.org/fact-sheets/). Most of the state chemical-specific values for these PFAS are higher than the USEPA (2024a) MCLs for PFOA (4.0 ng/L), PFOS (4.0 ng/L) PFNA (10 ng/L), PFHxS (10 ng/L) and GenX (10 ng/L), and they will be superseded by the USEPA MCLs.

Several other states (e.g., CO, MA, ME, OR, RI, VT) have developed drinking water standards or guidance values based on a total concentration 20 or 30 ng/L for four to six long-chain PFAS (Appendix A). As discussed above, these guidelines are not relevant or applicable to drinking water concentrations below PQLs that would result from use of the newer more stringent toxicity factors for these long-chain PFAS, because any detection of those PFAS would result in an exceedance of the drinking water standard. Additionally, these states will now need to comply with the recently finalized USEPA (2024a) MCLs for long-chain PFAS (PFOA, PFOS, PFNA, and PFHxS) mentioned above.

In addition to its chemical-specific drinking water values for six individual PFAS, Minnesota (MDH, 2022) uses an approach analogous to a Hazard Index (called a Health Risk Index) to evaluate risks of contaminants that co-occur in groundwater (based on drinking water exposure). It is based on grouping contaminants (including PFAS and others) that cause toxicity to the same target organ (e.g., liver, kidney, thyroid).

International

Several international drinking water guidelines for PFAS as the entire class or certain subclasses of PFAS have been proposed or adopted. Examples include:

- The European Union (EU, 2020) Drinking Water Directive, which directs member states to use a “PFAS Total” value of 500 ng/L, including trifluoroacetic acid, or a “Sum of PFAS” value of 100 ng/L for the total concentration of a list of 20 specified PFAS (perfluorocarboxylates and perfluorosulfonates with 4-13 carbon atoms). Technical guidance for analytical methods to be used for “PFAS Total” recommends the TOP assay, EOF-CIC, or LC-HRMS suspect and non-target analysis (liquid chromatography high resolution mass spectrometry) “as a proxy for PFAS Total” (EU, 2024). EU (2024) recognizes that these methods are not standardized or harmonized, that further validation is needed, and that reliable data on the uncertainty of measurement and the limit of quantitation (LOQ) is not available for most of the methods. As such, “it is not yet possible to ensure compliance with the [European Union’s] analytical performance requirements” for “PFAS Total.”

- The Health Canada (2024) non-enforceable drinking water objective of 30 ng/L for total concentration of 25 PFAS included in USEPA Method 533. It is noted that the Health Canada guideline does not consider newer toxicity factors for long-chain PFAS based on human data that are much lower than current toxicity factors based on animal data.

- Denmark (Denmark Ministry of the Environment, 2023) established drinking water guidelines of 2 ng/L for the total concentration of PFOA, PFOS, PFNA, and PFHxS, and 100 ng/L for the total concentration of a list of 22 specified PFAS.

Assessment of treatment technologies for removal of PFAS from drinking water and wastewater

New Jersey P.L.2023, c.279 requires the New Jersey Department of Environmental Protection (NJDEP), in consultation with the New Jersey Drinking Water Quality Institute (DWQI), to conduct an assessment of “treatment technologies that may be effective in removing perfluoroalkyl and polyfluoroalkyl substances from drinking water or wastewater.”

As discussed above, NJDEP established a Maximum Contaminant Level (MCL) of 13 nanograms per liter (ng/L) for PFNA in 2018, and MCLs of 14 ng/L for PFOA and 13 ng/L for PFOS in 2020. Conventional drinking water (e.g., coagulation, sedimentation, disinfection) and wastewater treatment technologies (e.g., bar screens, grit removal, clarifiers, filtration, aeration) are generally not effective for the removal of PFAS, and specific treatment removal technologies are needed. To comply with the MCLs, numerous New Jersey public water systems have therefore installed or plan to install treatment technologies to remove PFAS. Specifically, NJDEP had approved 116 permits for permanent treatment to remove PFAS in 84 different public water systems, including community and non-community systems[7], as of December 2025. Of these approved permits, 56 New Jersey drinking water treatment plants had installed treatment to remove PFAS to concentrations below the New Jersey MCLs as of April 2025. In addition to the

---

[7] Treatment for PFAS at some non-community public water systems may have been approved at the county level and are not included in the numbers above.

permits that were approved for permanent treatment, other permit applications for PFAS treatment are under review, and additional permits for temporary treatment (e.g., pilot scale) have also been approved by NJDEP.

This section of the report provides an assessment of technologies for removal of PFAS from drinking water and wastewater based both on information from the published literature and knowledge about treatment removal of PFAS that NJDEP has acquired since its PFAS MCLs were established.[8]

While cost was excluded as a key performance indicator in this evaluation, cost may be a limiting factor when implementing or designing for PFAS removal and is mentioned where relevant. For wastewater, effluent treatment was the focus of this assessment, and treatment of wastewater byproducts such as activated sludge and biosolids were not evaluated.

Of the three major technology categories discussed in this assessment - adsorption, membranes, and destruction, adsorption-based technologies are currently the most frequently applied for PFAS treatment in water systems. More specifically, granular activated carbon (GAC) and ion exchange (IX) resins have been studied extensively (USEPA, 2024g; ITRC, 2026) and have been deployed for both drinking water and industrial wastewater treatment in New Jersey (NJDEP, 2022; Integral Consulting, 2025) and elsewhere. As of April 2025, NJDEP records indicate that 56 New Jersey drinking water treatment plants (27 for GAC and 29 for IX resins) have installed adsorption-based treatment to remove PFAS to concentrations below the New Jersey MCLs. Additionally, of the 116 permits approved by NJDEP for permanent treatment as of December 2025, 57 are for GAC, 57 for IX resins, and 2 for other adsorbents. Several other water treatment facilities in New Jersey have also been investigating the applications of other adsorbents such as surface modified clay, plant-based adsorbents, and powdered activated carbon (e.g., pilot scale). Other adsorption-based processes such as foam fractionation could be applied for wastewater treatment in the future as well (We et al., 2024). Although many PFAS that may be present in water can be removed by adsorption technologies, differences in breakthrough times and removal efficiencies among PFAS must be considered to ensure adequate removal of all PFAS of interest. For both GAC and IX resins, breakthrough times for short-chain perfluoroalkyl acids (PFAAs) are generally shorter than for long-chain PFAAs, and they are also shorter for PFAAs that are carboxylates than those that are sulfonates (Murray et al., 2021). The main challenge for adsorbents in general is disposal of the material after it has been concentrated with PFAS. Adsorbents can be reactivated (thermal treatment) or regenerated (chemical treatment) for reuse, specifically reactivation for GAC at present time,

---

[8] An evaluation of a technique, brand, or product does not constitute an endorsement by NJDEP.

but they must eventually be disposed (Mayerberger et al., 2025; Kempisty et al., 2024). Options for adsorbents after end of use include destruction via incineration at facilities approved to handle PFAS materials and disposal at landfills approved to handle PFAS materials (US DOE, 2023). However, an increasing number of landfills will not accept solids with PFAS contamination (ITRC, 2026).

Membrane-based technologies could be an alternative for the removal of PFAS from drinking water, but their use for PFAS removal from wastewater could be limited by challenges such as fouling of the membrane and disposal of the reject water containing concentrated PFAS (ITRC, 2026). Under proper operating conditions, reverse osmosis and nanofiltration can remove certain PFAS to levels below reporting limits (0.25 - 5 nanograms per liter, ng/L) (Liu et al., 2021; Appleman et al., 2013). Although RO and NF appear to be promising, more research is needed on full-scale applications, long-term operation, and causes of failure. Other challenges to be considered when using these technologies include disposal options for the PFAS reject water and cost (US DOE, 2023; USEPA, 2024g).

Destruction-based technologies could serve as the ideal final approach to ending the release and recirculation of PFAS through the environment in the future. A few examples of destruction-based technologies applicable for PFAS removal include electrochemical oxidation, supercritical water oxidation, and plasma. However, more research is needed on the long-term operation of these destruction-based technologies, including identification of possible byproducts, and performance enhancement (Zeidabadi et al., 2023; Sahle-Demessie and Krause, 2021; Meegoda et al., 2022).

Ultra-short chain PFAS, particularly trifluoroacetic acid (TFA), are a rising concern for treatment facilities (Zheng et al., 2023; Kim et al., 2022). IX resins and RO could be possible technologies that can reduce these types of PFAS (Schueurer et al., 2017; Björnsdotter et al., 2020). However, more research is needed to understand ultra-short chain removal and optimization of available technologies. To guarantee a comprehensive removal of PFAS with varying sizes, more than one treatment technology should be included in the treatment train.

Although several PFAS treatment technologies are currently available on the market and others are in development, selection of effective treatment for the removal of PFAS requires careful consideration and design. When designing treatment for PFAS removal, water systems must assess the specific PFAS present in their source water and their influent concentrations, as well as their specific source water quality, volume of water treated, existing treatment, waste management, and the presence of other regulated and unregulated contaminants of concern. Every treatment facility has different water quality goals (e.g., target concentration of specific

PFAS parameters, pH, water temperature, etc.) and site-specific constraints (e.g., cost, space, sewer availability), and installation of treatment technology for removal of PFAS could require significant allocation of resources. Therefore, any treatment technique for PFAS should be carefully designed and tailored to the specific treatment facility where it will be used.

References

Appleman, T. D., Higgins, C. P., Quiñones, O., Vanderford, B. J., Kolstad, C., Zeigler-Holady, J. C., & Dickenson, E. R. V. (2013). Treatment of poly- and perfluoroalkyl substances in U.S. full-scale water treatment systems. Water Research, 51: 246 – 255. https://doi.org/10.1016/j.watres.2013.10.067

Bil, W., Zeilmaker, M., Fragki, S., Lijzen, J., Verbruggen, E., & Bokkers, B. (2021). Risk Assessment of Per- and Polyfluoroalkyl Substance Mixtures: A Relative Potency Factor Approach. Environmental Toxicology and Chemistry. 40, 859-870. https://doi.org/10.1002/etc.4835

Björnsdotter, M. K., Yeung, L., W. Y., Kärrman, A., & Jogsten, I. E. (2020). Challenges in the analytical determination of ultra-short-chain perfluoroalkyl acids and implications for environmental and human health. Analytical and Bioanalytical Chemistry. 412, 4785–4796. https://doi.org/10.1007/s00216-020-02692-8

CA Water Board (2024a). California State Water Resources Control Board. Comments on Analytical Methods for Unregulated Contaminant Monitoring Rule 6. Submitted to USEPA. April 5, 2024. Posted at https://www.regulations.gov/comment/EPA-HQ-OW-2023-0469-0087

CA Water Board (2024b). California State Water Resources Control Board. Broad-Spectrum Per- and Polyfluoroalkyl Substances (PFAS) Method Comparison Study Results and Selection of Broad-Spectrum Methods to Support Statewide Monitoring for the Class of PFAS. April 24, 2024. https://www.waterboards.ca.gov/pfas/docs/broad-spectrum-pfas-method-comparison-study-summary-combined.pdf

Cousins, I. T., DeWitt, J. C., Glüge, J., Goldenman, G., Herzke, D., Lohmann, R., Ng, C. A., Scheringer, M., & Wang, Z. (2020a). The high persistence of PFAS is sufficient for their management as a chemical class. Environmental Science. Processes & Impacts. 22, 2307–2312. https://doi.org/10.1039/d0em00355g

Delaware House of Representatives (2021). 151st General Assembly. House Bill No. 8. An Act to amend Title 29 of the Delaware Code relating to drinking water. https://legiscan.com/DE/text/HB8/id/2413483

Denmark Ministry of the Environment (2023). Decree on water quality and supervision of water supply facilities. https://www.retsinformation.dk/eli/lta/2023/1023

DWQI (2022). New Jersey Drinking Water Quality Institute. Review of Interim USEPA Health Advisories for PFOA and PFOS and Other Relevant Information. December 2, 2022. https://www.nj.gov/dep/watersupply/pdf/dwqi-health-effects-pfas-report.pdf

DWQI (2025). New Jersey Drinking Water Quality Institute. Health Effects Subcommittee review of internal assessment report for regulating PFAS as an entire class or subclass/mixture. Memorandum from J. Gleason, Health Effects Subcommittee chair, to Phoebe Stapleton, DWQI chair. July 1, 2025. https://dspace.njstatelib.org/items/d3d30e37-91b9-42cb-a107-7d909992a6e2

ECOS (2025). Environmental Council of the States. Compendium of State PFAS Actions. April 2025. https://www.ecos.org/wp-content/uploads/2025/04/ECOS-PFAS-Compendium-FINAL.pdf

EU (2020). Directive (EU) 2020/2184 of the European Parliament and of the Council of 16 December 2020 on the quality of water intended for human consumption (recast). https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32020L2184

Harrill, A. H., Hagiwara, S., Weitekamp, C. A., Stanish, P. C., Wall, J. T., Sayre, R. R., Davidson-Fritz, S. E., Vitense, K., Chang, D. T., Devito, M. J., Gonzales, C. J., Groover, M., Hughes, M. F., Judson, R. S., Lambert, J. C., Lowe, C. N., Mutlu, E., Friedman, K. P., Watkins, A. M., Williams, A. J., … Thomas, R. S. (2026). Database-calibrated toxicity values for human health assessment based on existing toxicology data for one thousand chemicals. Journal of toxicology and environmental health. Part B, Critical reviews. 29(2), 128–167. https://doi.org/10.1080/10937404.2025.2552108

Health Canada (2024). Objective for Canadian Drinking Water Quality Per- and Polyfluoroalkyl Substances. https://www.canada.ca/content/dam/hc-sc/documents/services/publications/healthy-living/objective-drinking-water-quality-per-polyfluoroalkyl-substances/objective-for-canadian-drinking-water-quality-en-final.pdf

HIDOH (2024). Hawaii Department of Health. Interim PFAS Guidance. Attachment 1 of *Interim Soil and Water Environmental Action Levels (EALs) for Perfluoroalkyl and Polyfluoroalkyl*

Substances (PFASs). April 12, 2024. https://health.hawaii.gov/heer/files/2024/04/PFAS-Update-signed-April-2024.pdf

Integral Consulting (2025). Focused Preliminary Assessment PFAS and Alternative PFAS Solvay Specialty Polymers USA, LLC (now known as Syensqo Specialty Polymers USA, LLC) 10 Leonard Lane West Deptford, NJ 08086 Program Interest No: 015010. September 2025. https://www.syensqo.com/sites/g/files/alwlxe161/files/2025-10/202509-Final-PA-Report.pdf

ITRC (2026). Interstate Technology & Regulatory Council. PFAS Technical and Regulatory Guidance Document and Fact Sheets, PFAS-1. Washington, D.C.: Interstate Technology & Regulatory Council, PFAS Team. https://pfas-1.itrcweb.org/ Last updated January 2026.

Kempisty, D. M., Gordon, C., Haxen, J., Mowla, O., Nickelsen, M. G., & Woodard, S. (2024). THE TREATMENT OF PFAS-IMPACTED GROUNDWATER USING NOVEL REGENERABLE ION EXCHANGE RESIN: A FIVE-YEAR CASE STUDY. Australian Water Association. 10(3). https://montrose-env.com/wp-content/uploads/2017/09/RIEX_Water_E-journal_August_2024-1.pdf

Kim, J., Xin, X., Mamo, B. T., Hawkins, G. L., Li, K., Chen, Y., Huang, Q., & Huang, C. H. (2022) Occurrence and fate of ultrashort-chain and other per-and polyfluoroalkyl substances (PFAS) in wastewater treatment plants. ACS ES&T Water. 2 (8), 1380– 1390. https://doi.org/10.1021/acsestwater.4c00541

Liu, C. J., Strathmann, T. J., & Bellona, C. (2021). Rejection of per- and polyfluoroalkyl substances (PFASs) in aqueous film-forming foam by high-pressure membranes. Water Research, 188: 116456. https://doi.org/10.1016/j.watres.2020.116546

Mayerberger, E., Rodriguez, A., Townsend, E., DiStefano, R., Alward, R., & Matthis, J. (2025). Destruction of PFAS During Thermal Reactivation of Granular Activated Carbon Used in Potable Water Treatment. Remediation Journal. 35(4). https://doi.org/10.1002/rem.70030

McCord, J. P., Strynar, M. J., Washington, J. W., Bergman, E. L., & Goodrow, S. M. (2020). Emerging Chlorinated Polyfluorinated Polyether Compounds Impacting the Waters of Southwestern New Jersey Identified by Use of Nontargeted Analysis. Environmental Science & Technology Letters. 7(12), 903–908. https://pubs.acs.org/doi/10.1021/acs.estlett.0c00640

McDonough, C. A., Guelfo, J. L., & Higgins, C. P. (2019). Measuring Total PFASs in Water: The Tradeoff between Selectivity and Inclusivity. Current Opinion in Environmental Science & Health. 7, 13–18. https://www.sciencedirect.com/science/article/abs/pii/S2468584418300515

MDH (2020). Minnesota Department of Health. Evaluating Concurrent Exposures to Multiple Chemicals. Updated October 3, 2022. Accessed May 7, 2024. https://www.health.state.mn.us/communities/environment/risk/guidance/gw/additivity.html#:~:text=The%20MDH%20Water%20Guidance%20and,based%20guidance%20for%20that%20chemical

Meegoda, J. N., Bezerra de Souza, B., Casarini, M. M., & Kewalramani, J. A. (2022). A Review of PFAS Destruction Technologies. International Journal of Environmental Research and Public Health. 19(24), 16397. https://doi.org/10.3390/ijerph192416397

Murray, C. C., Marshall, R. E., Liu, C. J., Vatankhah, H., & Bellona, C. L. (2021). PFAS treatment with granular activated carbon and ion exchange resin: Comparing chain length, empty bed contact time, and cost. Journal of Water Process Engineering. 44, 102342. https://doi.org/10.1016/j.jwpe.2021.102342

NJDEP (2004). New Jersey Department of Environmental Protection. Opportunity for Public Comment on possible regulatory strategies to address the occurrence of unregulated organic contaminants in drinking water. (Notice requesting public comment published in New Jersey Register 36 (3), February 2, 2004) https://hdl.handle.net/10929/154235

NJDEP (2007). Determination of Perfluorooctanoic Acid (PFOA) in Aqueous Samples, Final Report, January 2007. http://www.nj.gov/dep/watersupply/final_pfoa_report.pdf

NJDEP (2014). New Jersey Department of Environmental Protection. Occurrence of Perfluorinated Chemicals in Untreated New Jersey Drinking Water Sources Final Report. April 2014. http://www.nj.gov/dep/watersupply/pdf/pfc-study.pdf

NJDEP SAB (2020). New Jersey Department of Environmental Protection Science Advisory Board. Approaches for Addressing Drinking Water and Wastewater Contaminants of Emerging Concern (CECs) in a Broader Context: Identification, Ranking and Treatment Removal. April 22, 2020. https://dep.nj.gov/wp-content/uploads/sab/sab-cec-2020.pdf

NJDEP (2022). New Jersey Department of Environmental Protection. Public comment on: *PFOS and PFOA in Drinking Water, Draft background document for development of World Health Organization (WHO) Guidelines for Drinking Water Quality*. Submitted November 11, 2022.https://dep.nj.gov/wp-content/uploads/dsr/njdep-comments-who-pfas-guidelines.pdf

NJDEP (2026) New Jersey Department of Environmental Protection. Per- and Polyfluoroalkyl Substances (PFAS) Research. Last updated March 12, 2026. https://dep.nj.gov/dsr/pfas/

NJDOH (2024). New Jersey Department of Health. Drinking Water Facts: Per- and Polyfluoroalkyl Substances (PFAS) in Drinking Water. https://www.nj.gov/health/ceohs/documents/pfas_drinking%20water.pdf Last updated April 2024.

NSF (2026). National Sanitation Foundation. PFAS in Drinking Water. https://www.nsf.org/consumer-resources/articles/pfas-drinking-water

OECD (2021). Organisation for Economic Co-operation and Development. Reconciling Terminology of the Universe of Per- and Polyfluoroalkyl Substances: Recommendations and Practical Guidance. Series on Risk Management. No.61. https://one.oecd.org/document/ENV/CBC/MONO(2021)25/En/pdf

Pelch, K. E., McKnight, T., & Reade, A. (2023). 70 analyte PFAS test method highlights need for expanded testing of PFAS in drinking water. Science of the Total Environment. 876, 162978. https://doi.org/10.1016/j.scitotenv.2023.162978

Post, G.B., Louis, J.B., Lippincott, R.L., & Procopio, N.A. (2013). Occurrence of perfluorinated chemicals in raw water from New Jersey public drinking water systems. Environmental Science & Technology. 47(23), 13266-13275. https://pubs.acs.org/doi/10.1021/es402884x

Post, G.B., Gleason, J.A., & Cooper, K.R. (2017). Key scientific issues in developing drinking water guidelines for perfluoroalkyl acids: Contaminants of emerging concern. PLoS Biology. 15(12), e2002855. https://journals.plos.org/plosbiology/article/file?id=10.1371/journal.pbio.2002855&type=printable

Safer States (2024). PFAS Definition Factsheet: Why a Strong PFAS Definition Matters. https://www.saferstates.org/resource/pfas-definition-factsheet/

Sahle-Demessie, E. & Krause, M. (2021). Potential PFAS destruction technology: supercritical water oxidation. https://www.epa.gov/sites/production/files/2021-01/documents/pitt_research_brief_scwo_final_jan_25_2021_508.pdf

Scheurer, M., Nödler, K., Freeling, F., Janda, J., Happel, O., Riegel, M., Müller, U., Storck, F. R., Fleig, M., Lange, F. T., Brunsch, A., & Brauch, H-J. (2017). Small, mobile, persistent: Trifluoroacetate in the water cycle: Overlooked sources, pathways, and consequences for drinking water supply. Water Research. 126, 460 - 471. https://doi.org/10.1016/j.watres.2017.09.045

US DOE (2023). United States Department of Energy. DOE Commercial Potential Evaluation (CPE) Report // PFAS in Wastewater. https://science.osti.gov/-/media/sbir/pdf/Application_Resources/2023/CPE-PFAS-Final-Report.pdf

USEPA (2009). United States Environmental Protection Agency. Long-Chain Perfluorinated Chemicals (PFCs) Action Plan. December 30, 2009. https://www.epa.gov/sites/default/files/2016-01/documents/pfcs_action_plan1230_09.pdf

USEPA (2022). United States Environmental Protection Agency. Drinking Water Contaminant Candidate List 5—Final. Federal Register. 87 (281), 68060-68085. November 14, 2022. https://www.govinfo.gov/content/pkg/FR-2022-11-14/pdf/2022-23963.pdf

USEPA (2021). United States Environmental Protection Agency. National PFAS Testing Strategy: Identification of Candidate Per- and Polyfluoroalkyl Substances (PFAS) for Testing. October 2021. https://www.epa.gov/system/files/documents/2021-10/pfas-natl-test-strategy.pdf

USEPA (2023). United States Environmental Protection Agency. Toxic Substances Control Act Reporting and Recordkeeping Requirements for Perfluoroalkyl and Polyfluoroalkyl Substances. Fed. Reg. 88 (195): 70516-70559. October 11, 2023. https://www.govinfo.gov/content/pkg/FR-2023-10-11/pdf/2023-22094.pdf

USEPA (2024a). United States Environmental Protection Agency. PFAS National Primary Drinking Water Regulation. Federal Register 89 (82): 32532-32757. April 26, 2024. https://www.govinfo.gov/content/pkg/FR-2024-04-26/pdf/2024-07773.pdf

USEPA (2024b). United States Environmental Protection Agency. Final Human Health Toxicity Assessment for Perfluorooctanoic Acid (PFOA) and Related Salts. EPA Document No. 815R24006. April 2024. https://www.epa.gov/system/files/documents/2024-04/main_final-toxicity-assessment-for-pfoa_2024-04-09-refs-formatted.pdf

USEPA (2024c). United States Environmental Protection Agency. Final Human Health Toxicity Assessment for Perfluorooctane Sulfonic Acid (PFOS) and Related Salts. EPA Document No. 815R24007. April 2024. https://www.epa.gov/system/files/documents/2024-04/main_final-toxicity-assessment-for-pfos_2024-04-09-refs-formatted_508c.pdf

USEPA (2024d). United States Environmental Protection Agency. Standard Methods for Development of EPA Transcriptomic Assessment Products (ETAPs). EPA/600/X-23/083. March 2024.
https://cfpub.epa.gov/si/si_public_file_download.cfm?p_download_id=548702&Lab=CCTE

USEPA (2024e). United States Environmental Protection Agency. Frequent Questions about PFAS Methods for NPDES Permits. Updated January 31, 2024. https://www.epa.gov/cwa-methods/frequent-questions-about-pfas-methods-npdes-permits

USEPA (2024f). United States Environmental Protection Agency. Method 1621. Determination of Adsorbable Organic Fluorine (AOF) in Aqueous Matrices by Combustion Ion Chromatography (CIC). January 2024. https://www.epa.gov/system/files/documents/2024-01/method-1621-for-web-posting.pdf

USEPA (2024g). United States Environmental Protection Agency. Best Available Technologies and Small System Compliance Technologies for Per- and Polyfluoroalkyl Substances (PFAS) in Drinking Water. March 2024. https://www.epa.gov/system/files/documents/2024-04/2024-final-pfas-bat-ssct_final-508.pdf

USEPA (2025). United States Environmental Protection Agency. USEPA BOSC DCAP Panel: January 16-17, 2025. https://www.epa.gov/bosc/bosc-dcap-panel-january-16-17-2025 Last updated March 26, 2025.

USEPA (2026). United States Environmental Protection Agency. Occurrence Data from the Unregulated Contaminant Monitoring Rule. https://www.epa.gov/dwucmr/occurrence-data-unregulated-contaminant-monitoring-rule Last updated February 12, 2026.

VT ANR (2020). Vermont Agency of Natural Resources. Notice of Decision Not To Adopt A Maximum Contaminant Level Regulating PFAS as a Class in Public Drinking Water Systems. April 2021. https://dec.vermont.gov/sites/dec/files/PFAS/PFAS-MCL-Final-Decision.pdf

Washington, J. W., Rosal, C. G., McCord, J. P., Strynar, M. J., Lindstrom, A. B., Bergman, E. L., Goodrow, S. M., Tadesse, H. K., Pilant, A. N., Washington, B. J., Davis, M. J., Stuart, B. G., Jenkins, T. M. (2020). Nontargeted mass-spectral detection of chloroperfluoropolyether carboxylates in New Jersey soils. Science (New York, N.Y.). 368(6495), 1103–1107. https://www.science.org/doi/10.1126/science.aba7127

We, A., Zamyadi, A., Stickland, A. D., Clarke, B. O., & Freguia, S. (2024). A review of foam fractionation for the removal of per- and polyfluoroalkyl substances (PFAS) from aqueous matrices. Journal of Hazardous Materials. 465, 133182. https://doi.org/10.1016/j.jhazmat.2023.133182

Zeidabadi, F. A., Esfahani, E. B., & Mohseni, M. (2023). Effects of water matrix on per- and poly-fluoroalkyl substances (PFAS) treatment: Physical-separation and degradation processes – A review. Journal of Hazardous Materials Advances. 10, 100322. https://doi.org/10.1016/j.hazadv.2023.100322

Zheng, G., Eick, S. M., & Salamova, A. (2023). Elevated Levels of Ultrashort- and Short-Chain Perfluoroalkyl Acids in US Homes and People. Environmental Science & Technology. 57 (42), 15782 – 15793. https://doi.org/10.1021/acs.est.2c06715

APPENDIX A: SUPPORTING TECHNICAL DOCUMENTATION

Assessments of:
Feasibility of Regulation of Per- and Polyfluoroalkyl Substances (PFAS) in Drinking Water as the Entire Class or as Certain Subclasses or Mixtures
and
Treatment Technologies for Removal of PFAS from Drinking Water or Wastewater in Response to P.L.2023, c.279.

Prepared by:
New Jersey Department of Environmental Protection

Prepared for:
P.L.2023, c.279
Senate Environment and Energy Committee
Assembly Environment and Solid Waste Committee
Members of the Legislature

March 2026

Mikie Sherrill, Governor
State of New Jersey

Dr. Dale G. Caldwell, Lt. Governor
State of New Jersey

Ed Potosnak, Acting Commissioner
Department of Environmental Protection

Visit the DEP website:
https://dep.nj.gov/

Acknowledgements

Gloria Post, Ph.D., D.A.B.T. (NJDEP Office of the Commissioner) was the primary author of the first sections of this document. Camila Llerena-Olivera, Ph.D. (NJDEP Division of Science and Research) was the primary author of the final section on treatment technologies for removal of PFAS from drinking water and wastewater, with extensive input from Filina Poonolly and Cory Stevenson (NJDEP Division of Water Supply and Geoscience). The thorough reviews and helpful comments provided by Jessie Gleason (NJ Department of Health and NJ Drinking Water Quality Institute) on the first section of this document, and by Sandra Goodrow, Ph.D. (NJDEP Contaminated Site Remediation & Redevelopment), Lori Lester, Ph.D. and Nick Procopio, Ph.D. (NJDEP Division of Science and Research), and Katrina Angarone (NJDEP Office of the Commissioner) on the entire document are gratefully acknowledged.

Table of Contents

Introduction

On January 16, 2024, New Jersey enacted P.L.2023, c.279.[1] (https://www.njleg.state.nj.us/bill-search/2022/S3176), a law that requires NJDEP, in consultation with the DWQI, to conduct "an assessment of the feasibility of establishing a maximum contaminant level [MCL] or other standard for the entire class, or for certain subclasses or mixtures, of PFAS in drinking water, rather than for each individual substance" and to assess "treatment technologies that may be effective in removing perfluoroalkyl and polyfluoroalkyl substances from drinking water or wastewater."

This Appendix provides more detailed technical information to support the assessments required by P.L.2023, c. 279 found in the accompanying report. These assessments are based on evaluation of relevant information including peer-reviewed publications and documents from government agencies.

Per- and polyfluoroalkyl substances (PFAS) are a large class of thousands of synthetic organic compounds that contain one or more totally fluorinated carbon atoms. Due to their chemical structures, PFAS repel both water and oil and are resistant to high temperatures and chemical reactions. Because of these useful properties, PFAS have been produced and used since the 1950s for many purposes including in consumer products (e.g., stain-resistant coatings for upholstery and carpeting, waterproof cosmetics, water-resistant breathable outdoor clothing, greaseproof food packaging), in aqueous film forming foams (AFFF) used for fighting petroleum fires, and as processing aids (i.e., surfactants) in the production of fluoropolymers used in non-stick cookware and other products (ITRC, 2026, Section 2 https://pfas-1.itrcweb.org/; NJDEP, 2026 https://dep.nj.gov/pfas/about/).

Large amounts of PFAS have been released to the environment, and PFAS have been detected in surface water, groundwater, finished drinking water, and other environmental media in New Jersey, throughout the U.S., and worldwide. Sources of PFAS in the environment include industrial facilities where they are made or used, release of AFFF during training or firefighting, industrial and domestic wastewater treatment plant effluent, land application of biosolids (sludge) from wastewater treatment plants, and leachate from industrial waste or consumer products disposed of in landfills (ITRC, 2026, Section 2; NJDEP, 2026).

---

[1] From P.L.2023, c.279: "The Department of Environmental Protection, in consultation with the Drinking Water Quality Institute established pursuant to section 10 of P.L.1983, c.443 (C.58:12A -20), shall conduct a study on the regulation of perfluoroalkyl and polyfluoroalkyl substances in drinking water. The study shall include an assessment of the feasibility of establishing a maximum contaminant level or other standard for the entire class, or for certain subclasses or mixtures, of perfluoroalkyl and polyfluoroalkyl substances in drinking water, rather than for each individual substance. The study shall also include an assessment of treatment technologies that may be effective in removing perfluoroalkyl and polyfluoroalkyl substances from drinking water or wastewater." A written report is due to the Senate Environment and Energy Committee and the Assembly Environment and Solid Waste Committee, or their successors, and the Legislature no later than 24 months after the effective date of the law.

PFAS are of particular concern as drinking water contaminants for several important reasons. They are known as “forever chemicals” because they persist indefinitely in the environment, due to the strength of their carbon-fluorine bonds. Additionally, they are highly water-soluble, in contrast to other well-known persistent, bioaccumulative, and toxic (PBT) organic pollutants (e.g., dioxins and polychlorinated biphenyls) which distribute primarily to soils and sediments (Post et al., 2017 https://journals.plos.org/plosbiology/article/metrics?id=10.1371/journal.pbio.2002855).

Certain PFAS are detected in the blood serum of almost all U.S. residents. However, exposures from low PFAS levels often found in drinking water exceed typical exposures from common sources such as food and consumer products, and consumption of contaminated drinking water increases the levels of these PFAS in blood serum over time. The PFAS commonly detected in blood serum are excreted very slowly, and the elevated blood serum levels persist for many years after exposure to contaminated drinking water ends. Because human health effects of some PFAS are associated even with exposure levels that are prevalent in the general population, it is important to minimize additional exposure from contaminated drinking. Notably, infants are a susceptible subpopulation for adverse effects of certain PFAS, and PFAS exposures to infants from contaminated water are higher than in older individuals, particularly in breastfed infants but also in infants who consume formula prepared with contaminated water (Post et al., 2017; NJDOH, 2024 https://www.nj.gov/health/ceohs/documents/pfas_drinking%20water.pdf).

The New Jersey Department of Environmental Protection (NJDEP) began to evaluate PFAS when they were first reported in New Jersey waters over 20 years ago. At that time, PFAS were not widely recognized as important environmental contaminants, but NJDEP scientists soon realized that they are different from other contaminants and that their presence in drinking water is a cause for concern. Since that time, PFAS have become a high priority environmental issue throughout the U.S. and the world, and information on their sources, occurrence, environmental fate and transport, and health effects has increased exponentially (NJDEP, 2026 https://dep.nj.gov/dsr/pfas/).

NJDEP conducted the first U.S. statewide occurrence studies of PFAS in public water systems in 2006 and 2009. In these studies, perfluorooctanoic acid (PFOA) was detected (above the reporting level of 4-5 ng/L) in raw or treated water of about 60% of the 54 public water systems tested, and perfluorooctane sulfonate (PFOS) was found in about 30%. In the 2009 study, perfluorononanoic acid (PFNA), a PFAS which was not well known at the time, was found in a New Jersey public water system at the highest level that had been reported in drinking water worldwide, and an industrial source was later identified (NJDEP, 2007 http://www.nj.gov/dep/watersupply/final_pfoa_report.pdf; Post et al., 2013 https://pubs.acs.org/doi/10.1021/es402884x; NJDEP, 2014 http://www.nj.gov/dep/watersupply/pdf/pfc-study.pdf).

In 2007, NJDEP developed guidance for chronic (lifetime) exposure to PFOA in drinking water of 40 ng/L) based on the health effects information that was then available. This guidance value was much lower than other PFOA drinking water guidelines at the time, but it is similar to the drinking water guidelines that were later established by USEPA and several other states (NJDEP, 2026). Subsequently, NJDEP established drinking water standards (Maximum Contaminant Levels; MCLs) for PFNA (13 ng/L) in 2018 and PFOA (14 ng/L) and PFOS (13 ng/L) in 2020. These MCLs had been recommended to NJDEP by the New Jersey Drinking Water Quality Institute (DWQI), an advisory body established in the New Jersey Safe Drinking Water Act. It is notable that NJDEP's MCL for PFNA that was adopted in 2018 was the first MCL for any PFAS in the United States (NJDEP, 2026).

In 2024, USEPA (2024a) established lower federal MCLs for PFOA and PFOS of 4 ng/L, which is the lowest concentration that could be reliably measured in drinking water. The USEPA MCLs considered recent epidemiology studies demonstrating human health effects at very low exposure levels. USEPA (2024a) also established MCLs for the total concentration of four other PFAS (PFNA, perfluorohexane sulfonate [PFHxS], perfluorobutane sulfonate [PFBS], hexafluoropropylene oxide dimer acid [HFPO-DA, GenX]) in 2024.

Since NJDEP adopted its PFAS MCLs in 2018-2020, many New Jersey public water systems have taken actions to address PFAS. Specifically, NJDEP had approved 116 permits in 84 different public water systems for permanent treatment to remove PFAS as of December 2025. Of these approved permits, 56 New Jersey drinking water treatment plants had installed treatment to remove PFAS to concentrations below the New Jersey MCLs as of April 2025.

Definition of PFAS

In general, PFAS are a group of thousands of fluorinated organic compounds with many subgroups whose structures vary, as shown in Figures 1 and 2 below. Several definitions of the chemical structures that are included in the PFAS class have been developed by different scientists and organizations. Available definitions are reviewed by Hammel et al. (2022 https://www.sciencedirect.com/science/article/pii/S2589004222002905). Using defined structural filters, the USEPA CompTox Chemicals Dashboard developed a list of almost 11,000 PFAS (Williams et al., 2022 https://www.frontiersin.org/articles/10.3389/fenvs.2022.850019/full).

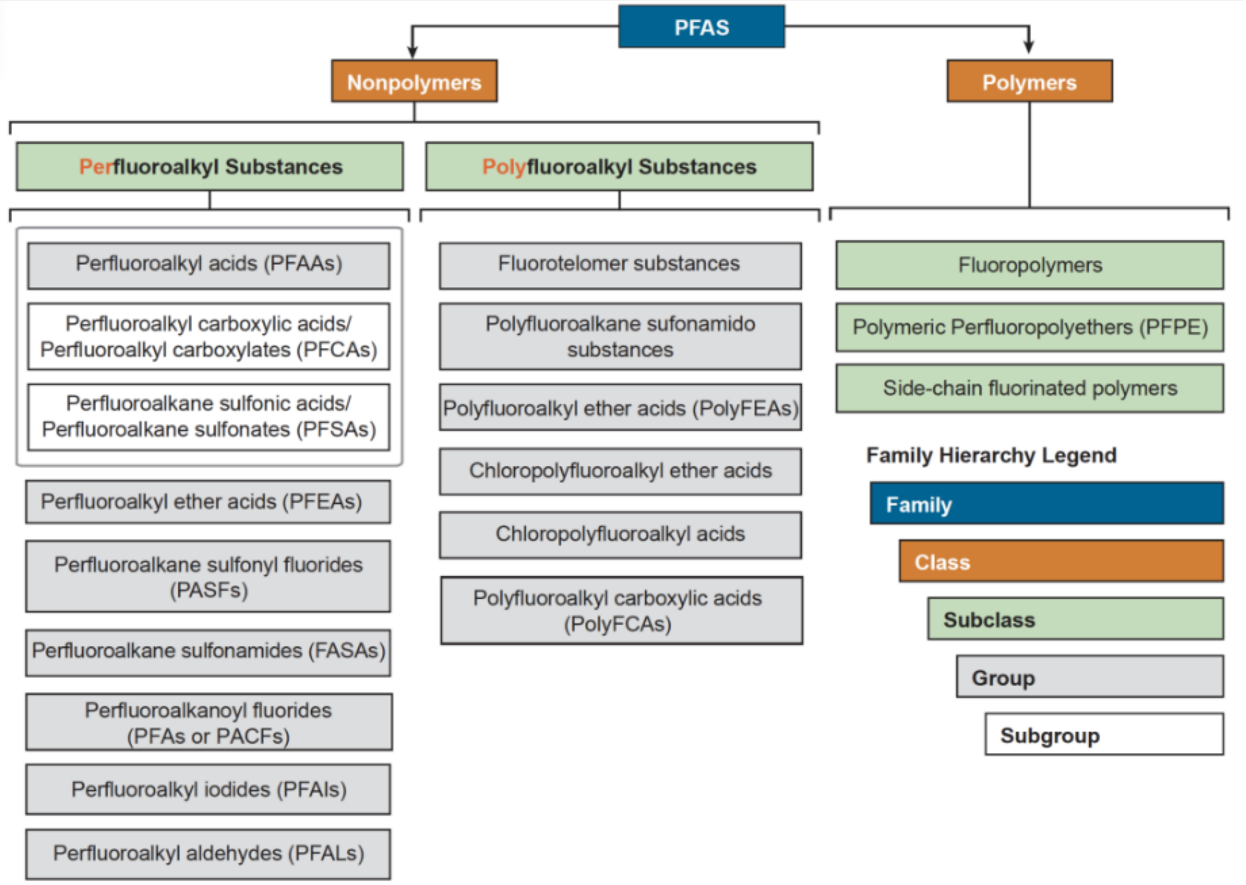


Figure 1. The PFAS Family (ITRC, 2026, Section 2.2 https://pfas-1.itrcweb.org/2-2-chemistry-terminology-and-acronyms/)

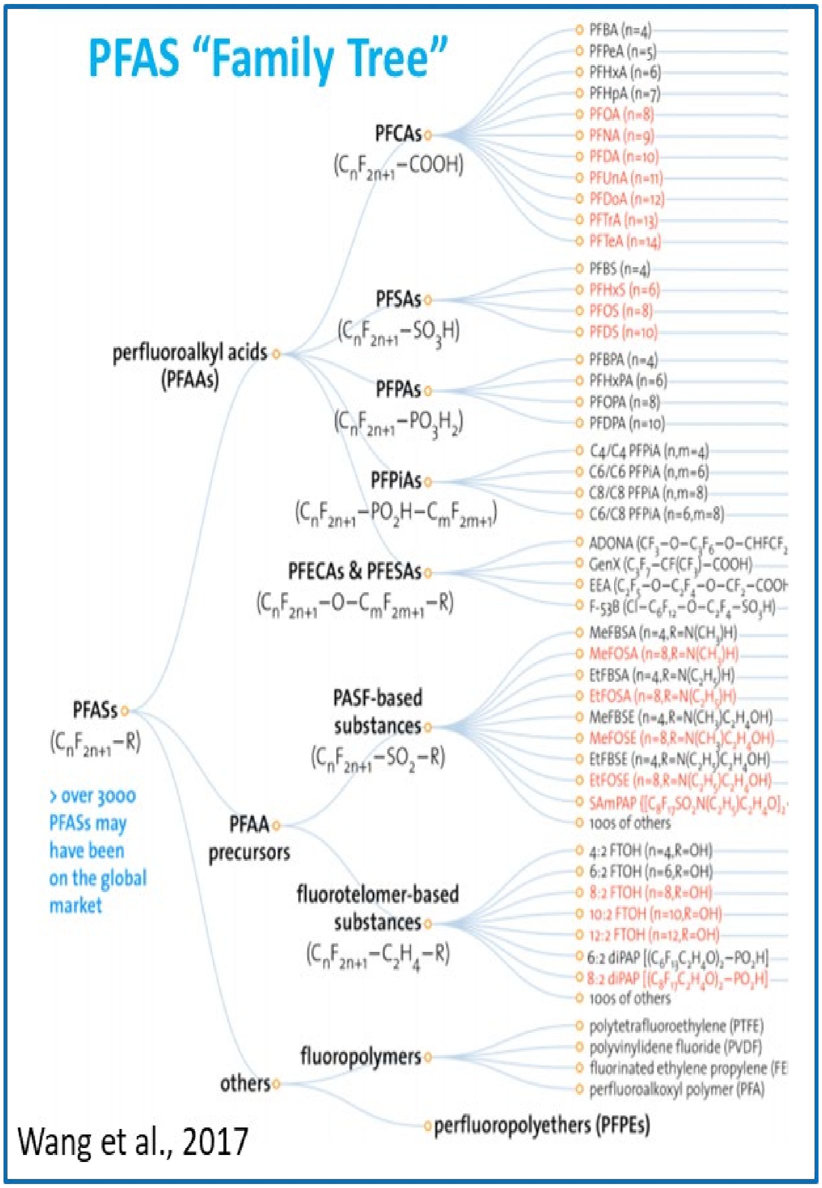


Figure 2. PFAS Family Tree. Wang et al. (2017 https://pubs.acs.org/doi/10.1021/acs.est.6b04806). PFAS shown in red were noted by the authors to be "restricted under national/regional/global regulatory or voluntary frameworks, with or without specific exemptions."

PFAS are defined in New Jersey P.L.2023, c.279 as "any member of the class of fluorinated organic chemicals containing at least one fully fluorinated carbon atom." This is an inclusive definition and is identical or consistent with the definitions adopted by the Organisation for Economic Co-operation and Development (OECD), at least 23 other states, and Congress in the National Defense Authorization Act (Safer States, 2024 https://www.saferstates.org/resource/pfas-definition-factsheet/; OECD, 2021 https://one.oecd.org/document/ENV/CBC/MONO(2021)25/En/pdf).

Importantly, this definition includes ultrashort-chain PFAS such as trifluoroacetic acid (TFA), which has one fully fluorinated carbon.

In contrast, the two USEPA programs mentioned below and at least one state (Delaware) have adopted definitions that exclude compounds with only one fully fluorinated carbon atom. These less inclusive definitions are generally supported by industrial stakeholders.

The definitions used by USEPA Office of Pollution Prevention and Toxics (OPPT), which administers the Toxic Substances Control Act (TSCA), and the USEPA Office of Water, in its Contaminant Candidate List 5 (CCL5), differ slightly but (as mentioned above) both exclude PFAS with one fluorinated carbon.[2]

Delaware defines PFAS as "non-polymeric perfluoroalkyl and polyfluoroalkyl substances that are a group of man-made chemicals that contain at least 2 fully fluorinated carbon atoms, excluding gases and volatile liquids." (DE House of Representatives, 2021 https://legiscan.com/DE/text/HB8/id/2413483). This definition excludes polymeric PFAS, which are generally not found in drinking water, and compounds with one fully fluorinated carbon such as TFA, which is frequently detected in drinking water, and PFAS that are gases and volatile liquids.

Perfluoroalkyl acids (PFAA) are a well-known PFAS subgroup that consist of a fully fluorinated carbon chain and negatively charged carboxylate or sulfonate group. PFAAs can be subdivided by chain length (long-chain, short-chain, ultrashort-chain); this terminology has also been used for PFAS with other structures. Carbon chain length is relevant to the health effects, analytical, and treatment removal considerations discussed below.

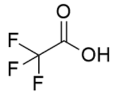
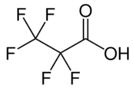
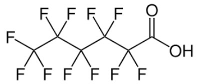
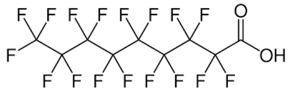
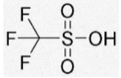
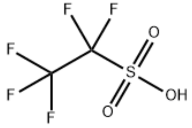
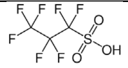
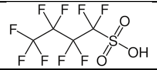
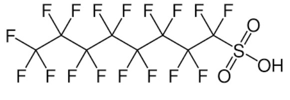
As shown in Table 1, long-chain PFAAs are defined as perfluorocarboxylates/perfluorocarboxylic acids (PFCAs) with 8 or more carbons (i.e., PFOA and longer) and perfluorosulfonates/perfluorosulfonic acids (PFSAs) with 6 or more carbons (i.e., PFHxS and longer) (USEPA, 2009 https://www.epa.gov/sites/default/files/2016-01/documents/pfcs_action_plan1230_09.pdf). Short-chain PFAAs are PFCAs with four to seven carbons and PFSAs with four or five carbons (ITRC, 2026 Section 2.2 https://pfas-1.itrcweb.org/2-2-

---

[2] CCL5 defines PFAS as "chemicals that contain at least one of these three structures…: 1. R-(CF2)-CF(R')R", where both the CF2 and CF moieties are saturated carbons, and none of the R groups can be hydrogen; 2. R-CF2OCF2-R', where both the CF2 moieties are saturated carbons, and none of the R groups can be hydrogen; CF3C(CF3)RR', where all the carbons are saturated, and none of the R groups can be hydrogen." (USEPA, 2022a https://www.govinfo.gov/content/pkg/FR-2022-11-14/pdf/2022-23963.pdf).
The OPPT TSCA definition is similar but slightly different: "…including at least one of these three structures: R-(CF2)-CF(R')R", where both the CF2 and CF moieties are saturated carbons; R–CF2OCF2-R', where R and R' can either be F, O, or saturated carbons; and CF3C(CF3)R'R", where R' and R" can either be F or saturated carbons. (USEPA, 2023a https://www.govinfo.gov/content/pkg/FR-2023-10-11/pdf/2023-22094.pdf). This definition is used in TSCA's National Testing Strategy for PFAS (USEPA, 2021a https://www.epa.gov/system/files/documents/2021-10/pfas-natl-test-strategy.pdf.

chemistry-terminology-and-acronyms/). Ultrashort-chain PFAS are PFCAs with two or 3 carbons and PFSAs with one, two, or three carbons.

Table 1. Ultrashort-chain, short-chain, and long-chain PFCAs and PFSAs.

Perfluoroalkyl acid (PFAA) subgroup	***Chain-length***	***Compound***	***Abbrevi--ation(s)***	***Number of carbons***	***Structure[a]***
Perfluorocarboxylic acids (PFCAs)	Ultrashort-chain	Trifluoroacetic acid	TFA	2	
		Perfluoropropionic acid	PFPrA	3	
	Short-chain	Perfluorobutanoic acid	PFBA	4	
		Perfluoropentanoic acid	PFPeA	5	
		Perfluorohexanoic acid	PFHxA	6	
		Perfluoroheptanoic acid	PFHpA	7	
	Long-chain	Perfluorooctanoic acid	PFOA	8	
		Perfluorononanoic acid	PFNA	9	
		Perfluorodecanoic acid	PFDA	10	
		Perfluoroundecanoic acid	PFUnDA; PFUnA	11	
		Perfluorododecanoic acid	PFDoDA; PFDoA	12[b]	
Perfluorosulfonic acids (PFSAs)	Ultrashort-chain	Trifluoromethane sulfonic acid	PFMeS	1	
		Pentafluoroethane sulfonic acid; perfluoroethane sulfonic acid	PFEtS	2	
		Perfluoropropane sulfonic acid	PFPrS	3	
	Short-chain	Perfluorobutane sulfonic acid	PFBS	4	
		Perfluoropentane sulfonic acid	PFPeS	5	
	Long-chain	Perfluorohexane sulfonic acid	PFHxS	6	
		Perfluoroheptane sulfonic acid	PFHpS	7	
		Perfluorooctane sulfonic acid	PFOS	8[b]	

[a] Structures of representative compounds for each category are shown.

[b] Additional long-chain PFAS have a larger number of carbon atoms in their chains.

Assessment of Feasibility of Regulation of PFAS in Drinking Water as the Entire Class or as Certain Subclasses or Mixtures

In New Jersey, three per- and polyfluoroalkyl substances (PFAS) are currently regulated individually in drinking water. Chemical-specific MCL recommendations for these three PFAS were developed in 2015 through 2018 by the DWQI. The recommendation of chemical-specific MCLs for these PFAS was consistent with the DWQI's previous general approach for other contaminants, although several New Jersey MCLs (PCBs, trihalomethanes, trihaloacetic acids) are based on the total concentration of multiple compounds. NJDEP adopted the recommended MCL of 13 ng/L for PFNA in 2018 and the recommended MCLs of 14 ng/L for PFOA and 13 ng/L for PFOS in 2020.[3]

New Jersey P.L.2023, c.279 requires NJDEP, in consultation with the DWQI, to conduct "an assessment of the feasibility of establishing a maximum contaminant level [MCL] or other standard for the entire class, or for certain subclasses or mixtures." This section provides an assessment of the feasibility of regulating PFAS in drinking water as the entire class or as certain subclasses or mixtures. In this assessment, "feasibility" refers to scientific, technical, and regulatory considerations relevant to this evaluation; costs were not considered. Comments and input provided by the New Jersey Drinking Water Quality Institute and its subcommittees have been incorporated.

Previous DWQI, NJDEP, and NJDEP Science Advisory Board (SAB) evaluations relevant to regulation of multiple PFAS in drinking water

DWQI MCL recommendations for PFNA, PFOA, and PFAS (2015-2018)

Although the DWQI recommended MCLs for PFNA, PFOA, and PFOS based on the concentration of the individual compounds, the DWQI Health Effects Subcommittee recognized that multiple PFAS co-occur in New Jersey drinking water and may have additive toxicity. The potential for additive toxicity of multiple PFAS was acknowledged as an uncertainty in the Health-based MCL Support Documents for all three PFAS (DWQI, 2015a https://www.nj.gov/dep/watersupply/pdf/pfna-health-effects.pdf; DWQI, 2017a https://www.nj.gov/dep/watersupply/pdf/pfoa-appendixa.pdf; DWQI, 2018 https://www.nj.gov/dep/watersupply/pdf/pfos-recommendation-appendix-a.pdf). The DWQI Health Effects Subcommittee also concluded that toxicological effects and mode of action may differ among

---

[3] These DWQI MCL recommendations and the accompanying technical support documents are posted at https://www.nj.gov/dep/watersupply/g_boards_dwqi.html

PFAS and that the dose-response relationship for PFAS mixtures may be complex and dose-dependent (Post, Gleason, Cooper, 2017 https://journals.plos.org/plosbiology/article/file?id=10.1371/journal.pbio.2002855&type=printable; DWQI, 2018 https://www.nj.gov/dep/watersupply/pdf/pfos-recommendation-appendix-d.pdf).

The DWQI Treatment Subcommittee evaluations of PFNA, PFOA, and PFOS concluded that the same treatment technologies can remove these three PFAS because they have similar physical and chemical properties (DWQI, 2015b https://www.nj.gov/dep/watersupply/pdf/pfna-pfc-treatment.pdf). Additionally, the overall DWQI recommendation for the PFOA MCL states: "An additional benefit of the treatment technologies used to remove PFOA is that they also remove other synthetic organic chemicals, natural organic compounds, and other compounds affecting taste and odor that may be present." (DWQI, 2016 https://www.nj.gov/dep/watersupply/pdf/pfoa-recommend.pdf). Also relevant to this topic, a peer reviewed publication by three DWQI members (Post, Gleason, Cooper, 2017 https://journals.plos.org/plosbiology/article?id=10.1371/journal.pbio.2002855) discussed that treatment removal processes intended to remove a specific PFAS may also partially or totally remove other PFAS and other unregulated contaminants, including contaminants not detected by the analytical method used and thus not known to be present.

DWQI Health Effects Subcommittee (2022) evaluation of risks of PFAS mixtures

The DWQI Health Effects Subcommittee (DWQI, 2022 https://www.nj.gov/dep/watersupply/pdf/dwqi-health-effects-pfas-report.pdf)[4] reviewed information on assessment of the risks of PFAS mixtures. This review was part of the Subcommittee's evaluation of whether current scientific information supports decreasing the current New Jersey Health-based MCLs for PFOA and PFOS (14 ng/L and 13 ng/L, respectively) to below the New Jersey PQLs for PFOA and PFOS (6 ng/L and 4 ng/L, respectively).[5] Evaluation of the human health risks of PFAS mixtures is relevant to this issue because, all other things being equal, consideration of additive or synergistic (greater than additive) toxicity of PFOA, PFOS, and/or other PFAS that co-occur in drinking water supports more stringent Health-based MCLs than if such interactions are not considered.

The Health Effects Subcommittee reviewed available information on the toxicity of PFAS mixtures, including the draft USEPA (2021b) "Framework for Estimating Noncancer Health Risks Associated with Mixtures of PFAS" (posted at https://sab.epa.gov/ords/sab/f?p=114:19:11488469483433:::19:P19_ID:975#materials) and the USEPA Science Advisory Board PFAS Review Panel (USA SAB, 2022 posted at https://sab.epa.gov/ords/sab/f?p=100:12:8777962449060) review of USEPA (2021).

---

[4] A PowerPoint presentation summarizing this report is posted at https://www.nj.gov/dep/watersupply/pdf/dwqi-health-effects-pfas-reporting-levels.pdf.

[5] This evaluation was requested by the NJDEP Commissioner when the USEPA (2022b,c) interim drinking water Health Advisories for PFOA and PFOS, which were much more stringent than the New Jersey Health-based MCLs, PQLs, and regulatory MCLs for these PFAS, became available (https://www.nj.gov/dep/watersupply/pdf/dwqi-cmmr-ltr-usepa-pfas-health-advisories.pdf).

In summary, DWQI (2022) stated:

> "The [Health Effects] Subcommittee notes that PFOA, PFOS, and other PFAS typically occur in drinking water as mixtures and that it is important to consider toxicological interactions of PFAS that co-occur in drinking water. The Subcommittee agrees with USEPA (2021) and USEPA SAB (2022) that dose additivity is an appropriate and health-protective default assumption for assessing the non-cancer risks of PFAS mixtures, in the absence of chemical-specific data. Although a quantitative assessment of the risks of PFAS mixtures was outside of the scope of the Subcommittee's evaluation, the Subcommittee concludes that consideration of toxicological interactions of PFAS that co-occur in drinking water supports more stringent Health-based MCLs for PFOA and PFOS."

NJDEP (2004) discussion paper on approaches for reducing unregulated synthetic organic contamination (SOC) from public drinking water supplies

The NJDEP (2004 https://hdl.handle.net/10929/154235) discussion paper provides approaches for reducing unregulated synthetic organic contaminants (SOCs) in public water systems.[6] This discussion paper was developed in response to several research studies showing multiple co-occurring unregulated SOCs in some New Jersey public drinking water systems with both groundwater and surface water sources. Although written prior to awareness of PFAS in New Jersey waters, many of the concepts included in NJDEP (2004) appear to be relevant to the assessment of the feasibility of regulating PFAS in drinking water as a class or as certain subclasses or mixtures required by P.L.2023, c.279.

NJDEP (2004) notes that the chemical-by-chemical MCL approach is not feasible for many unregulated contaminants detected in New Jersey drinking water because health effects information needed for development of chemical-specific MCLs is not available. It also mentions that most of these unregulated contaminants are not detected by analytical methods approved for regulatory use. Furthermore, it is noted that granular activated carbon (GAC) can remove many SOCs from drinking water.

NJDEP (2004) states that the New Jersey Safe Drinking Water Act (N.J.S.A. 58:12A-3 https://www.nj.gov/dep/watersupply/pdf/statut_58.12A-1_SDWA.pdf) provides for regulating a contaminant in drinking water with a treatment technique if it is "not economically or technologically feasible to ascertain the level of such contaminant" (i.e., an analytical method appropriate for regulatory use is not available). NJDEP (2004) also states that "a treatment

---

[6] Some of the SOCs that were detected in these studies may be considered to be contaminants of emerging concern (CEC) based on knowledge of their occurrence and/or potential toxicity, while little or nothing is known about many of the other SOCs that were detected.

technique is an enforceable procedure or level of technological performance that public water systems must follow to ensure indirect control of a contaminant" such as the requirements for disinfection and filtration in the Surface Water Treatment Rule and corrosion control in the Lead and Copper Rule.

The "treatment technique" provision in the NJ Safe Drinking Water Act was interpreted by NJDEP (2004) as providing for establishment of a New Jersey regulation that requires drinking water systems vulnerable to SOC contamination to install treatment, specifically GAC. This proposed strategy was stated to "represent a proactive approach to protecting public health in the absence of little or no definitive scientific information on the contaminants being detected" based on the assumption that "the contaminants may have adverse effects on human health."

In the approach proposed by NJDEP (2004), the presence of a regulated volatile organic chemical (VOC)[7] is used as an indicator of vulnerability to unregulated SOC contamination. This approach also requires identification of a "marker" contaminant(s) that can be used to determine the efficiency of the required treatment (e.g., GAC). NJDEP (2004) states that a regulated organic compound that is removed by GAC can be used for this purpose in the proposed approach for SOCs.

In considering the potential application of this approach to regulating PFAS as a class or as certain subclasses or mixtures, the contaminant(s) used as indicator(s) of a public water system's vulnerability to PFAS contamination, and the analyte(s) used as marker(s) for the effectiveness of treatment removal would need to be selected. For example, the detection of any of the individual PFAS included in USEPA analytical methods for PFAS in drinking water could potentially be used as both an indicator of vulnerability and a marker for treatment removal efficiency. However, as discussed in the section on treatment technologies, efficiency of treatment removal varies among PFAS.

Additionally, the NJDEP (2004) interpretation of the New Jersey Safe Drinking Water Act as allowing for establishment of a New Jersey regulation that requires drinking water systems vulnerable to SOC contamination to install treatment would likely require a legal review and opinion.

NJDEP Science Advisory Board (2020) report

A request to the NJDEP Science Advisory Board (SAB) to develop the NJDEP SAB report "Approaches for Addressing Drinking Water and Wastewater Contaminants of Emerging Concern (CECs) in a Broader Context: Identification, Ranking and Treatment Removal" (NJDEP SAB, 2020 https://dep.nj.gov/wp-content/uploads/sab/sab-cec-2020.pdf) was designated a priority issue by NJDEP. The report responds to charge questions from NJDEP which are related to addressing

---

[7] MCL exceedances for VOCs are usually addressed with air stripping rather than GAC as the treatment technology.

drinking water contaminants as groups rather than individually. These charge questions included consideration of "evaluating water contaminants of emerging concern in a broader context, to supplement the current chemical-by-chemical approach for development of MCLs;" grouping and addressing drinking water contaminants "based on common toxicity and/or removal by the same treatment technology;" and whether there is "valid reasoning that would support … requiring or recommending additional treatment processes at public water systems in geographical areas known to be impacted by multiple unregulated contaminants." In responding to these charge questions, NJDEP SAB (2020) reviewed relevant information on health effects and risk assessment, analytical methods, and treatment removal.

Although the focus of NJDEP SAB (2020) is on contaminants of emerging concern (CECs) in general and is not specific to PFAS, the information provided in this report is relevant to assessment of the feasibility of regulation of PFAS in drinking water as the entire class or as certain subclasses or mixtures. It is noted that some of the recommendations made by NJDEP SAB (2020) could require a legal opinion as to whether they could be implemented under current New Jersey legislation and regulations.

NJDEP SAB (2020) concluded that, in general, CECs can be grouped based on common toxicity if there is enough evidence of similarities in biological, chemical, and/or physical interactions. The report also recommended GAC and reverse osmosis (RO) for treatment of water contaminants (including CECs) in general, with RO and biological activated carbon (BAC) particularly recommended for drinking water treatment. However, the review of treatment technologies focused mainly on CECs other than PFAS.

Additional potentially relevant approaches and conclusions from NJDEP SAB (2020) are as follows:

1. Using indicator compounds (compounds that show a visible change in the presence of certain chemical species or water quality parameters) to indirectly track CECs
    - Challenges:
        - Underestimation of CEC concentrations and potential transformation products more toxic than the original CEC
        - Toxicity of indicator compounds continuing to be an issue
2. Requiring the implementation of certain treatment technologies for CEC removal
    - Challenges:
        - Water quality variability (i.e., types of CECs, other compounds)
        - Treatment plant variability (i.e., other processes, costs, operations, size/footprint)
        - Could potentially limit the innovation of future treatment technologies
3. Measuring and monitoring toxicity and/or mutagenicity of wastewater treatment plant effluents and raw and/or finished drinking water across toxicological endpoints to support innovative treatment technology
    - Challenges:

- Requires more research and development of these methods

NJDEP SAB (2020) concluded that the third approach would be the most "scientifically sound," but it is not currently feasible. Specifically, it was recognized that more research is needed, especially for application to wastewater. As a result, a combination of all three approaches for both drinking water and wastewater was recommended.

General considerations for regulating PFAS as the entire class or as certain subclasses or mixtures

A key concept for this assessment is that considerations for regulating PFAS as the **entire class** (i.e., any chemical included in the definition of PFAS) are different from considerations for regulating a **certain PFAS subclass or mixture** (i.e., the combined concentrations of more than one specific PFAS).

PFAS as the entire class

New Jersey Public Law P.L.2023, c.279 requires an assessment of the feasibility of establishing a drinking water standard for "the entire class" of PFAS (i.e., all of the thousands of chemicals defined as PFAS). Considerations for regulation of PFAS as the entire class are reviewed in Section 7.1.7 of the Interstate Technology and Regulatory Council (ITRC) PFAS document (ITRC, 2026 https://pfas-1.itrcweb.org/7-human-and-ecological-health-effects-of-select-pfas/#7_1). Such approaches are not based on risk assessment (e.g., the level of exposure at which health effects may occur) and do not assume that all PFAS are equally toxic. Virtually all PFAS persist indefinitely (i.e., do not degrade in the environment) or can transform to terminal PFAS that persist indefinitely. As such, approaches to address the entire PFAS class are primarily based on environmental persistence as a common property and the principles of green chemistry, specifically concerns that "the continual release of highly persistent PFAS will result in increasing concentrations [in the environment] and increasing probabilities of the occurrence of known and unknown effects (Cousins et al., 2020a https://pubs.rsc.org/en/content/articlelanding/2020/em/d0em00355g).

Importantly, actions to address PFAS as the entire class have primarily focused on products that contain PFAS rather than environmental media (e.g., drinking water) contaminated with PFAS. It is feasible from a practical viewpoint to address PFAS in products "as a class" by restricting the manufacture, sale, and use of products that contain any intentionally added PFAS, including the use of PFAS-containing processing aids in manufacturing. Such restrictions are based on information on the components used to make the products provided by companies who make and sell the products, and they do not require that the products be analyzed to determine if any PFAS are present. As discussed below, considerations for addressing PFAS as an entire class in drinking water are different than for products because a treatment technology or technologies that can remove all PFAS that may be present and an analytical method or methods that can determine whether any PFAS are present after treatment are required.

New Jersey and several other regulatory bodies have proposed or adopted measures to address PFAS in products "as a class." New Jersey has recently enacted P.L.2025, c.202 which prohibits the sale of cosmetics, carpet and fabric treatments, and food packaging containing intentionally added PFAS. The California Department of Toxic Substances Control (DTSC) also regulates PFAS as a class in certain consumer products, based primarily on their common property of environmental persistence which is listed as a hazard trait in the California Code of Regulations (Balan et al., 2021 https://ehp.niehs.nih.gov/doi/epdf/10.1289/EHP7431). Additionally, a Maine law prohibited the sale of any product containing intentionally added PFAS in the state "unless the use of PFAS in the product is specifically designated as a currently unavoidable use" by the Maine Department of Environmental Protection (https://www.maine.gov/dep/spills/topics/pfas/PFAS-products/), and a Minnesota law "bans non-essential use of PFAS" in 11 categories of products by a certain date, with additional product categories to be added at later dates (https://www.pca.state.mn.us/get-engaged/pfas-in-products; https://insideepa.com/pfas-news/amid-struggle-maine-narrows-pfas-reporting-reworks-product-bans). A state of Washington law requires that certain classes of chemicals found in products, including PFAS, be evaluated to determine if there are safer alternatives and, if safer alternatives are available, whether their use should be restricted by regulation (Smith et al., 2024 https://ehp.niehs.nih.gov/doi/epdf/10.1289/EHP13549). Finally, the European Chemicals Agency (ECHA, 2020 https://echa.europa.eu/documents/10162/cad38c27-ede8-2268-00c6-939ea066743c)[8] has proposed to restrict the manufacture, sale, and use of all PFAS in the European Union, with time-limited exceptions ("derogations") for some uses to allow for development of alternatives, primarily based on persistence.[9] Some additional examples of relevant regulatory actions are provided by Kwiatkowski et al. (2020 https://pubs.acs.org/doi/10.1021/acs.estlett.0c00255) and ECOS (2025 https://www.ecos.org/documents/ecos-compendium-of-state-pfas-actions/).

In contrast, considerations for addressing PFAS as an entire class in drinking water are different than for products. Specifically, regulation of PFAS as an entire class in drinking water requires a

---

[8] Additionally, an informative ECHA PowerPoint presentation on the proposed restriction is found at https://echa.europa.eu/documents/10162/2082415/2023-02-07_pfas+media+briefing_en.pdf/1661579d-353a-2fb0-1062-38fc3eb4bd78?t=1675849038730

[9] The proposed restriction aims to address the risks to human health and the environment posed by the use of per- and polyfluoroalkyl substances (PFAS). All PFAS in scope of the proposed restriction (or their degradation products) have very high persistence and may remain in the environment from decades to centuries, longer than any other man-made chemical. In addition, many have varying (eco)toxicological effects, are bioaccumulative, mobile and can even reach remote and pristine areas of the world. PFAS are ubiquitously present in a wide range of products intended for industrial, professional and consumer uses and are continuously emitted into the environment. Due to the high persistence, ongoing emissions, and lack of appropriate remediation measures, concentrations of PFAS are constantly and irreversibly increasing in the environment and will inevitably lead to negative effects for human health and the environment.

treatment technology or technologies that can remove all PFAS that may be present and an analytical method or methods that can determine whether any PFAS are present after treatment. No state standards or guidance intended to address the PFAS as an entire class in drinking water were identified in the review conducted for this report. As discussed below, current analytical methods for PFAS in drinking water that can be used for regulatory compliance detect only a subset of all PFAS that may be present, and methods for estimation of the concentration of total PFAS in drinking water cannot currently be used for regulatory purposes (i.e., compliance with MCLs). Additionally, because the PFAS class includes compounds with diverse chemical structures, effective removal of the entire class from drinking water would likely require the strategic use of multiple treatment technologies in a chain, and such treatment approaches have not yet been fully evaluated.

The USEPA Drinking Water Contaminant Candidate List 5 (CCL5)[10] (USEPA, 2022a https://www.govinfo.gov/content/pkg/FR-2022-11-14/pdf/2022-23963.pdf) includes PFAS[11] as a group. However, USEPA (2022) explains that listing PFAS as a group instead of as individual contaminants "does not necessarily mean that EPA will make subsequent regulatory decisions for the entire group." USEPA (2022) states that the intent of listing PFAS as a group is to "limit duplication of … efforts, such as data gathering, analyses and evaluations" and that USEPA "will evaluate scientific data on the listed groups, subgroups, and individual contaminants included in the group to inform any regulatory determinations."

Two states (Vermont and Hawaii) previously evaluated regulation of PFAS as the entire class, but neither of these evaluations resulted in decisions or actions to do so. The California State Water Resources Control Board (CA Water Board) is currently investigating potential "broad spectrum" approaches for measurement and treatment removal relevant to addressing PFAS as a class in drinking water, in response to a legislative requirement. These three state efforts are summarized below.

In response to a legislative requirement, the Vermont Agency for Natural Resources (VT ANR, 2020 https://dec.vermont.gov/sites/dec/files/PFAS/PFAS-MCL-Final-Decision.pdf) evaluated regulation of PFAS in drinking water as a class or subclass. VT ANR (2020) concluded that it was "technically infeasible" to establish an MCL for PFAS as a class because the necessary toxicological information and analytical methods were not available. They also concluded that a treatment technique-based standard was also not appropriate. Instead, Vermont established an MCL for the total concentration of a subclass of five PFAS (PFOA, PFOS, PFNA. perfluorohexane sulfonate [PFHxS], and perfluoroheptanoic acid [PFHpA]).

---

[10] A list of contaminants in drinking water that are "currently not subject to any proposed or promulgated national primary drinking water regulations" and "are known or anticipated to occur in public water systems and may require regulation under the USEPA Safe Drinking Water Act (https://www.govinfo.gov/content/pkg/FR-2022-11-14/pdf/2022-23963.pdf)."

[11] As defined in the USEPA Contaminant Candidate List 5; see footnote 5 above.

The Hawaii Department of Health *Interim PFAS Guidance* (HIDOH, 2024 https://health.hawaii.gov/heer/files/2024/04/PFAS-Update-signed-April-2024.pdf)[12] includes an approach for estimation of total PFAS risk in environmental samples, discussed further in the Health Effects section below. Because estimates of both total PFAS concentration and risk from this approach are highly uncertain, HIDOH envisions its for screening of environmental media (e.g., groundwater) at sites that are contaminated with PFAS, but not as the basis of an enforceable standard. Specifically, HIDOH has not stated that it plans to use this approach as the basis for a PFAS drinking water guidance value or standard.

California Assembly Bill 178 (CA Assembly, 2022) includes requirements to “develop standard operating procedures for and validate a broad-spectrum test for the class of PFAS” in drinking water and “develop a treatment-based regulation for the entire class of PFAS” in drinking water. Adsorbable organic fluorine- combustion ion chromatography (AOF-CIC) with Method 1621 extraction procedureswas identified as the optimal broad-spectrum method available at this time in a method comparison study (CA Water Board, 2024a https://www.regulations.gov/comment/EPA-HQ-OW-2023-0469-0087; CA Water Board, 2024b https://www.waterboards.ca.gov/pfas/docs/broad-spectrum-pfas-method-comparison-study-summary-combined.pdf). This method estimates total PFAS based on the concentration of organic fluorine absorbed to granular activated carbon (GAC) and is discussed further in the *Analytical Considerations* section, below.

In a larger study of approximately 3500 public wells serving disadvantaged communities, which encompass the state of California both geographically and in regard to rural/urban locations, which is currently underway, samples are being analyzed with both AOF-CIC (broad-spectrum PFAS) and with the targeted USEPA Method 533 for comparison. Additionally, samples from a subset of the wells are being analyzed with IC-MSMS (for ultrashort PFAS, which are missed by AOF-CIC), and will also undergo non-targeted analysis (Newton and Linck, 2025 https://dep.nj.gov/wp-content/uploads/pfas-summit/pfas-summit-day-2.pptx). In preliminary data presented by Newton and Linck (2025), adsorbable organic fluorine was detected in 36% of 2031 public well samples analyzed with AOF-CIC, while the 25 individual PFAS included in Method 533 were detected in 0% to <10% of the samples. In a subset of 351 samples analyzed for ultrashort PFAS with IC-MSMS, trifluoroacetic acid (TFA) was detected in 100% of samples and two other ultrashort PFAS, were detected in 8% and 3% of samples, respectively.

To address the requirement in California Assembly Bill 178 for development of a “treatment-based regulation for the entire class of PFAS,” the CA Water Board is in the process of selecting drinking water treatment systems for broad spectrum PFAS analysis before and after treatment, with the goal of eventually proposing a regulatory approach for PFAS as the entire class (Newton and Linck, 2025). These California Water Board efforts are discussed in more

---

[12] This document and other supporting files are posted at https://health.hawaii.gov/heer/guidance/ehe-and-eals/.

detail later in this report. These efforts by California and relevant efforts by others may provide approaches for future regulation of entire PFAS class in drinking water. As such, it is recommended that the possibility of regulating the entire class of PFAS in drinking water be reevaluated annually as these and other relevant efforts progress.

Certain subclasses or mixtures of PFAS

The New Jersey P.L. 2023, c.279 also requires an assessment of the feasibility of establishing a drinking water standard for “certain subclasses or mixtures” of PFAS “rather than for each individual substance.” A drinking water standard for a PFAS subclass or mixture is based on the combined concentrations of more than one individual PFAS. Drinking water standards that consider multiple PFAS (i.e., “certain subclasses”) are more stringent and therefore more public health protective than individual, chemical-by-chemical standards for those same PFAS.

Cousins et al. (2020b https://pubs.rsc.org/en/content/articlehtml/2020/em/d0em00147c) discussed several potential approaches for grouping PFAS into subclasses, although some of these approaches may not be relevant to regulation of PFAS in drinking water.

PFAS subgroups could potentially be based on:

- Similar chemical structure
- Similar intrinsic properties
- Risk assessment considerations/toxicological interactions
- Analytical considerations
- Treatment removal considerations

PFAS could be grouped into subclasses based on their **chemical structures**, such as the categories and sub-categories shown in Figures 1 and 2 above. A well-known example of a PFAS subclass based on chemical structure is perfluoroalkyl acids (PFAAs), which may be further subdivided in different ways (e.g., perfluoroalkyl carboxylates and perfluoroalkyl sulfonates; long-chain, short-chain, and ultrashort-chain PFAAs).

Other potential approaches for grouping PFAS mentioned by Cousins et al. (2020b) are based on **“intrinsic properties”** (e.g., persistence, potential to bioaccumulate, mobility in water or other media, molecular size, or whether they are “polymers of low concern”) or **risk assessment considerations** (i.e., “cumulative exposure and/or effects”).

Groupings based on **toxicological interactions** (often referred to as “mixtures” risk assessment), detection with the same **analytical method**, and/or removal by the same **treatment technology** are most relevant to potential regulation of certain subclasses of PFAS in drinking water. Additionally, occurrence in New Jersey drinking water, including frequency, concentrations, and co-occurrence with regulated PFAS, should be considered in determining whether such a regulation should be established.

Drinking water standards for a subclass/mixture of PFAS use two general approaches. For both approaches, analytical methods and treatment removal technologies appropriate for regulatory use must be available for the PFAS that are included.

1. **Total concentration**: Some drinking water guidelines are based on the total concentration (sum) of the individual PFAS included in the guideline, without the need for chemical-specific values for each of these PFAS. In this approach, the concentration of each individual PFAS that is included is **weighted equally**.
2. **Additive toxicity, but toxicological potencies differ**: Some drinking water guidelines assume that the toxicity of the included PFAS is additive, but consider differences in their toxicological potency (dose at which toxicity occurs). In this approach, the concentrations of the individual PFAS are weighted differently to account for their differing potencies. Specific approaches of this type are further discussed in the section on regulation based on health effects below.

Development of standards based on the total concentration approach is generally less resource intensive than for standards based on additive toxicity, but with differing potencies. The latter approach requires development of chemical-specific values for each included PFAS. However, the total concentration approach requires more assumptions and is associated with greater uncertainty than approaches which consider the differing potencies of the included PFAS.

New Jersey and several other states (e.g., CA, MN[13], IL, NH, NY, MI, PA, WA) have established chemical-by-chemical drinking water standards or guidance values for individual PFAS, while the standards or guidance values developed by some other states consider PFAS mixtures. Other states (MA, ME, RI, VT, OR) have adopted drinking water standards or guidance values for the total concentration of four to six long-chain PFAS, based on assumed toxicological equivalence of the included PFAS.[14] The recently finalized USEPA (2024 https://www.govinfo.gov/content/pkg/FR-2024-04-26/pdf/2024-07773.pdf) MCL for the combined concentrations of PFNA, PFHxS, PFBS, and GenX[15] assumes additive toxicity, with differing potencies for the four included PFAS, each with a chemical-specific drinking water concentration.

---

[13] Minnesota also considers cumulative risks of contaminants with the same target organ, as discussed further in the *Health Effects Considerations* section below.

[14] A compilation of state, federal, and international guidelines that address multiple PFAS is found in the last section of this report. Additionally, ITRC provides a comprehensive table of current state, federal and international standards and guidance values for PFAS in water and soil, which is frequently updated, at https://pfas-1.itrcweb.org/fact-sheets/, and ECOS (2025 https://www.ecos.org/wp-content/uploads/2025/04/ECOS-PFAS-Compendium-FINAL.pdf) includes a summary of state drinking water guidelines for individual and grouped PFAS, including the rationales for states' approaches.

[15] Additive toxicity and Hazard Index are further discussed in the section on *Health Effects Considerations* below.

Importantly, drinking water guidelines for mixtures that include long-chain PFAS may need reconsideration in light of newer toxicity factors for long-chain PFAS based on human data and/or carcinogenicity. These newer toxicity factors are much more stringent than the earlier toxicity factors based on non-cancer effects in laboratory animal studies which were used in existing state guidelines for PFAS mixtures. Use of these newer toxicity factors results in health-based drinking water concentrations below analytical quantitation levels (i.e., PQLs). The MCL for such a PFAS is set at the PQL, and any detection of that individual PFAS would result in an exceedance of the drinking water standard. Additionally, for an MCL for a PFAS mixture that is based on the health-based concentrations (i.e., MCLGs) of the individual PFAS (e.g., Hazard Index), it is not appropriate to include PFAS with MCLs set at their analytical PQLs rather than the For these reasons, it is not appropriate or meaningful to include a PFAS with a health-based drinking water concentration below its PQL in a standard for a mixture of PFAS. At least one state, Massachusetts, is considering the possibility of revisiting its current MCL for a mixture of six long chain PFAS in light of this issue (personal communication with MA DEP, 2/26/2026). This issue was also acknowledged by USEPA (2024a) in its explanation of why PFOA and PFOS, whose health-based concentrations (MCLGs) are below their PQLs, were not included in the recently finalized USEPA MCL for a mixture of four other PFAS. More detail on this issue is found in the subsection on "Problematic issue for health-based drinking water standards for long-chain PFAS using recent toxicity factors based on human data for long-chain PFAS," below.

Additionally, Health Canada (2024 https://www.canada.ca/content/dam/hc-sc/documents/services/publications/healthy-living/objective-drinking-water-quality-per-polyfluoroalkyl-substances/objective-for-canadian-drinking-water-quality-en-final.pdf) has established a non-enforceable drinking water objective of 30 ng/L for the total concentration based on analytical considerations. This objective applies to the total concentration of the 25 PFAS included in USEPA Method 533. Health Canada (2024) does not explicitly state that all PFAS are assumed to be toxicologically similar, but rather that a "precautionary group-based approach" to PFAS in drinking water is necessary because of "the potential for exposure to multiple PFAS at the same time, the potential for negative health impacts, [and] the uncertainty and the limited data on many PFAS." It is noted that the Health Canada guideline does not consider the newer more stringent toxicity factors for long-chain PFAS.

As discussed above, an important issue with the potential use of this approach is that it is not appropriate to include long-chain PFAS with newer USEPA health-based concentrations below PQLs in a drinking water standard for multiple PFAS. However, this does not preclude consideration of a drinking water standard for a mixture of other PFAS whose health-based concentrations are above their PQLs. As mentioned above, occurrence of such PFAS in New Jersey drinking water, including frequency, concentrations, and co-occurrence with regulated PFAS, should be considered in determining whether such an MCL should be established.

Health effects considerations

PFAS as the entire class

As discussed above, current efforts to address all PFAS as a class are based primarily on environmental persistence as a common property, since virtually all PFAS persist indefinitely or can transform to terminal PFAS that persist indefinitely. These approaches are not based on risk assessment (e.g., the level of exposure at which health effects may occur), and they do not assume that all PFAS are equally toxic.

The Hawaii Department of Health *Interim PFAS Guidance* (HIDOH, 2024 https://health.hawaii.gov/heer/files/2024/01/Hawaii-PFAS-EALs-HIDOH-Public-Review-Draft-January-2024.pdf)[16] includes an approach for estimation of the human health risk of total PFAS in environmental samples. This approach is based on assumed additive toxicity for mixtures of PFAS, specifically the sum of the Hazard Indices[17] for: 1) PFAS included in targeted analysis for which toxicity factors are available; 2) PFAS precursors that are converted in the Total Oxidizable Precursor (TOP) assay to terminal PFAS that are target analytes with available toxicity factors, and 3) additional PFAS whose concentration is estimated with a Total Organic Fluorine (TOF) method. The toxicity of these additional unidentified PFAS is assumed to be the same as the ultrashort-chain PFAS, perfluoropropionic acid (PFPrA).

Because the total PFAS concentration and the risk estimates from this approach are highly uncertain, HIDOH envisions its use for screening of environmental media (e.g., groundwater) at PFAS-contaminated sites. HIDOH has not stated that this approach will be used as the basis for a PFAS drinking water guidance value or standard.

Certain subclasses or mixtures of PFAS

It is well established that humans are exposed to mixtures of PFAS in drinking water, as well as in other exposure sources. This section provides an overview of approaches for considering toxicological interactions in drinking water standards for mixtures of individual PFAS. These approaches focus on non-carcinogenic effects since cancer risk is most appropriately evaluated on an individual chemical basis. For more detail, see the informative reviews in Sections 7.1.5 and 17.2.7 of the ITRC (2026) PFAS document (https://pfas-1.itrcweb.org/7-human-and-ecological-health-effects-of-select-pfas/#7_1 ; https://pfas-1.itrcweb.org/17-additional-information/#17_2_7) and Appendix 5 (p. 71-75) of the DWQI PFAS report (2022 https://www.nj.gov/dep/watersupply/pdf/dwqi-health-effects-pfas-report.pdf).

---

[16] This document and other supporting files are posted at https://health.hawaii.gov/heer/guidance/ehe-and-eals/.

[17] Hazard Index is discussed in the section on Health-based drinking water guidelines using chemical-specific toxicity information below.

Toxicological interactions in chemical mixtures may be additive, synergistic (greater than additive), or antagonistic (less than additive) (reviewed in ITRC, 2026; DWQI, 2022). Types of additive interactions include dose additivity and response additivity. Dose additivity is applicable to non-cancer effects. It assumes that the chemicals in the mixture cause the same effects with the same shape dose-response curve, and they differ only in potency (the dose at which effect occurs). Response additivity[18] is generally used to assess cancer risk and is not discussed further herein.

Toxicology studies of mixtures of chemicals in laboratory animals include: 1) studies of defined mixtures (mixtures in which the identities and concentrations of the components are known); and 2) studies of complex mixtures (mixtures in which the identities and concentrations of the components are not fully characterized), such as aqueous film forming foams (AFFFs) that contain PFAS. In general, empirical data on toxicological interactions in chemical mixtures comes from defined mixture studies. However, somewhat surprisingly, very few toxicology studies of defined PFAS mixtures have been conducted; available studies are reviewed in Section 17.2.7.2 of ITRC (2026 https://pfas-1.itrcweb.org/17-additional-information/#17_2_7_2).

Although additive, synergistic, and antagonistic interactions have been observed in the limited number of available toxicology studies of PFAS mixtures, health-based drinking water guidelines that have been developed for mixtures of PFAS use the assumption of dose additivity. Use of this assumption for PFAS was supported by USEPA Science Advisory Board PFAS Review Panel (USEPA SAB, 2022) and the DWQI Health Effects Subcommittee (DWQI, 2022).

Although, strictly speaking, dose additivity requires a common mode of action (i.e., the sequence of biochemical events that lead to an adverse response) for the toxicological effects considered, USEPA SAB (2022) supported the use of a similar health outcome (e.g., the same target organ) instead of a common mode of action as a default approach for evaluating the risk of PFAS mixtures. They concluded that multiple physiological systems and multiple modes of action can contribute to a common health outcome. Additionally, there is little or no information on the mode(s) of action of many PFAS, and the available information indicates that mode(s) of action can differ among PFAS (e.g., PFOA versus PFOS) and among toxicological effects (e.g., liver, developmental, immune) of a specific PFAS.

As discussed by USEPA SAB (2022), current risk assessments of PFAS mixtures used Reference Doses based on animal data. However, Reference Doses based on human data had been developed for some PFAS and more could become available in the future. USEPA SAB (2022)

---

[18] Response additivity, which has not been used for risk assessment of PFAS mixtures, assumes that the toxic effect of a mixture can be predicted by summing the doses of each chemical in the mixture (relative to each chemical's critical effect dose) such that the contribution from each chemical to the overall effect (e.g., risk) of the mixture is not influenced by the other chemicals. It is most commonly used for cancer risk, by summing the cancer risk of each individual co-occurring carcinogen to estimate the total cancer risk of the mixture.

suggested that "EPA consider how toxicity factors based on human data could be used in evaluations of PFAS mixtures, including for mixtures where toxicity factors are based on animal data for some PFAS and based on human data for other PFAS."

Many human epidemiological studies have evaluated associations of PFAS with health effects using blood serum PFAS levels as the exposure (i.e., dose) metric, and additional studies continue to become available. Humans are exposed to multiple PFAS, and multiple PFAS are detected in blood serum in these studies. These studies provide important information on health effects associated with PFAS mixtures. Additionally, the contributions of individual PFAS and interactive effects among individual PFAS can be evaluated using statistical methods.

USEPA and several states have recently developed draft or final toxicity factors (Reference Doses; cancer slope factor for PFOA) for several long-chain PFAS using data from human studies such as those described above. However, it is not feasible to consider these toxicity factors based on human data in a drinking water standard for a PFAS mixtures. All of the Reference Doses for long-chain PFAS that have been developed from human data are much lower than earlier Reference Doses using animal data, and these lower Reference Doses result in health-based drinking water concentrations below the PQLs; for more detail, see *Problematic issue for drinking water standards for long-chain PFAS using recent toxicity factors based on human data* below. This may also be the case for other PFAS if additional Reference Doses using human data are developed in the future. As above, it is not appropriate or meaningful to include a PFAS with a health-based drinking water concentration below the PQL in a standard for multiple PFAS because any detection of that PFAS would result in an exceedance of the drinking water standard, and because such a standard is based on the health-based concentrations (i.e., MCLGs) of the individual PFAS.

Drinking water guidelines for total concentration of included PFAS

Several states' drinking water guidelines are based on the "total concentration" of certain individual PFAS (also called the "simple additive" approach). These guidelines assume that the included PFAS are all equally potent, cause the same toxicological effects, and have additive toxicity.[19] Although this approach is not strictly science-based, since the toxicological potencies and most sensitive toxicological effects differ among the included PFAS, it has been applied as a conservative, public health-protective policy decision.

Based on this approach, the PFAS MCLs of 20 ng/L established by Maine, Massachusetts, Rhode Island, and Vermont apply to the total concentration of five or six long-chain, and the Oregon

---

[19] It should be noted that drinking water guidelines for total concentration of a group of individual PFAS are not necessarily health-based. For example, the Health Canada (2024) drinking water objective of 30 ng/L applies to the total concentration of PFAS included in a specific analytical method, USEPA 533.

drinking water guideline of 30 ng/L applies to the total concentration of four long-chain PFAS (Table 2).

Table 2. Examples of state PFAS drinking water guidelines based on the total concentration approach (Σ 4 - 6 long-chain PFAS).

State	***Guideline (ng/L)***	***Included PFAS***					
		PFOA	**PFOS**	**PFNA**	**PFHxS**	**PFHpA**	**PFDA**
Massachusetts	20	x	x	x	x	x	x
Maine	20	x	x	x	x	x	x
Rhode Island	20	x	x	x	x	x	x
Vermont	20	x	x	x	x	x	
Oregon	30	x	x	x	x		

Massachusetts DEP (MADEP, 2019 https://www.mass.gov/doc/per-and-polyfluoroalkyl-substances-pfas-an-updated-subgroup-approach-to-groundwater-and/download) provides a detailed explanation of the basis for this approach. While recognizing that PFOA and PFOS can cause carcinogenic effects, the approach considered only non-cancer effects from animal toxicology studies. MADEP (2019) concluded that this group of "longer-chain PFAS…are structurally very similar, cause similar effects…and have long half-lives…" which "supports treating this subgroup of longer-chain PFAS as having additive toxicity." It was also concluded that "available data are not sufficient to firmly distinguish [the] individual RfDs) [Reference Doses for PFOA, PFOS, PFNA, PFHxS, and PFDA] as being significantly different" from each other. Although "insufficient toxicity data exist[ed] for PFHpA to assess similarities in effects" (MADEP, 2019) and available information indicated that its human half-life was shorter than PFOA's, a science-policy decision was made to assume that PFHpA is equally toxic as the other longer chain PFAS. Based on these conclusions, the MADEP Reference Dose of 5 ng/kg/day for PFOA and PFOS, which resulted in a chemical-specific health-based drinking water level of 20 ng/L using MADEP (2019) exposure assumptions, was used as a "surrogate" for the toxicity value for PFNA, PFHxS, PFHpA, and PFDA to support an MCL of 20 ng/L for the combined concentration of the six PFAS.

It should be noted that these MCLs were established before the much more stringent toxicity factors for long-chain PFAS based on human data and/or cancer risk became available, and they may need to be reevaluated to consider these newer toxicity factors. As above, this approach is not applicable when more stringent toxicity factors, such as those developed recently by USEPA and several states, result in drinking water guidelines below the PQL for the PFAS (i.e., PFOA and PFOS, in this case) selected to represent all of the included PFAS. This is because any detection of those PFAS would result in an exceedance of the drinking water standard. At least one state, Massachusetts, is considering the possibility of revisiting its current MCL for a mixture of six long chain PFAS in light of this issue (personal communication with MA DEP, 2/26/2026).

Drinking water guidelines based on additive toxicity, with differing potencies for included PFAS

The approaches (Hazard Index and Relative Potency Factor) reviewed in this section are based on dose additivity and consider differences in toxicological potency (dose at which effects occur) among the included PFAS. More detail on these approaches is provided in Sections 7.1.5 and 17.2.7 of the ITRC (2026) PFAS document (https://pfas-1.itrcweb.org/7-human-and-ecological-health-effects-of-select-pfas/#7_1; https://pfas-1.itrcweb.org/17-additional-information/#17_2_7) and Appendix 5 (p. 71-75) of DWQI (2022 https://www.nj.gov/dep/watersupply/pdf/dwqi-health-effects-pfas-report.pdf).

Hazard Index approach

The **Hazard Index** (HI) approach, originally developed by USEPA in 1989 (USEPA, 1989 https://www.epa.gov/sites/default/files/2015-09/documents/rags_a.pdf), assumes dose additivity for non-cancer effects and considers differences in toxicological potency among the chemicals present in the mixture. The Hazard Index approach is often used to evaluate the cumulative risk of non-cancer effects of multiple chemicals present at contaminated sites.

In the Hazard Index approach, the Hazard Quotient, which is the exposure (ng/kg/day) as a fraction of the Reference Dose (ng/kg/day), or the measured water concentration (ng/L) as a fraction of the health-based drinking water guideline (ng/L), is determined for each individual contaminant in the mixture. The Hazard Quotients are then added together to determine the Hazard Index. For drinking water, the fractions of the health-based drinking water guidelines (ng/L) for each individual contaminant present in the sample can be added to determine the Hazard Index. This is illustrated by the equation for determination of the Hazard Index for four PFAS from the USEPA (2024a https://www.govinfo.gov/content/pkg/FR-2024-04-26/pdf/2024-07773.pdf) PFAS MCL rule:

$$HI\ MCL = \left(\frac{[HFPO{-}DA_{water} ng/L]}{[10\ ng/L]}\right) + \left(\frac{[PFBS_{water} ng/L]}{[2000\ ng/L]}\right) + \left(\frac{[PFNA_{water} ng/L]}{[10\ ng/L]}\right) + \left(\frac{[PFHxS_{water} ng/L]}{[10\ ng/L]}\right) = 1$$

A Hazard Index of < 1 indicates that adverse effects are unlikely, while a Hazard Index of > 1 is interpreted as suggesting potential risks that warrant further investigation and/or actions to reduce exposure.

A **"general" Hazard Index** can be used to estimate the risk of non-cancer effects for mixtures of chemicals with References Doses based on different target organs (e.g., liver, immune, developmental). USEPA mixtures risk assessment guidance (USEPA, 1989 https://www.epa.gov/sites/default/files/2015-09/documents/rags_a.pdf; USEPA, 2000 https://ofmpub.epa.gov/eims/eimscomm.getfile?p_download_id=4486) indicates that the general Hazard Index is scientifically uncertain and is intended for use as an initial screening approach. The USEPA Science Advisory Board PFAS Review Panel (USEPA SAB, 2022, posted as EPA-SAB-22-008 at https://sab.epa.gov/ords/sab/f?p=100:12:8777962449060) also stated that this approach is appropriate "for initial screening of whether exposure to a mixture of PFAS poses a potential risk that should be further evaluated," and the DWQI Health Effects Subcommittee (2025) further concluded that this approach is recommended for "screening only because of scientific uncertainty with use of different target organs."

A **"target organ specific" Hazard Index** evaluates the risk of mixtures of chemicals using Reference Doses based on effects in the same target organ. It is more definitive and less scientifically uncertain than the general Hazard Index (ATSDR, 2020 https://www.atsdr.cdc.gov/HAC/pha/pease/PeaseAFB-HC-508.pdf; USEPA, 2021b, posted under *Agency Review Documents* at https://sab.epa.gov/ords/sab/f?p=114:19:11488469483433:::19:P19_ID:975#materials). Multiple Reference Doses for the same compound may be developed for toxicological effects in different target organs.

When Reference Doses for multiple target organs are available for the contaminants present in a mixture, they can be used to determine the target organ specific Hazard Index for effects other than the most sensitive effects that are the basis of the primary Reference Doses. For example, the primary Reference Doses for Chemicals A, B, and C might be based on liver, kidney, and thyroid effects, respectively, but Chemicals A and B might each have an additional Reference Dose based on thyroid effects. In this case, a target organ specific Hazard Index for thyroid effects could be determined for the mixture of the three chemicals.

Examples of use of the "general" and "target organ-specific" Hazard Index approaches for health-based drinking water values are:

- The **USEPA MCLG and MCL** (USEPA, 2024a https://www.govinfo.gov/content/pkg/FR-2024-04-26/pdf/2024-07773.pdf) of a Hazard Index of 1 for mixtures of four PFAS (PFBS, PFHxS, PFNA, GenX) uses the "general" Hazard Index approach which considers Reference Doses based on differing target organs and toxicological endpoints for the included PFAS. As mentioned above, USEPA (1989) guidance for mixtures risk assessment, the USEPA SAB PFAS Review Panel (2022), and the DWQI Health Effects Subcommittee (2025) concluded that this approach is appropriate for screening because it is scientifically uncertain. However, USEPA (2024a) provides the following rationales for using the general Hazard Index as the basis for the MCL:
  1) The four PFAS included in the MCL have many common health effects and target organs. However, Reference Doses for multiple health effects are be needed for a

“target organ-specific” Hazard Index, and such Reference Doses are not available for these PFAS.
2) The Reference Doses used in the “general” Hazard Index are based on the most sensitive known effects of these PFAS. Therefore, they are protective of all types of toxicity/adverse health effects, not just those effects that occur in a specific organ or system.

- **Minnesota Department of Health** (MDH, 2020 https://www.health.state.mn.us/communities/environment/risk/guidance/gw/additivity.html#:~:text=The%20MDH%20Water%20Guidance%20and,based%20guidance%20for%20that%20chemical) uses an approach analogous to a “target organ-specific” Hazard Index (called a Health Risk Index) to evaluate risks of contaminants that co-occur in groundwater based on drinking water exposure assumptions. This approach is based on grouping of contaminants (including PFAS and others) that cause toxicity to the same target organ (e.g., liver, kidney, thyroid).[20]

Practical issues with use of the Hazard Index approach for drinking water standards for PFAS mixtures are:

- Reference Doses needed to develop health-based drinking water values are not currently available for some PFAS such as perfluoropentanoic acid (PFPeA) and PFHpA that are commonly found in drinking water.[21]
- Carcinogenic effects are not considered.
- As discussed above, recent toxicity factors for long-chain PFAS result in health-based drinking water values below the PQL, and it is not appropriate or feasible to include such PFAS in a drinking water standard based on a Hazard Index.

Relative Potency Factor approach

The **Relative Potency Factor (RPF)** approach is also based on the assumption of dose additivity. An RPF is assigned to each PFAS based on its relative potency (e.g., 0.1, 1, 10) for a toxicological effect common to all of the included PFAS (e.g., liver toxicity) as compared to an index compound (e.g., PFOA) which is assigned a potency factor of 1.

To assess the risks of a PFAS mixture, the concentration of each PFAS that is present in the environmental medium of interest (e.g., drinking water) is multiplied by its RPF. As shown

---

[20] From MDH (2020): The MDH Water Guidance and Additivity Calculator (Excel; linked at https://www.health.state.mn.us/communities/environment/risk/docs/guidance/gw/guidance.xlsx) “facilitates evaluation of exposure to multiple chemicals. For each chemical sharing a health endpoint, a ratio is calculated by comparing the groundwater concentration of the chemical to the exposure duration-specific health-based guidance for that chemical. The ratios are grouped by duration and summed within each health endpoint group.”
[21] For example, see USEPA Unregulated Contaminant Monitoring Rule 5 (UCMR5) occurrence data at https://www.epa.gov/dwucmr/occurrence-data-unregulated-contaminant-monitoring-rule#5).

below, the RPF-adjusted concentrations are then summed, and the toxicity of the total RPF-adjusted concentration is assumed to be equal to the equivalent concentration of the index compound (e.g., PFOA).

Example of application of RPF approach to PFAS:

PFAS A: concentration 1 x RPF1 = PFOA Equivalents 1
PFAS B: concentration 2 x RPF2 = PFOA Equivalents 2
PFAS C: concentration 3 x RPF3 = PFOA Equivalents 3
+ **PFAS n: concentration n x RPFn = PFOA Equivalents n**
Sum = PFAS concentration in mixture in terms of PFOA

An example of the application of RPFs is drinking water containing a PFAS mixture of:

- 10 ng/L of PFAS A with an RPF of 1
- 20 ng/L of PFAS B with an RPF of 0.5
- 30 ng/L of PFAS C with an RPF of 0.2

The total PFAS concentration in terms of PFOA equivalents is calculated as follows:

(10 ng/L x 1) + (20 ng/L x 0.5) + (30 ng/L x 0.2) = 26 ng/L PFOA equivalents.

Therefore, this mixture of three PFAS in drinking water would be assumed to have the same toxicity as drinking water containing 26 ng/L of PFOA.

The RPF approach (also known as the toxicity equivalency factor [TEF] approach) has been previously used for risk assessment of other groups of chemicals (dioxins and related dioxin-like compounds;[22] organophosphate pesticides) known to cause toxicity through a common and well-defined mode of action such as inhibition of a certain enzyme important to the function of the nervous system or activation of a certain receptor that regulates gene expression. However, use of the RPF approach for PFAS is more uncertain than for these other groups of chemicals because the toxicological effects of PFAS do not occur through a single common mode of action, and the mode of action may not be the same either for all toxicological effects (e.g., liver, immune, developmental) of a specific PFAS or for the same toxicological effect (e.g., liver toxicity) caused by different PFAS.

---

[22] For information on Toxicity Equivalence Factors (TEFs) for dioxins and dioxin-like compounds, see https://www.epa.gov/toxics-release-inventory-tri-program/dioxin-and-dioxin-compounds-toxic-equivalency-information.

RPFs for 22 PFAS, with PFOA used as the index compound, were proposed by RIVM (Netherlands National Institute for Public Health and the Environment) scientists (Bil et al., 2021 https://setac.onlinelibrary.wiley.com/doi/abs/10.1002/etc.4835). RPFs of 0.001 to 10 for were developed by modeling dose-response data for increased relative liver weight in subchronic male rat studies (without assuming that this effect necessarily occurs through a common mode of action) for PFOA and 15 other PFAS. Relative liver weight was selected as the basis for the RPFs because data were available for this effect for more PFAS than for other effects. RPF ranges for seven additional PFAS for which no relative liver weight data were available were estimated by read-across/interpolation from relative liver weight data for structurally related PFAS.

Several scientific issues with the RIVM RPF approach for PFAS were noted by the NJDEP SAB (2020 https://dep.nj.gov/wp-content/uploads/sab/sab-cec-2020.pdf).

- The RPFs developed by RIVM are based on toxicological effects in laboratory animals. Newer toxicity factors for long-chain PFAS based on human data indicate toxicity at much lower doses.
- RPFs based on increased liver weight may not be sufficiently protective for some of the included PFAS because other toxicological effects (e.g., immune system suppression, delayed mammary gland development) are more sensitive endpoints.
- The RPF approach can only be used for those PFAS for which the relative potency for the effect used (e.g., increased liver weight) is known or can be estimated from closely related compounds. Therefore, this approach is not applicable to mixtures that include PFAS without known or estimated toxicity data for the target effect.
- The RIVM RPFs are based on dose-response data for the administered (external) PFAS doses that caused increased liver weight in male rats. The RPFs do not consider differences among PFAS in the relative half-lives between humans and male rats (i.e. differences in the human:male rat half-life ratio). These ratios range from 8 and ~500 for the set of PFAS with RIVM RPFs, and consideration of these differences would substantially affect some of the RPF values. In contrast, differences in the human:animal half-life ratio are accounted for in Reference Doses for PFAS that are based on animal toxicology data.

More recently, Bil et al. (2022 https://ehp.niehs.nih.gov/doi/epdf/10.1289/EHP10009; Bil et al., 2023 https://www.sciencedirect.com/science/article/pii/S0160412022006547) developed RPFs for relative liver weight and immune system toxicity in rats based on internal doses (serum PFAS levels) from laboratory animal studies for a smaller number of PFAS (liver weight: n=9; immune effects: n= 7). These internal dose-based RPFs are intended for evaluation of serum PFAS data from human biomonitoring studies, and their application to drinking water PFAS data, or external PFAS dose data in general, would require substantial additional investigation. Additionally, like the earlier RPFs based on administered dose, they do not consider health effects data from human studies that indicate effects at much lower exposures than data from animal studies.

Problematic issue for drinking water standards for long-chain PFAS using recent toxicity factors based on human data

Long-chain PFAAs[23] (e.g., PFOA, PFOS, PFNA, PFHxS, PFDA) are among the PFAS of greatest concern in drinking water. They are associated with multiple human health effects from very low exposures, cause numerous types of toxicity in laboratory animals, are highly bioaccumulative with human half-lives of several years, and commonly occur in finished drinking water.[24] As such, these long-chain PFAS would be a priority for inclusion in a drinking water standard for a subclass or mixture of PFAS, if it were feasible to do so.

As discussed above, USEPA and several states have established health-based drinking water guidelines (standards or guidance values) for certain subclasses or mixtures of PFAS. All of these guidelines include long-chain PFAS (PFOA, PFOS, PFNA, PFHxS, and/or PFDA), with shorter chain PFAS (PFHpA, GenX, PFBS, and/or others) also included in some guidelines. The toxicity factors used in these guidelines are Reference Doses for non-cancer effects from **laboratory animal data**. For example, see discussion of the basis for the Massachusetts approach (MA DEP, 2019 https://www.mass.gov/files/documents/2019/12/27/PFAS%20TSD%202019-12-26%20FINAL.pdf) above.[25]

Importantly, USEPA recently developed Reference Doses from **human epidemiology data** for the five long-chain PFAS mentioned above (final - PFOA, PFOS, PFHxS, PFDA; draft - PFNA), as well as cancer slope factors based on human data for PFOA and animal data for PFOS; citations are provided in Table 3. The toxicity assessments that support the USEPA (2024a) MCLs for PFOA and PFOS[26] develop and consider these recent toxicity factors,[27] and the DWQI Health Effects Subcommittee (2022 https://www.nj.gov/dep/watersupply/pdf/dwqi-health-effects-pfas-report.pdf)

---

[23] Long-chain perfluoroalkyl acids (PFAAs, formerly referred to as perfluorinated chemicals [PFCs]) are defined by USEPA (2009 https://www.epa.gov/sites/default/files/2016-01/documents/pfcs_action_plan1230_09.pdf) as perfluorocarboxylates with 8 or more carbons (i.e., PFOA and longer) and perfluorosulfonates with 6 or more carbons (i.e., PFHxS and longer).

[24] With the exception of PFDA which is infrequently found in drinking water.

[25] The MADEP approach acknowledges potential cancer risk of some long-chain PFAS but does not consider cancer risk in its MCL.

[26] USEPA (2024b) [PFOA]. https://www.epa.gov/system/files/documents/2024-04/main_final-toxicity-assessment-for-pfoa_2024-04-09-refs-formatted.pdf; USEPA (2024c) [PFOS]. https://www.epa.gov/system/files/documents/2024-04/main_final-toxicity-assessment-for-pfos_2024-04-09-refs-formatted_508c.pdf

[27] Drinking water guidelines for PFOA and PFOS that consider Reference Doses from human data and cancer slope factors have also been developed by Minnesota (MDH, 2024a [PFOA] https://www.health.state.mn.us/communities/environment/risk/docs/guidance/gw/pfoa2024.pdf ; MDH, 2024b [PFOS]) and California (CAlEPA, 2024 https://oehha.ca.gov/media/downloads/air/public-health-goal-document/pfoapfosphgfinaldraft040524.pdf). They are shown in Table 1.

concluded that it is appropriate to use toxicity factors based on human data and/or cancer risk for these two PFAS.[28] However, the USEPA (2024a) MCL for the combined concentration of four PFAS uses Reference Doses for PFNA and PFHxS that are based on animal data because the draft USEPA Reference Doses based on human data for PFNA and PFHxS[29] were not final when the MCLs were adopted.

As shown in Table 3, the health-based drinking water concentrations for long-chain PFAS based on Reference Doses using **animal data** are higher than the analytical levels (MRLs or PQLs), such that an MCL using these toxicity factors can be set at the health-based concentrations. However, health-based drinking water concentrations for long-chain PFAS using toxicity factors based on **human data** or, in the case of PFOS, a cancer slope factor from animal data, are much lower and are generally below the level of quantitation (e.g., PQL). When the health-based concentration is below the PQL, the enforceable standard (MCL) is set at the analytical level (assuming that it can be achieved by treatment technology). It is not appropriate or meaningful to include a PFAS with a health-based level below its levels of quantitation (e.g., PQLs) in a drinking water standard that applies to multiple PFAS (based on either total concentration or chemical-specific toxicity), since any detection of this contaminant would result in an exceedance of even a drinking water standard for just the single PFAS. Additionally, for a standard for a PFAS mixture that is based on the health-based concentrations of the individual PFAS it is not appropriate to include PFAS with MCLs set at their analytical PQLs.

This USEPA (2024a) PFAS MCL rule states that PFOA and PFOS were not included in the Hazard Index-based MCL for four other PFAS because "any measured concentration above 4.0 ng/L [the PQL] for PFOA and PFOS would result in an exceedance of the Hazard Index MCL." If the USEPA IRIS Reference Doses for PFNA and PFHxS, which were draft at the time, had been considered, these two PFAS would similarly not be included in the Hazard Index-based MCL.

An additional consideration is that the risk assessment approaches used to develop health-based drinking water guidelines for mixtures of contaminants (e.g., Hazard Index) consider non-cancer effects but do not consider cancer risk for carcinogenic contaminants. This is because drinking water guidelines for carcinogens are based on a specified increase in risk of cancer (e.g., 1×10^{-6}) from chronic exposure to the individual contaminant and are most appropriately evaluated on an individual chemical basis.[30]

---

[28] The DWQI Health Effects Subcommittee did not review information on the other long-chain PFAS discussed here.

[29] PFNA – USEPA (2024d) https://ordspub.epa.gov/ords/eims/eimscomm.getfile?p_download_id=548669; PFHxS - USEPA (2023b) - https://ordspub.epa.gov/ords/eims/eimscomm.getfile?p_download_id=547143

[30] NJDEP Health-based MCLs for carcinogens are based on a cancer risk level of one in one million. USEPA Maximum Contaminant Level Goals (MCLGs, health-based levels) for carcinogens are set at the aspirational goal of zero.

Relevant to this discussion, it is noted that Massachusetts DEP is considering reevaluation of its current MCL for the total concentration of six long-chain PFAS since drinking water concentrations based on newer toxicity factors (Reference Doses and/or cancer slope factors) are below the PQL (personal communication with MA DEP, 2/26/2026).

Finally, it is emphasized that these considerations do not preclude development of a drinking water standard for mixtures of PFAS whose health-based drinking water concentrations are not below their PQLs. This issue applies only to those long-chain PFAS with health-based drinking water levels below their PQLs.

Table 3. Comparison of Health-based Drinking Water Values for long-chain PFAS based on animal versus human data

(Health-based drinking water concentrations below Minimum Reporting Levels (MRLs) are shown in **blue bold**)

Contaminant	***USEPA MRL/PQL (ng/L)***[1]	***Basis - Animal Toxicology Data***			***Basis - Human Epidemiology Data***		
		Toxicity Factor[2]		Health-based drinking water concentration (ng/L)[3]	Toxicity Factor[2]		Health-based drinking water concentration (ng/L)[3]
		Source	Numerical Value		Source	Numerical Value	
PFOA	**4**	NJ (2017) RfD	2 ng/kg/day	14	USEPA (2024b) RfD (MCL)	0.03 ng/kg/day	**0.2** [4]
					MN (2024a) RfD	NA – used target human serum level	**0.24** (using MN exposure assumptions)
					CA (2024) RfD	0.87 ng/kg/day	**3** (using CA exposure assumptions**)**
		NJ (2017) CSF	0.0000025 $(ng/kg/day)^{-1}$	14	USEPA (2024) CSF (MCL)	0.0293 $(ng/kg/day)^{-1}$	**0.0011** [4]
					MN (2024a) CSF	0.0126 $(ng/kg/day)^{-1}$	**0.0027** (10^{-6} cancer risk level and NJ exposure assumptions)[4]
							0.0079 (MN value using 10^{-5} risk level and MN exposure assumptions)
					CA (2024) CSF	0.0026 $(ng/kg/day)^{-1}$	**0.007** (using CA exposure assumptions)
PFOS	**4**	NJ (2018) RfD	1.8 ng/kg/day	13	USEPA (2024c) RfD (MCL)	0.1 ng/kg/day	**0.7** [4]
					MN (2024b) RfD	NA – used target human serum level	**2.3** (using MN exposure assumptions)
					CA (2023) RfD	0.64 ng/kg/day	**2** (using CA exposure assumptions)
		NJ (2018) CSF[5]	0.000009 $(ng/kg/day)^{-1}$	4	NA	NA	NA
		USEPA (2024) CSF[6] (MCL)	0.0000395 $(ng/kg/day)^{-1}$	**0.84**			
		MN (2024b) CSF	0.000013 $(ng/kg/day)^{-1}$	**2.6** (using 10^{-6} cancer risk level and NJ exposure assumptions)			
				7.6 (MN value using 10^{-5} risk level and MN exposure assumptions)			
		CA (2024) CSF[6]	0.0000156 $(ng/kg/day)^{-1}$	**1**			
PFNA	**4**	NJ (2015) RfD	0.74 ng/kg/day	13	USEPA (2024d) RfD (draft IRIS)[8]	0.007 ng/kg/day	**0.05** [4]
		USEPA (2023) RfD (MCL)[7]	2 ng/kg/day	10			
PFHxS	**3**	USEPA (2024a) RfD (MCL)[7]	3 ng/kg/day	10	USEPA (2024k) RfD (IRIS)[9]	0.0004 ng/kg/day	**0.003** [4]
PFDA	**3**	NA	NA	NA	USEPA (2024l) RfD (IRIS)[9]	0.002 ng/kg/day	**0.01** [4]

[1] MRLs from UCMR5; PFOA, PFOS, PFNA, and PFHxS values are also USEPA PQLs from the USEPA (2024a) PFAS MCL rule.

[2] Lower Reference Doses (RfDs) result in lower drinking water levels, while higher cancer slope factors (CSFs) result in lower drinking water values.

[3] Health-based drinking water concentrations based on default NJ exposure assumptions unless otherwise noted.

[4] Calculated from draft IRIS RfDs for purposes of the comparisons being made in this table using default exposure assumptions; not official value.

[5] PFOS health-based drinking water concentration based on CSF was developed by DWQI for comparison purposes.

[6] USEPA and CA PFOS CSFs are more stringent than NJ and MN because they consider pancreatic tumors as well as liver tumors.

[7] RfD is based on ATSDR MRLs and are used in USEPA (2024a) PFAS MCL rule.

[8] Draft USEPA(2024d) IRIS RfD was not used in USEPA (2024a) PFAS MCL rule because it was not final; it remains draft at this time.

[9] USEPA (2023b) IRIS RfD s not used in USEPA (2024a) PFAS MCL rule because it was draft when the rule was finalized; USEPA (2024k) IRIS RfD is now final.

Consideration of PFAS that lack health effects data

Mammalian toxicology data (e.g., repeated dose systemic and/or developmental studies) or human epidemiology data that can be used to develop a Reference Dose and health-based drinking water concentration are not available for some PFAS that are detected in New Jersey drinking water, such as perfluoropentanoic acid (PFPeA, C5), which is the most frequently detected PFAS in UCMR5 as of January 2026 (USEPA UCMR5 Occurrence Data https://www.epa.gov/dwucmr/occurrence-data-unregulated-contaminant-monitoring-rule). . Additional PFAS that lack such toxicity data may be identified in New Jersey drinking water in the future. The mammalian toxicology studies needed for toxicity factor (e.g., Reference Dose) development are time consuming and expensive, and it is unlikely that such studies will be available in a reasonable timeframe for some PFAS detected in New Jersey drinking water, such as PFPeA.

Approaches are available and continue to be developed for predicting the *in vivo* toxicity of compounds that lack repeated dose mammalian toxicology data. Such approaches include quantitative structure-activity relationship (QSAR) evaluations, “read across” from structurally related PFAS that have toxicity data, and predictions from toxicodynamic and toxicokinetic high throughput testing data (e.g., *in vitro* assays in cultured cells).

In general, toxicity values, specifically Reference Doses, based on such approaches may be more uncertain than those based on mammalian toxicology or human epidemiology studies. Of at least equal importance, the USEPA risk assessment guidelines used by NJDEP and NJ DWQI to develop toxicity factors do not currently provide for use of such data as the basis for toxicity factor development, and use of such data as the basis for health-based drinking water standards would require a change in risk assessment guidance.

The potential use of these approaches for evaluation of PFAS detected in New Jersey drinking water was reviewed in the PFAS case study included in the NJDEP Science Advisory Board (NJDEP SAB, 2020 https://dep.nj.gov/wp-content/uploads/sab/sab-cec-2020.pdf) report entitled “Approaches for Addressing Drinking Water and Wastewater Contaminants of Emerging Concern (CECs) in a Broader Context: Identification, Ranking and Treatment Removal.” The NJDEP SAB (2020) noted that, at the time of its evaluation, there were scientific and technical issues with application of these approaches to PFAS because of their “unique physical-chemical, toxicokinetic, and toxicological properties.” Specifically, the NJDEP SAB concluded that “PFAS are not amenable to the current approaches for predicting toxicity for contaminants with limited data such as QSAR and related methods.” For high throughput assays, the NJDEP SAB concluded that “technical issues related to both the procedures used to conduct the assays and the interpretation of the results must be resolved before they can be used for routine toxicity screening,” but that they “may provide a future approach for rapid evaluation of toxicity of individual PFAS and PFAS mixtures.” As such, they recommended that “NJDEP toxicologists remain aware of the progress of this effort [related to high throughput testing of PFAS] and its applications in risk assessment.”

Because of the issues (discussed above) with the use of predictive and *in vitro* toxicology data, it does not appear feasible at this time to use such data as the basis of a health-based drinking water standard for a certain PFAS subclass that includes PFAS without repeated dose mammalian toxicology data. However, it does appear to be feasible to include such PFAS in a standard for a certain subclass based on analytical and/or treatment considerations (as discussed in sections below).

Subsequently, USEPA developed the EPA Transcriptomic Assessment Product (ETAP), a standardized short-term (5 day) *in vivo* (rat) study design and data analysis process in which transcriptomic (gene expression) changes are evaluated (USEPA, 2024e https://cfpub.epa.gov/si/si_public_file_download.cfm?p_download_id=548702&Lab=CCTE). These data are used to develop transcriptomic-based reference values (TRVs), defined by USEPA as "an estimate of a daily oral dose that is likely to be without appreciable risk of adverse effects following chronic exposure" and intended to be analogous to chronic Reference Doses. ETAP assessments are intended to rapidly provide human health risk information for data poor chemicals, and the first ETAP assessment completed by USEPA is for a data-poor PFAS, perfluoro-3-methoxypropanoic acid (USEPA, 2024m https://cfpub.epa.gov/si/si_public_record_Report.cfm?dirEntryId=360638&Lab=CCTE).

More recently, USEPA developed the Database-Calibrated Assessment Process (DCAP), a standardized approach to generate Calibrated Toxicity Values (CTVs) for non-cancer effects, similar to Reference Doses, for large numbers of chemicals (USEPA, 2025a https://www.epa.gov/bosc/bosc-dcap-panel-january-16-17-2025; Harrill et al., 2026 https://www.tandfonline.com/doi/full/10.1080/10937404.2025.2552108). CTVs are generated from dose-response summary values (DRSVs) for *in vivo* laboratory animal toxicity studies from the USEPA Toxicity Values Database. Standardized approaches and factors are used to convert the DSRVs to human equivalent doses, generate points-of-departure using a statistical approach, and apply uncertainty factors.

If it is determined that approaches such as ETAP and DCAT are sufficiently predictive of non-carcinogenic effects, it may be feasible to use them to develop toxicity factors for PFAS that lack repeated dose mammalian toxicology data, so that such PFAS could be included in a health-based drinking water standard for a PFAS subclass or mixture. Relevant to this point, it is noted that the 1983 amendments to the New Jersey Safe Drinking Water Act (N.J.S.A. 58:12A1 et seq., P.L. 1983, c. 443) state that New Jersey MCLs for non-carcinogens should be developed with the goal of eliminating "all adverse physiological effects which may result from ingestion." However, the amendments do not specify that the human health basis of the MCLs must be based on data from traditional repeated dose animal toxicology studies or human epidemiology studies.

It is noted that it does appear to be feasible to include PFAS that lack toxicology data needed to develop a health-based drinking water concentration in a drinking water standard for a subclass that is based on considerations other than health effects (discussed in sections below). As discussed below, the numerical value of such a standard is a policy decision.

Analytical considerations

A subclass of PFAS for regulation in drinking water could potentially be defined on the basis of their inclusion in one or more analytical methods. This section briefly reviews available analytical approaches for PFAS in drinking water and discusses regulatory considerations for these approaches. General overviews of the analytical methods for individual and aggregate PFAS discussed in this section are illustrated graphically in Figures 3 and 4 below. It is important to be aware that analytical methods used for regulatory compliance with NJDEP MCLs must be promulgated for drinking water analysis by USEPA through federal rulemaking or validated for drinking water analysis by NJDEP and promulgated by NJDEP through rulemaking. As discussed below, USEPA has promulgated two targeted analytical methods that encompass 29 individual PFAS, but neither USEPA or NJDEP has yet promulgated an analytical method for estimation of total PFAS. While NJDEP could potentially validate and promulgate a method for use in MCL compliance as an Alternate Test Procedure as described in N.J.S.A. 7:18, Section 2:20 (https://dep.nj.gov/wp-content/uploads/rules/rules/njac7_18.pdf), an approved reference method that has been developed elsewhere must be available. For this reason, methods for compliance with MCLs established by NJDEP have typically been developed and validated by USEPA or a similar reference setting body such as Standard Methods for the Examination of Water and Wastewater or ASTM International.

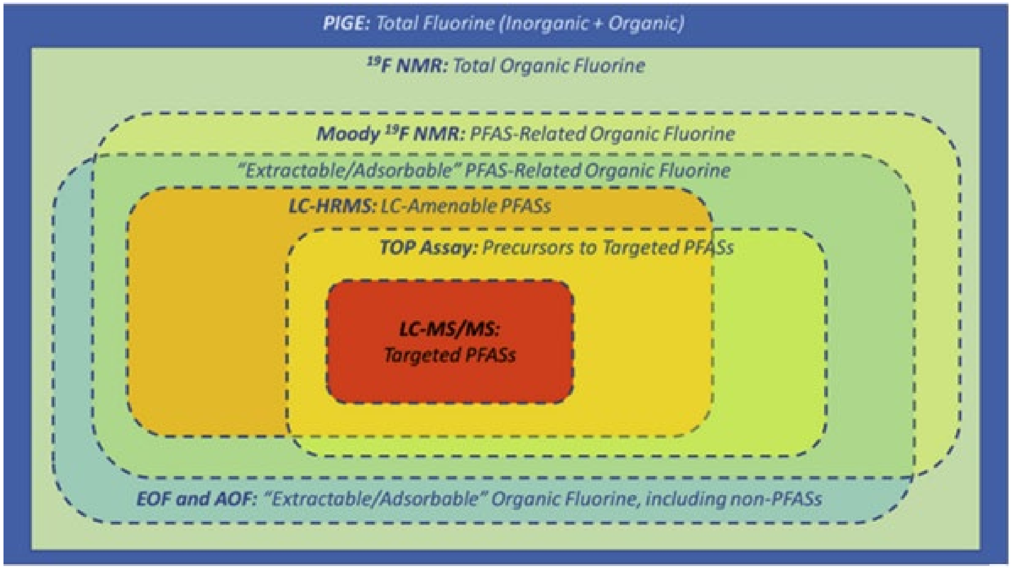
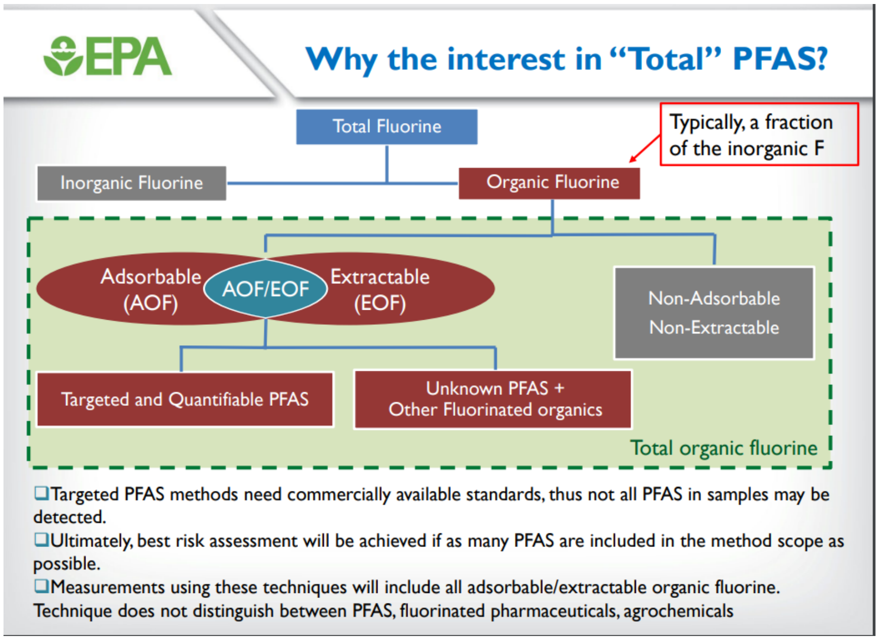


Figure 3. Selectivity and inclusivity associated with total organofluorine methods. From McDonough et al. (2019 https://www.sciencedirect.com/science/article/abs/pii/S2468584418300515). The authors note that the sizes of the boxes do not represent the actual relative abundance of each fraction and that the Moody ^{19}F NMR method is rarely used for water samples.



EPA

Why the interest in "Total" PFAS?

Total Fluorine

Typically, a fraction of the inorganic F

Inorganic Fluorine

Organic Fluorine

Adsorbable (AOF)

AOF/EOF

Extractable (EOF)

Non-Adsorbable Non-Extractable

Targeted and Quantifiable PFAS

Unknown PFAS + Other Fluorinated organics

Total organic fluorine

☐Targeted PFAS methods need commercially available standards, thus not all PFAS in samples may be detected.
☐Ultimately, best risk assessment will be achieved if as many PFAS are included in the method scope as possible.
☐Measurements using these techniques will include all adsorbable/extractable organic fluorine. Technique does not distinguish between PFAS, fluorinated pharmaceuticals, agrochemicals

Figure 4. From USEPA (2023c https://cfpub.epa.gov/si/si_public_file_download.cfm?p_download_id=548207&Lab=CESER)

Analytical methods for aggregate PFAS (estimation of entire PFAS class)

Informative reviews of the methods discussed below (Total Oxidizable Precursor [TOP], Total Organic Fluorine [TOF], Extractable Organic Fluorine [EOF], Adsorbable Organic Fluorine [AOF]) are provided by Section 11.2 of ITRC (2026 https://pfas-1.itrcweb.org/11-sampling-and-analytical-methods/#11_2), USEPA (2024g https://www.epa.gov/cwa-methods/frequent-questions-about-pfas-methods-npdes-permits), and McDonough et al. (2019 https://www.sciencedirect.com/science/article/abs/pii/S2468584418300515).

The **Total Oxidizable Precursor (TOP)** assay measures perfluoroalkyl acids (PFAAs) in samples analyzed before and after oxidation to convert PFAA precursors to PFAAs. Therefore, TOP estimates the concentration of precursors of the PFAAs included in the analytical method, but it does not identify the precursors that are converted to PFAAs. Additionally, it does not estimate the concentrations of PFAS that are not PFAA precursors that may be present. In contrast, such PFAS are captured by the other aggregate methods (TOF, EOF, and AOF) discussed below. For example, perfluoroethers such as hexafluoropropylene oxide dimer acid (HFPO-DA) (GenX, a replacement for PFOA, NJDEP, 2023 https://dep.nj.gov/wp-content/uploads/dsr/hfpo-da-genx-tsd.pdf) and chloroperfluoropolyether carboxylates (alternative PFAS used and released by an New Jersey industrial facility, NJDEP, 2021 https://dep.nj.gov/wp-content/uploads/dsr/clpfpecas-tsd.pdf) are not precursors of PFAAs and are not detected by TOP.

Regulatory considerations for TOP: As mentioned above, TOP captures PFAAs and PFAA precursors but does not capture other types of PFAS . It has not been promulgated by USEPA or NJDEP for drinking water or other media.

The approach proposed in the Hawaii Department of Health draft *Interim PFAS Guidance* (HIDOH, 2024 https://health.hawaii.gov/heer/files/2024/04/PFAS-Update-signed-April-2024.pdf), discussed in the Health Effects Considerations section above, uses the TOP method as well as other analytical approaches for screening. HIDOH has not stated that it plans to use this approach as the basis for a PFAS drinking water guidance value or standard.

Methods that measure **organic fluorine** include **Total Organic Fluorine [TOF], Extractable Organic Fluorine [EOF], and Adsorbable Organic Fluorine [AOF]**. These methods provide estimates of aggregate (i.e., total) PFAS concentration without identification of the specific PFAS present. Figures 3and 4 above include conceptual representations of the scope of these methods.

In summary, these methods use combustion ion chromatography (CIC) to completely decompose fluorinated organic compounds present in the sample, and the concentration of organic fluorine is estimated from concentration of inorganic fluoride produced during CIC. For this reason, inorganic fluoride present in the sample is also measured, and it must either be accounted for or removed from the sample.

- **Total Organic Fluorine (TOF)** refers to estimation of organic fluorine without pretreating the sample to adsorb or extract the fluorinated organic compounds, and this method requires measurement of inorganic fluorine in the sample. The concentration of organic fluorine is estimated by subtracting the concentration of inorganic fluorine from the total fluorine concentration. The sensitivity of TOF is limited by the presence of inorganic fluorine at much higher concentrations than organic fluorine, since background levels of inorganic fluorine in drinking water, surface water, and wastewater are often in the parts per million range. For this reason, the detection limit for TOF is orders of magnitude higher than for AOF or EOF (discussed below), which themselves have much higher detection limits than targeted analytical methods for PFAS (USEPA, 2024g https://www.epa.gov/cwa-methods/frequent-questions-about-pfas-methods-npdes-permits).

- In the **Adsorbable Organic Fluorine (AOF)** method, granular activated carbon (GAC) is used to adsorb organic fluorine compounds from an aqueous sample, inorganic fluorine is then removed with a wash solution, and the organic fluorine in the GAC is then analyzed with CIC. The efficiency of detection of individual PFAS with AOF depends on the specific GAC sorbent used, with the highest recoveries typically for compounds with carbon-chain lengths of 4 - 10 and lower recoveries for PFAS with longer and shorter chain lengths.

USEPA (2024h https://www.epa.gov/system/files/documents/2024-01/method-1621-for-web-posting.pdf) finalized Method 1621, an AOF method intended as a broad screen for PFAS for surface water and wastewater (USEPA, 2024g https://www.epa.gov/cwa-methods/frequent-questions-about-pfas-methods-npdes-permits). This method was proposed for promulgation by USEPA (2025b https://www.federalregister.gov/documents/2025/01/21/2024-29239/clean-water-act-methods-update-rule-22-for-the-analysis-of-contaminants-in-effluent), but the proposed rule has not yet been adopted. Additionally, this method is not proposed for analysis of drinking water.

USEPA (2024g https://www.epa.gov/cwa-methods/frequent-questions-about-pfas-methods-npdes-permits) states that "an AOF method can help provide context for what targeted analyses might miss, especially if used on a sample where PFAS contamination is suspected," and that the AOF method "can be a complementary analysis to targeted approaches…because aggregate concentrations can indicate the presence of PFAS not included in the targeted analyte list."

According to USEPA (2024g https://www.epa.gov/cwa-methods/frequent-questions-about-pfas-methods-npdes-permits): "The method does not quantify all of the organofluorine it captures with the same accuracy and has some known interferences that are discussed in the first section of the method." Similarly, USEPA (2024h https://www.epa.gov/system/files/documents/2024-01/method-1621-for-web-posting.pdf) states that "short-chain (less than 4 carbons) organofluorine compounds are poorly retained on GAC while long-chain (more than 8 carbons) hydrophobic organofluorine compounds readily adsorb to surfaces. These issues can cause low recoveries for these types of fluorinated compounds." Specifically, ultrashort chain PFAS such as trifluoroacetic acid (TFA) and perfluoropropionic acid (PFPrA), which may contribute a considerable percentage of the total PFAS in a water sample, are not accurately measured by AOF (Neuwald et al., 2022 https://pubs.acs.org/doi/10.1021/acs.est.1c07949).

USEPA (2024i https://www.epa.gov/cwa-methods/cwa-analytical-methods-and-polyfluorinated-alkyl-substances-pfas) states: "The method tells the user that organofluorines are present but cannot identify which specific organofluorines are present. The strength of the method is that it can broadly screen for thousands of known PFAS compounds at the part per billion level in aqueous (water) samples." The detection level for organic fluorine in the multi-laboratory validation study for USEPA Method 1621 was 1.5 ppb (µg/L), which is equivalent to 2.4 µg/L of perfluorohexane sulfonate (PFHxS), the compound used in the study. This detection level is orders of magnitude higher than for individual PFAS in targeted analytical methods for non-potable water (e.g., Method 1633A; USEPA, 2024j https://www.epa.gov/system/files/documents/2024-12/method-1633a-december-5-2024-508-compliant.pdf) and drinking water (e.g., Methods 533 and 537.1).

California Assembly Bill 178 (CA Assembly, 2022) requires that a broad-spectrum test for the PFAS as a class in drinking water be developed and validated. In response to this requirement, the California State Water Resources Control Board (CA Water Board) identified AOF-CIC with Method 1621 extraction procedures as the "optimal broad-spectrum method available at this time" but that recovery is poor for ultrashort PFAS (CA Water Board, 2024a; CA Water Board 2024b). The CA Water Board is currently expanding its evaluation of this method and other analytical methods for analysis of PFAS in drinking water. More detail on this effort is found in the section on CA Water Board evaluation of analytical approaches for PFAS as a class below.

- **Extractable Organic Fluorine (EOF)**. USEPA (2024g https://www.epa.gov/cwa-methods/frequent-questions-about-pfas-methods-npdes-permits) states that EOF "typically utilizes weak anion exchange (WAX) solid-phase extraction. An aqueous sample is passed through cartridges containing sorbent. Therefore, the method is selective for only those organofluorines that can be extracted from the sample. In contrast to AOF, where the sorbent is combusted and analyzed, in EOF the sample extract is analyzed by CIC. Like AOF, organofluorine concentrations are dependent on the sorbent selectivity, which may result in poor recoveries for PFAS compounds with chain-lengths less than C6 or neutral PFAS. Reported detection limits are significantly lower than those achieved by TOF, but were higher than AOF at the time EPA started validating Method 1621. More recent literature indicates that EOF may now be as sensitive or more sensitive than AOF, but there is very little wastewater data available."

  PFAS as a group is included in the USEPA drinking water Contaminant Candidate List 5 (USEPA, 2022). USEPA (2024f https://www.govinfo.gov/content/pkg/FR-2024-02-08/pdf/2024-02247.pdf) requested public input on drinking water analytical methods for PFAS as a group (and other contaminants listed in CCL5) to support future rounds of the USEPA Unregulated Contaminant Monitoring Rule (UCMR) program. In discussing potential analytical methods for PFAS as group, USEPA (2024f) stated that EOF "has potential application for screening [PFAS as a group], recognizing that it will not measure fluorinated compounds individually, but as an aggregate sum of the fluorinated compounds captured on the sorbent. Notably, non-PFAS fluorinated compounds may also be accounted for in the reported value along with residual inorganic fluoride that is added to drinking water to prevent tooth decay." USEPA (2024f) also stated that "aggregate techniques [for PFAS] considered to-date do not have the same sensitivity as targeted techniques. The quantitation capabilities of the EOF technique, and the suitability of the technique for drinking water monitoring, continue to be evaluated."

Regulatory considerations for aggregate PFAS methods: Methods for total organic fluorine can be used for screening purposes to estimate the concentration of "PFAS as an entire class." However, total organic fluorine methods are not currently appropriate as the basis for regulation of PFAS in drinking water for several reasons. Although USEPA (2024h https://www.epa.gov/system/files/documents/2024-01/method-1621-for-web-posting.pdf) recently finalized Method 1621, an AOF method for surface water and wastewater, neither USEPA or NJDEP has finalized or promulaged for aggregate PFAS in drinking water. Additionally, total organic fluorine methods in general are not specific to PFAS because they also detect organic fluorine arising from other fluorinated organic compounds such as fluorinated pharmaceuticals and pesticides with non-PFAS structures. Furthermore, detection levels for these methods in general are orders of magnitude higher than for targeted analysis of PFAS. Finally, for AOF, the detection efficiency (e.g., recovery) varies among individual PFAS.

The USEPA (2024f https://www.govinfo.gov/content/pkg/FR-2024-02-08/pdf/2024-02247.pdf) request for public input on drinking water analytical methods for contaminants listed in CCL5, including PFAS as a group, asked for "comments to support development and consideration of aggregate PFAS measurement," and was particularly interested in "techniques to extract or adsorb ultra short chain PFAS; alternative ways to remove inorganic fluoride from aqueous drinking water samples prior to or during the extraction or adsorption for organic fluoride; techniques to capture anionic, neutral and cationic PFAS in a single solid phase extraction procedure; and techniques to improve the selectivity of the extraction process to reduce or eliminate retention of non-PFAS fluorinated compounds." In response to this request, the California State Water Resources Control Board (CA Water Board) submitted comments describing their investigation of "broad-spectrum" analytical approaches relevant to evaluation of PFAS as a class (CA Water Board, 2024a https://www.regulations.gov/comment/EPA-HQ-OW-2023-0469-0087). Information on the California State Water Resources Control Board's investigation and conclusions is summarized in a subsection below.

Analytical methods for individual PFAS

Targeted analytical methods that detect a list of specific PFAS can demonstrate that the included PFAS are not present above the method's reporting levels and can quantitate those that are present above the reporting levels. Two USEPA methods for targeted analysis of PFAS in drinking water are approved for MCL compliance (Method 533 and Method 537.1).

While the current USEPA drinking water Methods 533 and 537.1 include a total of 29 unique PFAS, other targeted PFAS methods available from commercial laboratories include a larger number of analytes. For example, Eurofins offers a method for analysis of 70 PFAS analytes with low reporting levels (2 ng/L for 60 analytes; 3-5 ng/L for the other 9 analytes) (Eurofins, undated https://www.eurofinsus.com/environment-testing/pfas-testing/pfas-analyte-lists/; Pelch et al., 2023 https://www.sciencedirect.com/science/article/pii/S0048969723015966?via%3Dihub#s0125). Studies using these methods may identify currently unregulated PFAS that occur at frequencies and concentrations of potential concern in drinking water. Results of these studies could indicate the need for development of information needed for regulation such as health-based concentrations, promulgated analytical methods, and treatment removal evaluation.

<u>*Regulatory considerations for targeted analytical methods*</u>: Targeted analytical methods cannot establish that all members of the entire PFAS class that are present in drinking water have been detected and/or removed.

However, targeted analytical methods that are approved for MCL compliance could be used as the basis of a drinking water standard for a certain subclass of PFAS, such as all PFAS included in a certain method or methods. The numerical value for such a standard is a policy decision which does not consider differences in toxicological potency among the included PFAS. Such a standard could potentially be based on the total concentration of PFAS included in the method(s) or it could require that none of the PFAS included in the method(s) exceed an analytical benchmark (e.g., Method Detection Limit [MDL], Minimum Reporting Level [MRL], or PQL). Regulation of a subclass of PFAS based on inclusion in a targeted analytical method would require treatment removal technology that can reduce the total concentration of any combination of the included PFAS to below the standard. It is noted that such an approach could include individual PFAS with differing MDLs, MRLs, or PQLs.

As noted above, this approach does not consider the differences in toxicological potency among the included PFAS, since each included PFAS would be considered equally in determining the total concentration of PFAS and whether its analytical value is exceeded. However, a practical advantage of this approach is that development of health-based drinking water values for each individual PFAS is not necessary.

An important current consideration (discussed above) is that it is not appropriate or health-protective to include PFAS with health-based drinking water concentrations known to be below their analytical limits (e.g., PQLs) in such a total concentration standard, as discussed above. In consideration of this issue, a total concentration standard could be applied to the PFAS included in the selected analytical method(s) for which health-based levels are not below the PQLs. Those PFAS with health-based levels below PQLs could be regulated individually at their PQLs.

Relevant to the inclusion of PFAS as a group in CCL5 (USEPA, 2022), USEPA (2024f https://www.govinfo.gov/content/pkg/FR-2024-02-08/pdf/2024-02247.pdf) requested public input on drinking water analytical methods for contaminants listed in CCL5, including PFAS as a group, to support future rounds of the Unregulated Contaminant Monitoring Rule (UCMR) program. USEPA (2024f) states that it is “working to expand” the number of PFAS included in USEPA drinking water Methods 533 and 537.1, which currently include a total of 29 unique PFAS. It also requests input on “alternative techniques” for analyzing PFAS in drinking water.

An example of a drinking water guideline using this approach is Health Canada’s PFAS drinking water objective, which is non-enforceable guidance. Health Canada (2024 https://www.canada.ca/content/dam/hc-sc/documents/services/publications/healthy-living/objective-drinking-water-quality-per-polyfluoroalkyl-substances/objective-for-canadian-drinking-water-quality-en-final.pdf)[31] finalized a non-enforceable drinking water objective of 30 ng/L for total concentration of the 25 PFAS included in USEPA Method 533. In the objective, concentrations above the MRL are added together to determine the total concentration. A value of zero is assigned to detections below the MRL and non-detectable results.

In general, Health Canada drinking water objectives "set out a goal for a maximum level of a contaminant in drinking water, taking into account available treatment technology and analytical methods." Health Canada (2024) states that a "precautionary group-based approach" to PFAS in drinking water is necessary because of "the potential for exposure to multiple PFAS at the same time, the potential for negative health impacts, [and] the uncertainty and the limited data on many PFAS." The PFAS objective is stated to be an interim measure that was established because new information "raises concerns that need to be addressed more quickly" than revision of Health Canada's drinking water guidelines for PFAS, which may take many years to complete. The future revision of the Health Canada drinking water guidelines for PFAS "will include a comprehensive review of new toxicological evidence… and risk assessments…[and]… a comprehensive review of new information on analytical and treatment methods for PFAS as well as new findings for the management of treatment residuals" (Health Canada, 2024). It should be noted that the Health Canada objective does not consider newer draft toxicity factors for long-chain PFAS based on human data that are much lower than current toxicity factors based on animal data.

Non-targeted analysis uses high resolution mass spectrometry to identify PFAS for which no analytical standards are available. The chemical structures of the PFAS detected in the sample are determined through library matching or in-depth data analysis. Non-targeted analysis is invaluable in detecting and identifying PFAS in environmental media, including PFAS not previously known to be present or even to exist. This approach has been used in a joint NJDEP-USEPA Office of Research and Development study to identify previously unknown PFAS in New Jersey's environment (Washington et al., 2020 https://www.science.org/doi/10.1126/science.aba7127; McCord et al., 2020 https://pubs.acs.org/doi/10.1021/acs.estlett.0c00640).

Regulatory considerations for non-targeted analysis: Non-targeted analysis is not currently an appropriate basis for regulation of the entire class or certain subclasses of PFAS in drinking water for several reasons. Only estimated concentrations of the PFAS detected are possible without analytical reference standards, and the identities of the PFAS detected are, in some cases, considered tentative. Additionally, non-targeted analysis is time-consuming and requires specialized expertise and expensive equipment. Non-targeted methods for PFAS have not been finalized or promulgated by USEPA or NJDEP. Additionally, some PFAS that may be present in

---

[31] Main website for the Health Canada proposal is https://www.canada.ca/en/health-canada/programs/consultation-draft-objective-per-polyfluoroalkyl-substances-canadian-drinking-water/overview.html

drinking water are not detected with “traditional” non-targeted analysis and required specialized methods (Kirkwood-Donelson et al., 2023 https://www.science.org/doi/pdf/10.1126/sciadv.adj7048).

That being said, studies using non-targeted analysis may identify currently unregulated PFAS that occur at frequencies and concentrations of potential concern in drinking water. These data could indicate the need for development of information needed for regulation such as health-based concentrations, promulgated analytical methods, and treatment removal evaluation.

California State Water Resources Control Board (CA Water Board) evaluation of analytical approaches for PFAS as a class

California Assembly Bill 178 (CA Assembly, 2022) includes requirements to “develop standard operating procedures for and validate a broad-spectrum test for the class of PFAS” in drinking water and “develop a treatment-based regulation for the entire class of PFAS” in drinking water.

In response to these requirements, the CA Water Board conducted a method comparison study to determine the “most appropriate broad-spectrum analytical method for characterizing the occurrence of ‘total PFAS’ in drinking water” (CA Water Board, 2024b https://www.waterboards.ca.gov/pfas/docs/broad-spectrum-pfas-method-comparison-study-summary-combined.pdf). The study tested samples from nine public water system wells and also evaluated the recovery of several categories of PFAS over a wide concentration range in the analytical methods that were evaluated. Methods evaluated included an AOF-CIC method using an extraction procedure modeled after USEPA Method 1621, an Extractable Organic Fluorine-Combustion Ion Chromatography (EOF-CIC) method using an extraction procedure modeled after USEPA Method 533, and non-targeted and targeted analysis using several different sample preparation approaches.

AOF-CIC with Method 1621 extraction procedures was identified as the “optimal broad-spectrum method available at this time” (CA Water Board, 2024a). Compared to EOF-CIC with Method 533 extraction, the AOF-CIC method with Method 1621 extraction was superior in regard to both capturing organic fluorine and minimizing interference from inorganic fluorine compounds. However, results presented in CA Water Board (2024b) appear to indicate that a considerable portion of organic fluorine captured by the AOF-CIC method was not captured by a targeted analytical method. Specifically, ultrashort PFAS, as measured with an IC-MSMS (ion chromatography tandem mass spectrometry) method, contributed a considerable percentage of total PFAS in the well samples, but they were generally not recovered or had very low recovery in the AOF-CIC method. Additionally, the reporting and detection limits for the AOF-CIC method were much higher than for targeted methods, and further work to reduce the detection and reporting limits was recommended (CA Water Board, 2024b). That being said, the method was sufficiently sensitive (reporting limit of 560-800 ng/L organic fluorine) to detect organic fluorine in eight of the nine of the public well samples analyzed in this pilot project (CA Water Board, 2024a), and a considerable portion of organic fluorine captured by the AOF-CIC method was not captured by a targeted analytical method.

As required by California Assembly Bill 178 (CA Assembly, 2022), a larger study of approximately 3500 public wells serving disadvantaged communities, which encompass the state of California both geographically and in regard to rural/urban locations, is currently underway. In this study, samples are being analyzed with both AOF-CIC (broad-spectrum PFAS) and with the targeted USEPA Method 533 for comparison. Additionally, samples from a subset of the wells are being analyzed with IC-MSMS for ultrashort PFAS, which are missed by AOF-CIC, and these wells will also undergo non-targeted analysis (Newton and Linck, 2025 https://dep.nj.gov/wp-content/uploads/pfas-summit/pfas-summit-day-2.pptx). In preliminary data presented by Newton and Linck (2025), adsorbable organic fluorine was detected in 36% of 2031 public well samples analyzed with AOF-CIC, while the 25 individual PFAS included Method 533 were detected in 0% to <10% of the samples. In as subset of 351 samples analyzed for ultrashort PFAS with IC-MSMS, trifluoroacetic acid (TFA) was detected in 100% of samples and two other ultrashort PFAS, perfluoropropanesulfonic acid and bis(trifluoromethane)sulfonimide were detected in 8% and 3% of samples, respectively.

Treatment considerations

Treatment considerations relevant to regulation of PFAS in drinking water as the entire class or as certain subclasses/mixtures are discussed in this section. A comprehensive review of treatment removal technologies for removal of PFAS from drinking water and wastewater is provided in the next section of the report.

Several previous DWQI and NJDEP reports focused primarily on treatment removal considerations for the three individual PFAS for which New Jersey MCLs were developed (PFOA, PFOS, and PFNA).

- DWQI Treatment Subcommittee PFAS reports (DWQI, 2015b https://www.nj.gov/dep/watersupply/pdf/pfna-pfc-treatment.pdf; DWQI, 2016 https://www.nj.gov/dep/watersupply/pdf/pfoa-appendixc.pdf; DWQI, 2017b https://www.nj.gov/dep/watersupply/pdf/pfos-recommendation-appendix-c.pdf).

- NJDEP comments on the draft World Health Organization (WHO) drinking water guidelines for PFOA and PFOS (NJDEP, 2022 https://dep.nj.gov/wp-content/uploads/dsr/njdep-comments-who-pfas-guidelines.pdf).

Although not specifically focused on PFAS, the conclusions of two additional reports, NJDEP (2004) and NJDEP SAB (2020), are relevant to treatment removal considerations for PFAS as a class or as subclasses/mixtures. The conclusions of these reports are summarized above in the section on "Previous DWQI, NJDEP, and NJDEP Science Advisory Board (SAB) evaluations relevant to regulation of multiple PFAS in drinking water"

Two adsorption technologies, granular activated carbon (GAC) and ion exchange resins (IEX), are commonly used to remove PFAS from drinking water (USEPA, 2018 https://www.epa.gov/sciencematters/reducing-pfas-drinking-water-treatment-technologies), as discussed in more detail in the next section. Although many PFAS that may be present in drinking water can be removed by GAC and IEX, differences in breakthrough times and removal efficiencies among PFAS must be considered to ensure adequate removal of all PFAS of interest. For both GAC and IEX, breakthrough times for perfluoroalkyl acids (PFAAs) are generally shorter for short-chain than long-chain PFAS and for carboxylates than sulfonates (ITRC, 2026 – Section 12.2.1). Besides chain length, other structural differences among PFAS can also affect their treatment removal efficiency. For example, Sun et al. (2016) reported that replacing a CF_2 with an ether oxygen in a PFAS molecule with an otherwise similar structure resulted in decreased affinity for another a related adsorption technology, powdered activated carbon.

In addition to adsorption-based technologies, high-pressure membranes such as reverse osmosis (RO) and nanofiltration (NF) are effective PFAS removal technologies for drinking water (NJDEP, https://dep.nj.gov/wp-content/uploads/pfas/docs/faq-pfas-in-drinking-water.pdf), as discussed in more detail in the next section. Studies on RO and NF applications for PFAS removal at drinking water treatment plants (Appleman et al., 2013; Liu et al., 2021) have shown successful removal of multiple types of PFAS to below method reporting levels. However, widespread application of RO for PFAS removal at drinking water treatment plants is currently limited by factors such as cost and disposal of the reject water containing concentrated PFAS created after RO treatment. In addition, more research is needed on full-scale application of NF.

Considerations for treatment-based standards

PFAS as the entire class

A treatment-based standard for PFAS as the entire class would require use of a treatment technology or a chain of multiple treatment technologies that effectively remove all PFAS present in the source water. Because specific treatment technologies remove different PFAS with higher or lower efficiencies, multiple technologies used strategically in a chain would likely be necessary to effectively remove the entire class of PFAS.

Additionally, treating PFAS as an entire class based on a specific treatment technology may pose a challenge because treatment performance can vary even within the same technology. For example, granular activated carbon (GAC) differs widely based on raw materials and manufacturing processes, which affect surface area, adsorption capacity, and PFAS removal efficiency. Similarly, resin performance varies by resin type. Because of this variability, selecting the most effective treatment often requires bench- or pilot-scale testing of individual PFAS parameters.

Pre-treatment and post-treatment steps may also be necessary depending on a water system's water chemistry and existing treatment train. Waste stream management should also be considered when designing treatment, as appropriate disposal methods are necessary for spent media waste, backwash, and reverse osmosis reject water.

Additionally, a treatment-based standard for the entire class of PFAS would require the availability of analytical methods that can determine whether all PFAS have been removed from the drinking water. As discussed above, available analytical methods intended to measure PFAS as the entire class are not currently available for use in in drinking water regulation.

It is noted that California Assembly Bill 178 (CA Assembly, 2022) requires the development of a "treatment-based regulation for the entire class of PFAS." To address this requirement, the CA Water Board is in the process of selecting drinking water treatment systems for "broad spectrum" PFAS analysis before and after treatment, with the goal of eventually proposing a regulatory approach for PFAS as the entire class (CA Water Board, 2025).

PFAS as certain subclasses

A drinking water standard for a subclass consisting of those PFAS that are removed by a specific treatment technology would require that all PFAS removed by the method can be monitored with targeted analytical method(s) approved for MCL compliance. However, the identities of all PFAS removed by a specific treatment technology are not known, and all PFAS removed by a specific technology are not detected in targeted analytical methods. As such, this approach is not feasible for a PFAS subclass, and it is more relevant to treatment removal approaches for addressing PFAS as the entire class, discussed above.

Additional considerations for a standard based on a specific treatment technology include the need to consider the differences in removal efficiency of the included PFAS, which may be impacted by variability within the available treatment technologies, relative concentrations of other types of PFAS in the source water, other water quality parameters, and/or site-specific constraints. These considerations are further discussed in the assessment of treatment removal technologies in the next section of this report.

As mentioned above, regulation of a PFAS subclass selected based on common health effects, inclusion in the same analytical method, or for another reason could potentially require multiple treatment technologies. In such cases, the treatment technology/technologies used by a specific public water system would depend on which of the regulated PFAS are detected there as well as other site-specific considerations.

Conclusions and recommendations for regulation of PFAS in drinking water as entire class or as certain subclasses or mixtures

NJDEP, in consultation with the DWQI, recognizes that addressing the entire class of PFAS is a worthwhile goal but concludes that establishing a drinking water standard for PFAS as an entire class is not currently feasible because of the analytical and treatment constraints discussed above. Specifically, available analytical methods for estimation of total PFAS lack sensitivity and are not specific to PFAS, and methods for determination of total PFAS in drinking water have not been promulgated by USEPA or NJDEP. Additionally, multiple sequential treatment methods would likely be necessary to treat PFAS as an entire class. Efforts to develop the analytical methods and treatment removal approaches that may potentially make it possible to regulate the entire class of PFAS in drinking water are currently underway. These efforts include California's work towards developing a "broad spectrum" analytical approach for PFAS and a "treatment-based regulation for the entire class of PFAS." It is recommended that the possibility of regulating the entire class of PFAS in drinking water be reevaluated annually as these and other relevant efforts progress.

NJDEP, in consultation with the DWQI, further concludes that it is feasible to establish a drinking water standard for a subclass/mixture of PFAS selected on the basis of common health effects, detection with the same analytical method, or other considerations, with the caveats discussed above. Specifically, it is not appropriate or meaningful to include a PFAS with a health-based concentrations below its PQL in such an MCL. Additionally, many PFAS lack the toxicity data required for development of the health-based drinking water concentration needed for inclusion in a subclass based on health effects. Furthermore, each PFAS included in a subclass must be detected with an analytical method approved for MCL compliance and removed by an available treatment technology, and this is not the case for many PFAS. For a subclass of PFAS with approved methods and available treatment technologies, multiple analytical methods and sequential technologies may be required to address all included PFAS. Finally, the numerical drinking water standard for a subclass of PFAS selected based on detection with the same analytical method is a policy decision.

Occurrence information for PFAS in New Jersey drinking water should be considered in determining whether an MCL for a PFAS subclass is needed. Specifically, occurrence data should be evaluated to determine whether unregulated PFAS are present at frequencies and concentrations of potential concern. The USEPA Unregulated Contaminant Monitoring Rule 5 (UCMR5) monitored all U.S. public water systems serving more than 3300 people, and a subset of smaller systems in 2023-2025 for the 29 PFAS in included in the two USEPA methods approved for drinking water analysis. As such, UCMR5 data is a valuable source of occurrence information for PFAS with methods that can be used for MCL compliance monitoring.

Other analytical methods can identify many PFAS not included in the two methods approved for MCL compliance, and monitoring studies using these methods are important for identifying currently unregulated PFAS that occur in New Jersey drinking water. Additional targeted analytical methods for drinking water analysis available from commercial laboratories include a much larger number of PFAS analytes than the 29 PFAS detected in the two approved methods. Furthermore, studies using non-targeted analysis (NTA) have identified previously unknown PFAS in New Jersey waters, and future studies using NTA may identify other PFAS not included in targeted methods. Detection of unregulated PFAS at frequencies and levels of concern with these methods may indicate the need for development of information required for future regulation such as health-based concentrations, approved analytical methods, and evaluation of treatment removal.

NJDEP, in consultation with the DWQI, further concludes that regulation of a PFAS subclass selected based on removal by a specific treatment technology is not feasible. The identities of all PFAS removed by a specific treatment technology are not known, and all PFAS removed by a specific technology are not detected in targeted analytical methods. As such, this approach is more relevant to treatment removal approaches for addressing PFAS as the entire class, because, as discussed above, identification of all PFAS present and removed is not required. Additionally, the treatment technology or technologies that are most appropriate for use by a specific public water system depends on which of the regulated PFAS are detected there as well as other site-specific considerations.

Table 4 below provides a summary of considerations and conclusions for regulation of PFAS as the entire class or as certain subclasses or mixtures in drinking water.

	Considerations for Drinking Water Standards*	
	PFAS as entire class	PFAS as certain subclasses or mixtures
General considerations for all categories below	• Regulation of PFAS as entire class in drinking water is a worthwhile goal, but it is not feasible at this time. • Reconsideration is recommended when California evaluations (see below) are completed.	• Feasible, with caveats discussed. • Not appropriate to include long-chain PFAS with health-based level below PQL. • Occurrence of unregulated PFAS in NJ drinking water should be considered in deciding if an MCL is needed. • Sources of occurrence data include USEPA UCMR5 for 29 PFAS with approved analytical methods; studies with other targeted methods or non-targeted analysis for additional PFAS.
Standard based on same health effect(s)	• Similar toxicity of all PFAS not assumed, and approach not based on human health risk assessment. • Primary basis is common property of extreme environmental persistence.	• Toxicology data to develop health-based concentration is needed for each PFAS included in subclass; many PFAS lack such information. • Approved analytical method and a treatment removal technology must be available for each included PFAS; multiple analytical methods and sequential treatment technologies may be needed.
Standard based on inclusion in same analytical method	• Approved methods for regulation of total PFAS in drinking water not currently available. • Current methods for estimating total PFAS lack sensitivity and specificity. • California is developing broad-spectrum analytical approach for PFAS in drinking water; unclear if will be used for regulation.	• Feasible for PFAS detected in analytical method approved for MCL compliance; many PFAS are not detected in these methods. • Treatment removal technology must be available for each included PFAS; multiple sequential technologies may be needed. • Development of health-based concentration for each included PFAS is not required. • Numerical standard for total concentration of included PFAS is a policy decision; does not consider differences in toxicological potency among PFAS.
Standard based on removal by a specific treatment technology	• Would likely require multiple concurrent treatment methods. • Requires use of analytical method for total PFAS to evaluate treatment removal. • California evaluation of "treatment-based [drinking water] regulation" for PFAS as a class is in progress. Recommend future reevaluation of this issue based on this effort.	• Not feasible for subclass of specific PFAS. • All PFAS removed by a specific technology are not known and/or not detected with targeted analytical methods. • As such, this approach is more relevant to addressing PFAS as entire class, since identification of all PFAS present in source water and removed by treatment is not required.

*Costs were not considered in this evaluation.

State, federal, and international guidelines[32] that address PFAS as a class or as certain subclasses or mixtures

The ITRC maintains a comprehensive table (PFAS Water and Soil Values Table– Excel file) of current state, federal, and international standards and guidance values for PFAS in water and soil. The table is updated approximately every two months and can be accessed at https://pfas-1.itrcweb.org/fact-sheets/.

Additionally, ECOS (2025 https://www.ecos.org/wp-content/uploads/2025/04/ECOS-PFAS-Compendium-FINAL.pdf) provides a recent summary of state drinking water guidelines for individual and grouped PFAS, including the rationales provided by states for their approaches.

USEPA

USEPA (2024a https://www.govinfo.gov/content/pkg/FR-2024-04-26/pdf/2024-07773.pdf) finalized MCLs for five individual PFAS (PFOA, PFOS, PFNA, PFHxS, GenX) and an MCL of a Hazard Index of 1 for non-cancer effects of a mixture of four PFAS (PFNA, PFHxS, GenX, PFBS) in 2024.

PFOA and PFOS were classified as likely human carcinogens, and their Maximum Contaminant Levels Goals (MCLGs; health-based levels) were set at zero in accordance with USEPA policy for likely human carcinogens. Therefore, the enforceable MCLs for PFOA and PFOS were set at their PQLs (4.0 ng/L) because they are higher than the MCLGs.

Although carcinogenic effects are the primary basis of the PFOA and PFOS MCLs, the USEPA (2024b,c) Office of Water toxicity assessments of PFOA and PFOS[33] that provide the human health basis for the MCLs include Reference Doses for non-cancer effects based on human data that are several hundred-fold lower than the earlier USEPA Reference Doses based on animal data. These new Reference Doses result in health-based drinking water concentrations far below the PFOA and PFOS PQLs of 4.0 ng/L. USEPA (2024a) explained that it would not be appropriate or meaningful to include PFOA or PFOS in the MCL for a PFAS mixture because any detection (defined as the PQL for regulatory purposes) would result in an MCL exceedance.

The Reference Doses for PFNA and PFHxS used for the MCLs are based on animal toxicology data.[34] However, the USEPA Integrated Risk Information System (IRIS) program has developed

---

[32] “Guidelines” refer to standards and guidance values

[33] USEPA (2024b). Final Human Health Toxicity Assessment for Perfluorooctanoic Acid (PFOA) and Related Salts. April 2024. https://www.epa.gov/system/files/documents/2024-04/main_final-toxicity-assessment-for-pfoa_2024-04-09-refs-formatted.pdf;   USEPA (2024c). Final Human Health Toxicity Assessment for Perfluorooctane Sulfonic Acid (PFOS) and Related Salts. April 2024. https://www.epa.gov/system/files/documents/2024-04/main_final-toxicity-assessment-for-pfos_2024-04-09-refs-formatted_508c.pdf

[34] The References Doses used for the USEPA (2024a) PFNA and PFHxS MCLs come from Agency for Toxicity Substances and Disease Registry (ATSDR) Minimal Risk Levels (MRLs) for these PFAS. MRLs are developed to protect for non-carcinogenic effects through a similar process as is used for Reference Doses.

a final Reference Doses for PFHxS and a draft Reference Dose for PFNA using human data[35] whose bases are similar to the USEPA (2024a) Office of Water Reference Doses for PFOA and PFOS based on human data, mentioned above. These PFHxS and PFNA Reference Doses are several hundred-fold lower than the Reference Doses based on animal data used for the PFHxS and PFNA MCLs. As is the case for PFOA and PFOS, health-based drinking water concentrations for PFHxS and PFNA using these new Reference Doses would be far below their PQLs. Although PFHxS and PFNA are included in the USEPA (2024a) MCL for a PFAS mixture, it would not be appropriate or meaningful to include them in an MCL for a PFAS mixture if the newer IRIS Reference Doses are considered, because any detection would result in an MCL exceedance.

U.S. states[36]

New Jersey and several other states (e.g., CA, IL, MI, MN, NH, NY, WA) have developed chemical-specific drinking water guidelines for PFOA, PFOS, PFNA, PFHxS , and/or GenX. Most of the state chemical-specific values for these PFAS are higher than the recently finalized USEPA (2024) MCLs for PFOA (4.0 ng/L), PFOS (4.0 ng/L), PFNA (10 ng/L), PFHxS (10 ng/L), and GenX (10 ng/L), and they will be superseded by the USEPA MCLs.

Several other states (e.g., CO, MA, ME, OR, RI, VT) have developed drinking water standards or guidance values based on a total concentration of 20 or 30 ng/L for four to six long-chain PFAS. As discussed above, these guidelines are not relevant or applicable to drinking water concentrations below PQLs that would result from use of the newer more stringent toxicity factors for these long-chain PFAS, because any detection of those PFAS would result in an exceedance of the drinking water standard for the subclass of PFAS. Additionally, these guidelines will now need to consider the recently finalized USEPA (2024) MCLs for long-chain PFAS (PFOA, PFOS, PFNA, and PFHxS).

Additionally, Hawaii has developed a screening-level approach for estimating the concentration and risk of total PFAS but does not plan to apply this approach to drinking water.

---

[35] USEPA (2024d). IRIS Toxicological Review of Perfluorononanoic Acid (PFNA) and Related Salts. External Review Draft. https://ordspub.epa.gov/ords/eims/eimscomm.getfile?p_download_id=548669;
USEPA (20234kj). United States Environmental Protection Agency. IRIS Toxicological Review of Perfluorohexanesulfonic Acid (PFHxS) and Related Salts. EPA/635/R-25/012Fa. Washington, DC. https://iris.epa.gov/static/pdfs/0705tr.pdf

[36] Additionally, several states have used the 2016 USEPA Health Advisories of 70 ng/L for the total concentration of PFOA and PFOS as their drinking water guidelines (USEPA, 2016a https://www.epa.gov/sites/default/files/2016-05/documents/pfoa_health_advisory_final_508.pdf; USEPA, 2016b https://www.epa.gov/sites/default/files/2016-05/documents/pfos_health_advisory_final_508.pdf). These states' guidelines are not discussed in this report because the 2016 USEPA Health Advisories were superseded by the more recent 2022 USEPA Interim Health Advisories for PFOA and PFOS (USEPA, 2022b https://www.epa.gov/system/files/documents/2022-06/interim-pfoa-2022.pdf; USEPA, 2022c https://www.epa.gov/system/files/documents/2022-06/interim-pfos2022.pdf). The USEPA (2022a) Interim Health Advisories have now been superseded by the recently finalized USEPA (2024a) MCLs.

Information on each of the state water guidelines and/or approaches that consider multiple PFAS is provided below:

- **Colorado**

  The Colorado Water Quality Control Commission (2020 https://drive.google.com/file/d/119FjO4GZVaJtw7YFvFqs9pmlwDhDO_eG/view) has established a human health-based Water Quality Criterion of **70 ng/L** for the **total concentration of the following: PFOA; PFOS, PFNA, and three parent constituents (i.e., precursors)**[37] **of PFOA (8:2 FTS) and PFOS (N-ethyl perfluorooctane sulfonamidoacetic acid [NEtFOSAA]; N-methylperfluorooctane sulfonamidoacetic acid [NMeFOSAA])**.

  The criterion of 70 ng/L uses the USEPA (2016) Health Advisory of 70 ng/L for the total concentration of PFOA and PFOS as its starting point, and it also includes PFNA and three additional PFAS that can convert to PFOA or PFOS. The rationale for inclusion of PFNA was that the ATSDR Minimal Risk Levels (MRLs) for PFOA, PFOS, and PFNA are numerically identical or very similar, and all three MRLs are based on developmental effects. Colorado also established chemical-specific Water Quality Criteria for PFBS (400,000 ng/L) and PFHxS (700 ng/L).

  This criterion could be superseded by more stringent USEPA (2024a) MCLs of 4 ng/L for PFOA and PFOS and 10 ng/L for PFNA.

- **Hawaii**

  The Hawaii Department of Health *Interim PFAS Guidance* (HIDOH, 2024 https://health.hawaii.gov/heer/files/2024/04/PFAS-Update-signed-April-2024.pdf) includes an approach for estimation of the human health risk of total PFAS in environmental samples. This document and other supporting files are posted at https://health.hawaii.gov/heer/guidance/ehe-and-eals/. This approach is based on assumed additive toxicity for mixtures of PFAS, specifically the sum of the Hazard Indices [HIs][38] for: 1) PFAS that are target analytes with available toxicity factors; 2) PFAS precursors converted to terminal PFAS that are targeted analytes and have toxicity factors in the Total Oxidizable Precursor (TOP) assay, and 3) additional PFAS whose concentration is estimated with a Total Organic Fluorine (TOF) method and whose toxicity is assumed to be the same as the ultrashort chain PFAS, perfluoropropionic acid (PFPrA).

---

[37] Concentrations of the three parent compounds are adjusted to the equivalent molar concentration of PFOA or PFOS.

[38] Hazard Index is discussed in the section on *Health-based drinking water guidelines using chemical-specific toxicity information* below.

HIDOH recognizes that both the total PFAS concentration and the risk estimates from this approach are highly uncertain, and revisions to the approach (e.g., the assumption that the risk of PFAS estimated through TOF is the same as for PFPrA) are under consideration. HIDOH envisions possible use of this approach for screening of environmental media (e.g., groundwater) at PFAS-contaminated sites, but has not stated that it will use it as the basis for a PFAS drinking water guidance value or standard.

- **Maine** (https://www.maine.gov/dhhs/mecdc/environmental-health/dwp/pws/pfas.shtml#:~:text=An%20interim%20standard%20of%2020,other%20remedies%20must%20take%20place).

  The Maine legislature (2021 https://www.mainelegislature.org/legis/bills/getPDF.asp?paper=SP0064&item=3&snum=130) established an enforceable Interim Drinking Water Standard of **20 ng/L** for the **total concentration of 6 long-chain PFAS (PFOA, PFOS, PFNA, PFHxS, PFHpA, PFDA)** in June 2021. Although the supporting documentation was not identified, this standard is identical to the Massachusetts PFAS MCL (see below) and it is assumed that it is based on the same rationale.

  This Interim Drinking Water Standard for the 6 long-chain PFAS is not relevant or applicable to the drinking water concentrations below PQLs that would result from use of the newer more stringent final (PFOA, PFOS, PFHxS) and draft (PFNA) toxicity factors for four of these long-chain PFAS.

- **Massachusetts** (https://www.mass.gov/doc/pfas-mcl-revisions-to-310-cmr-2200-clean-version-9-16-2020/download).

  The Massachusetts MCL of **20 ng/L** for the **total concentration of 6 long-chain PFAS (PFOA, PFOS, PFNA, PFHxS, PFHpA, PFDA)** was established in 2020. Massachusetts DEP provides a detailed scientific rationale for this MCL (MADEP, 2019 https://www.mass.gov/doc/per-and-polyfluoroalkyl-substances-pfas-an-updated-subgroup-approach-to-groundwater-and/download). While recognizing that PFOA and PFOS can cause carcinogenic effects, the MCL considers only non-cancer effects from animal toxicology studies. MADEP (2019) concluded that these six "longer-chain PFAS…are structurally very similar, cause similar effects…and have long half-lives…" which "supports treating this subgroup of longer-chain PFAS as having additive toxicity." It was also concluded that "available data are not sufficient to firmly distinguish [the] individual RfDs [for PFOA, PFOS, PFNA, PFHxS, and PFDA] as being significantly different" from each other.

  Although "insufficient toxicity data exist[ed] for PFHpA to assess similarities in effects" (MADEP, 2019) and available information indicated that its human half-life was shorter than PFOA's, a science-policy decision was made to assume that PFHpA is equally toxic as the other longer chain PFAS. Based on these conclusions, the MADEP Reference Dose of 5 ng/kg/day for PFOA and PFOS, which resulted in a chemical-specific health-based drinking water level of 20 ng/L using MADEP (2019) exposure assumptions, was used as a "surrogate" for the toxicity value for PFNA, PFHxS, PFHpA, and PFDA to support an MCL of 20 ng/L for the combined concentration of the six PFAS.

It is noted that MADEP is considering reevaluation of its current MCL for 6 long-chain PFAS (personal communication, MADEP, 2/26/2026). Specifically, recent final (PFOA, PFOS, PFHxS, PFDA) and draft (PFNA) USEPA Reference Doses based on human epidemiology data for 5 of the 6 PFAS included in the Massachusetts MCL are much lower than the older Reference Doses based on animal toxicology data, and health-based drinking water concentrations using these newer Reference Doses are below PQLs. Additionally, the MADEP MCL does not consider carcinogenic affects, and USEPA (2024a) concluded that PFOA and PFOS are likely human carcinogens and developed cancer slope factors for these two PFAS.

- **Minnesota**
  Minnesota Department of Health (MDH) has developed chemical-specific health-based water concentrations for PFOA, PFOS, PFHxS, PFBA, PFBS, and PFHxA (MDH, 2024c https://www.health.state.mn.us/communities/environment/risk/guidance/gw/table.html). The MDH health-based water concentrations for PFOA, PFOS, and PFHxS are higher than the USEPA (2024a) MCLs and will be superseded by the USEPA MCLs.

  Additionally, MDH uses an approach analogous to a Hazard Index (called a Health Risk Index) to evaluate risks of contaminants that co-occur in groundwater (based on drinking water exposure). It is based on grouping contaminants (including PFAS and others) that cause toxicity to the same target organ (e.g., liver, kidney, thyroid). See MDH (2022 https://www.health.state.mn.us/communities/environment/risk/guidance/gw/additivity.html#:~:text=The%20MDH%20Water%20Guidance%20and,based%20guidance%20for%20that%20chemical).

  MDH (2022) states: The MDH Water Guidance and Additivity Calculator (Excel; linked at https://www.health.state.mn.us/communities/environment/risk/docs/guidance/gw/guidance.xlsx) "facilitates evaluation of exposure to multiple chemicals. For each chemical sharing a health endpoint, a ratio is calculated by comparing the groundwater concentration of the chemical to the exposure duration-specific health-based guidance for that chemical. The ratios are grouped by duration and summed within each health endpoint group."

- **Oregon** (OHA, undated https://www.oregon.gov/oha/PH/HEALTHYENVIRONMENTS/DRINKINGWATER/OPERATIONS/Pages/PFAS.aspx)
  In 2021, the Oregon Health Authority established a non-regulatory drinking water Health Advisory of **30 ng/L** for the **total concentration of PFOS, PFOA, PFNA and PFHxS**, based on the conclusion that these PFAS "may have cumulative health effects." This Health Advisory is not relevant or applicable to the drinking water concentrations below PQLs that would result from use of the newer more stringent final (PFOA, PFOS, PFHxS) and draft (PFNA) toxicity factors for these PFAS.

- **Rhode Island** (webserver.rilin.state.ri.us/BillText22/SenateText22/S2298.pdf)
  In 2022, the Rhode Island legislature passed a bill establishing an interim drinking water standard of **20 ng/L** for the total concentration of **PFOA, PFOS, PFNA, PFHxS, PFDA, and PFHpA** (identical to the Massachusetts and Maine PFAS drinking water standards discussed above). The bill included requirements for two rules: (1) a final rule adopting the interim drinking water standard of 20 ppt for the six PFAS as an MCL which must be filed by June 1, 2024, and (2) a rule regarding the regulation of PFAS as a class or subclass which must be finalized by June 30, 2025.

  The Rhode Island Department of Health (RIDOH, 2023 https://risos-apa-production-public.s3.amazonaws.com/DOH/13079/PBN_13079_20231120151949736.pdf) concluded that a rule establishing a final MCL of 20 ppt for the total of the six PFAS satisfies both requirements. They stated: "RIDOH believes that regulating these 6 PFAS constitutes regulating PFAS as a class/subclass based on the data and information RIDOH has collected from water systems in the State to date and the analysis it developed a few years ago to support draft regulations that were never published. RIDOH's data indicate that those 6 PFAS are the only PFAS detected in Rhode Island drinking water at levels that are expected to significantly impact human health. RIDOH believes that regulating the 6 PFAS named in the statute is the best approach to reduce human health risks from PFAS."

  This drinking water standard is not relevant or applicable to the drinking water concentrations below PQLs that would result from use of the newer more stringent final (PFOA, PFOS, PFHxS, PFDA) and draft (PFNA) USEPA toxicity factors for five of these long-chain PFAS.

- **Vermont**
  In 2018, the Vermont Department of Health (VT DOH, 2018 https://www.healthvermont.gov/sites/default/files/documents/pdf/ENV_DW_PFAS_HealthAdvisory.pdf) established a Health Advisory of **20 ng/L** for the **total concentration of 5 long-chain PFAS (PFOA, PFOS, PFNA, PFHxS, PFHpA).** This Health Advisory is based on the earlier USEPA (2016) Reference Dose for PFOA and PFOS of 20 ng/kg/day. This Reference Dose was also applied to PFNA, PFHxS, and PFHpA based on the assumption that their toxicity

is similar to PFOA and PFOS. The Health Advisory of 20 ng/L is based on the drinking water ingestion rate for infants, which is higher than for adults. An MCL of 20 ng/L for the total concentration of these five PFAS was established in 2020 (VT DEC, 2020 https://dec.vermont.gov/water/drinking-water/water-quality-monitoring/pfas#:~:text=In%202019%2C%20Act%2021%20(S,PFAS%20levels%20in%20drinking%20water).

This MCL is not relevant or applicable to the drinking water concentrations below PQLs that would result from use of the newer more stringent final (PFOA, PFOS, PFHxS) and draft (PFNA) USEPA toxicity factors for four of these long-chain PFAS.

International (examples of recent international guidelines; not a comprehensive list)

- **European Union (EU)**
  (EU, 2020 https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32020L2184)

  The EU Drinking Water Directive adopted in 2020 includes "Minimum Requirements for Parametric Values Used to Assess the Quality of Water Intended for Human Consumption" for PFAS as follows:

  - *PFAS Total* - 500 ng/L. " 'PFAS Total' means the totality of per- and polyfluoroalkyl substances [including trifluoroacetic acid]. This parametric value shall only apply once technical guidelines for monitoring this parameter are developed in accordance with Article 13(7). Member States may then decide to use either one or both of the parameters 'PFAS Total' or 'Sum of PFAS'." Technical guidance for analytical methods to be used for "PFAS Total" recommends the TOP assay, EOF-CIC, or LC-HRMS suspect and non-target analysis (liquid chromatography high resolution mass spectrometry) "as a proxy for PFAS Total" (EU, 2024). EU (2024) recognizes that these methods are not standardized or harmonized, that further validation is needed, and that reliable data on the uncertainty of measurement and the limit of quantitation (LOQ) is not available for most of the methods. As such, "it is not yet possible to ensure compliance with the [European Union's] analytical performance requirements" for "PFAS Total."

  - *Sum of PFAS* - 100 ng/L. " 'Sum of PFAS' means the sum of per- and polyfluoroalkyl substances considered a concern as regards water intended for human consumption listed in point 3 of Part B of Annex III. This is a subset of 'PFAS Total' substances that contain a perfluoroalkyl moiety with three or more carbons (i.e. –CnF2n–, n ≥ 3) or a perfluoroalkylether moiety with two or more carbons (i.e. –CnF2nOCmF2m–, n and m ≥ 1)." The list from Part B of Annex 3 for "Sum of PFAS" includes PFCAs and PFSAs with 4-13 carbon atoms, as follows: PFBA, PFPeA (C5), PFHxA, PFHpA, PFOA, PFNA, PFDA, PFUnDA (C11), PFDoDA (C12), PFTrA (C13), PFBS, PFPeS (C5-S), PFHxS, PFHpS (C7-S), PFOS, PFNS (C9-S), PFDS (C10-S), perfluoroundecane sulfonic acid, perfluorododecane sulfonic acid, and perfluorotridecane sulfonic acid.

- **Canada**

  Health Canada (2024 https://www.canada.ca/content/dam/hc-sc/documents/services/publications/healthy-living/objective-drinking-water-quality-per-polyfluoroalkyl-substances/objective-for-canadian-drinking-water-quality-en-final.pdf) established a drinking water objective of 30 ng/L for the total concentration of the 25 PFAS included in USEPA Method 533.

  In the objective, concentrations above the MRL are added together to determine the total concentration. A value of zero is assigned to detections below the MRL and non-detectable results.

  In general, Health Canada drinking water objectives “set out a goal for a maximum level of a contaminant in drinking water, taking into account available treatment technology and analytical methods.” Health Canada (2024) states that a “precautionary group-based approach” to PFAS in drinking water is necessary because of “the potential for exposure to multiple PFAS at the same time, the potential for negative health impacts, [and] the uncertainty and the limited data on many PFAS.” The proposed PFAS objective is stated to be an interim measure that was established because new information “raises concerns that need to be addressed more quickly” than revision of Health Canada’s drinking water guidelines for PFAS, which may take many years to complete. The future revision of the Health Canada drinking water guidelines for PFAS “will include a comprehensive review of new toxicological evidence… and risk assessments…[and]… a comprehensive review of new information on analytical and treatment methods for PFAS as well as new findings for the management of treatment residuals” (Health Canada, 2024).

  It should be noted that the Health Canada guideline does not consider newer toxicity factors for long-chain PFAS based on human data that are much lower than current toxicity factors based on animal data.

- **Denmark**

  (Denmark Ministry of the Environment, 2023 https://www.retsinformation.dk/eli/lta/2023/1023).

  Denmark established a drinking water guideline of 2 ng/L for the total concentration of PFOA, PFOS, PFNA, and PFHxS, and 100 ng/L for the total concentration of 22 PFAS (PFBA, PFPeA, PFHxA, PFHpA, PFOA, PFNA, PDA, PFUnDA, PFDoDA, PFTrDA, PFBS, PFPeS, PFHxS, PFHpS, PFOS, PFNS, PFDS, PFUnDS, PFDoDS, PFTrDS, PFOSA, 6:2 FTS).

Assessment of treatment technologies for removal of PFAS from drinking water and wastewater

Introduction

New Jersey P.L.2023, c.279 requires the New Jersey Department of Environmental Protection (NJDEP), in consultation with the New Jersey Drinking Water Quality Institute (DWQI), to conduct an assessment of "treatment technologies that may be effective in removing perfluoroalkyl and polyfluoroalkyl substances from drinking water or wastewater."

Conventional drinking water (e.g., coagulation, sedimentation, disinfection) and wastewater treatment technologies (e.g., bar screens, grit removal, clarifiers, filtration, aeration) are generally not effective for the removal of PFAS, and specific treatment removal technologies are needed. This section of the Appendix provides an assessment of three major technology categories - adsorption, membranes, and destruction – that are used for removal of PFAS from drinking water and wastewater.

As discussed earlier, NJDEP established a Maximum Contaminant Level (MCL) of 13 nanograms per liter (ng/L) for PFNA in 2018, and MCLs of 14 ng/L for PFOA and 13 ng/L for PFOS in 2020. To comply with these MCLs, numerous New Jersey public water systems have installed or plan to install treatment technologies to remove PFAS. Specifically, NJDEP had approved 116 permits in 84 different public water systems, including community and non-community water systems[39], for permanent treatment to remove PFAS as of December 2025. Of these approved permits, 56 New Jersey drinking water treatment plants had installed treatment to remove PFAS to concentrations below the New Jersey MCLs as of April 2025. In addition to the permits that were approved for permanent treatment, other permit applications for PFAS treatment are under review, and additional permits for temporary treatment (e.g., pilot scale) have also been approved by NJDEP. This assessment is based both on information from the published literature and knowledge about treatment removal of PFAS that NJDEP has acquired since its PFAS MCLs were established.

As mentioned above, research on PFAS removal in wastewater shows that conventional treatment processes are generally not effective for PFAS removal. A meta-analysis published this year reviewed PFAS concentrations in wastewater treatment plants (WWTPs) across the globe

---

[39] Treatment for PFAS at some non-community public water systems may have been approved at the county level and are not included in the numbers above.

(Abou-Khalil et al., 2026). In this study, the median total concentration of the 40 PFAS analytes included in EPA Method 1633 in samples from approximately 130 US wastewater treatment plants (WWTPs) included in the study was 89 ng/L for influent (n = 61 samples) and 135 ng/L (n = 119 samples) for effluent. The increase in total PFAS by the end of treatment could be caused by chemical and biological transformation of PFAS precursors, which were not detected by the analytical method used, to other PFAS that were detected during the secondary treatment stage (Kim et al., 2024). Additionally, NJDEP collaborated with Stevens Institute of Technology on two studies that analyzed the fate and transport of PFAS in four New Jersey WWTPs utilizing conventional treatment technologies. Three WWTPs showed an average increase of 4.2 – 22.5% of total PFAS by the end of treatment, while the remaining WWTP showed minimal decreases in PFAS (around 6 – 23%) (Mustafa et al. 2025a; Mustafa et al., 2025b). Additional research is needed to understand the contributing factors that can lead to the relatively high PFAS concentrations that are detected in wastewater after conventional treatment.

PFAS Treatment Technologies

As mentioned above, treatment technologies that are currently known to be effective for the removal of PFAS from drinking water and wastewater can be separated into three categories: adsorption, membranes, and destruction. This section will discuss the research/development status for each technology category, their advantages/challenges, and their deployment status if applicable.[40] While cost was excluded as a key performance indicator in this evaluation, cost may be a limiting factor when implementing or designing for PFAS removal and is mentioned where relevant. For wastewater, effluent treatment was the primary focus, and treatment of wastewater byproducts such as activated sludge and biosolids was not evaluated.

Adsorption

Most PFAS removal technologies that have been deployed for drinking water and wastewater treatment fall under the adsorption category (ITRC, 2026). Adsorption is a process in which contaminants adhere onto the surface of an adsorptive material, or media, due to intermolecular forces. Within the adsorption category, granular activated carbon (GAC) and ion exchange (IX) resins are the most thoroughly studied and most frequently utilized technologies (USEPA, 2018; USDOE, 2023). Of the 116 permits approved by NJDEP for permanent treatment as of December 2025, 57 are for GAC, 57 for IX resins, and 2 for other adsorbents. Of these approved permits, 56 New Jersey drinking water treatment plants have installed adsorption-based treatment to remove PFAS to concentrations below the New Jersey MCLs as of April 2025. Additionally, several other water treatment facilities in New Jersey have also been investigating the applications of other adsorbents such as surface modified clay, plant based

---

[40] An evaluation of a technique, brand, or product does not constitute an endorsement by NJDEP.

adsorbents, and powdered activated carbon (e.g., pilot scale). GAC, IX resins, and other technologies in the adsorption category are discussed in greater detail further below.

Although many PFAS that may be present in water can be removed by adsorption technologies, differences in breakthrough times and removal efficiencies among PFAS must be considered to ensure adequate removal of all PFAS of interest. Breakthrough is the term used for when the media exceeds its capacity to remove PFAS. For both GAC and IX resins, breakthrough times for short-chain perfluoroalkyl acids (PFAAs) are generally shorter than long-chain PFAAs (USEPA, 2024n). IX resins can have greater treatment removal efficiency and longer media life for short-chain PFAAs than GAC (Murray et al., 2021). Besides chain length, other structural differences among PFAS can also affect their treatment removal efficiency. For example, Sun et al. (2016) reported that replacing a CF_2 with an ether oxygen in a PFAS molecule with an otherwise similar structure resulted in decreased affinity for another adsorption technology, powdered activated carbon (PAC). Due to these varying removal efficiencies, adsorbent media must be continuously monitoring for breakthrough of all PFAS of concern that are present.

Water systems may design their treatments to utilize more than one adsorption technology in order to gain benefits of both. For example, some New Jersey drinking water systems are currently in the early stages of exploring and designing treatment which uses mixed-media treatment trains. In these designs, a lead-lag configuration of pressure vessels is used, with the lead pressure vessel containing GAC and the lag pressure vessel containing IX resins.

The addition of adsorptive treatments may require additional design considerations and facility upgrades. For example, additional pre-treatment steps for managing water quality may be necessary prior to adsorptive treatment for better PFAS removal efficiency, and well pumps or booster pumps may need to be upgraded to manage the loss in pressure across the adsorbent. Additionally, most designs will include a new building or a building-addition to house the pressure vessels because media vessels installed outdoors can have significant challenges with freezing and leaks, even with adequate heat tracing.

Granular activated carbon (GAC)

Granular activated carbon (GAC) is a material derived from organics that contain high amounts of carbon, such as coal and coconut shell (ITRC, 2026). Water is passed through treatment columns or beds of GAC to allow contact between the contaminant and the adsorptive media. GAC is an effective adsorbent due to its highly porous structure and large surface area on which adsorption of contaminants can occur (USEPA, 2024n).

GAC is the most thoroughly studied treatment technology for PFAS removal, and it is currently the most frequently deployed treatment technology in the U.S. for PFAS removal from both drinking water and wastewater (USEPA, 2018; US DOE, 2023). In drinking water, the typical GAC design for treating groundwater sources involves GAC media placed inside pressure vessels, which are available for purchase and can be used over a wide range of flow rates. For surface water sources, GAC treatment design has significant additional challenges and complexity due to the large volumes of water that are often treated, complex and variable influent water quality, and the need for compatibility with the existing treatment technologies required to address this water quality.

GAC is currently utilized to treat surface water sources for PFAS in some locations such as the Cape Fear Public Utility authority in North Carolina (CFPUA, 2026). However, treatment of surface water with GAC is associated with numerous challenges, and GAC is much less frequently used for treatment of surface water than groundwater (Nakazawa, 2023; USEPA, 2024n). That being said, several New Jersey drinking water systems with surface water sources are currently designing treatment for PFAS removal with proposed designs that include GAC within post-filtration gravity contactors (in which GAC is contained in open basins) or in pressure vessels. In order to carefully design this treatment, these systems are conducting extensive pilot testing to fully evaluate variables, optimize efficiencies, and identify operational impacts.

The empty bed contact time (EBCT; contact time between the water being treated and the media) needed for effective removal of PFAS with GAC is at least two to three times than for IX resin (Murray et al., 2021). GAC pressure vessels are typically designed in series with a lead/lag configuration to allow for sufficient EBCT (USEPA, 2024n). Additionally, GAC pressure vessels tend to be larger than IX resin vessels to increase the EBCT (Forrester and Bostardi, 2019), and therefore IX resins may be used more often when space is a constraint. A lower EBCT for PFAS removal may be feasible with GAC, such as a design which utilizes gravity contactors, and gravity contactors can also have slightly smaller footprints than pressure vessels (Carollo Engineers, 2023). However, sufficient pilot study data to support such a design is still needed. The hydraulic loading rate is also a critical constraint for GAC design. Too low of a loading rate could lead to preferential pathing in the media, leading to lower removal efficiencies, but higher loading rates can cause pressure concerns (WQA, 2013).

Proper operation of GAC after installation requires several considerations. Arsenic is a naturally occurring contaminant that is present in both coal-based and plant-based GAC, though significantly more common in coal, and it may leach out of GAC during start-up of treatment (Greico, 2021). When placing new GAC media into service, initial rinsing of the GAC is required to reduce effluent arsenic concentrations below the New Jersey arsenic MCL of 5 µg/L and achieve a stable pH. Acid-rinsed GAC may reduce the pH and arsenic levels and require less initial rinsing, but it is more expensive than standard GAC (Greico, 2021). Additionally, GAC treatment may require periodic backwashes (water forced in the opposite direction of typical flow) to expand the media and release trapped particles, which helps to prevent compaction and loading on the media (Turan, 2023). The frequency of backwashing is dependent on influent water quality, and more frequent backwashing may be needed due to water hardness, total suspended solids, or other water quality parameters (Kirchen, Fundneider, and Lackner, 2024).

Despite the challenges in design and implementation discussed above, GAC is an effective treatment technology for the removal of PFAS in drinking water applications. Data from a New Jersey public water system presented in 2014 showed that multiple long and short chain perfluorocarboxylates (PFCAs) were removed to below the detection limit of 5 ng/L by GAC designed for PFAS removal (Post, 2014). However, as mentioned above, breakthrough times for short-chain perfluoroalkyl acids (PFAAs) are generally shorter for than long-chain PFAAs (USEPA, 2024n). As of April 2025, at least 27 New Jersey public water treatment plants have installed GAC for PFAS removal from drinking water. Previously, in 2022, NJDEP conducted an evaluation of drinking water facilities that had installed GAC for PFAS removal. This evaluation showed that all seven facilities assessed were able to reduce PFOA and PFOS below the New Jersey MCLs of 14 ng/L and 13 ng/L, respectively (NJDEP, 2022).

Pilot-scale studies of GAC for removal of PFAS from wastewater have been conducted at some U.S. publicly owned treatment works (POTWs; i.e., sewage treatment plants that treat municipal and/or industrial wastewater [CFR, 2026]). However, there is no full-scale deployment of GAC specifically for PFAS removal in any New Jersey POTW at this time, and no such full-scale deployment was identified elsewhere in the U.S (Murray and Mohan, 2025).

USEPA (2021c) reports that some U.S. PFAS manufacturers and formulators utilize GAC to treat their process wastewater. Additionally, a study of 86 industrial PFAS users and four WWTPs conducted by the Michigan Department of Environment, Great Lakes, and Energy found that 15 different pretreatment or reduction methods (e.g., cleaning/replacement, disconnection of contaminated equipment/processes, limiting volume of wastewater accepted, treating with powdered activated carbon) were used to reduce PFAS in wastewater, with some facilities utilizing more than one method. Of 90 industrial users, 56 (60%) utilized GAC pretreatment systems, while the four WWTPs all limited the volume of wastewater that they accepted but did not use GAC (MI EGLE, 2025). In New Jersey, Solvay Specialty Polymers, an industrial facility that used processing aids containing PFAS in fluoropolymer manufacturing, treats its process wastewater to remove PFAS with GAC and/or IX resins (Integral Consulting, 2025).

A challenge with the utilization of GAC is the disposal of the spent GAC media after it has been used to remove PFAS. In some cases, GAC can be reactivated for reuse with a thermal treatment process which is typically performed at a separate facility (Mayerberger et al., 2025). Once reactivated, GAC may be combined with virgin GAC (to account for media loss during the reactivation process) and returned to the water system for continued use. However, reactivation can decrease GAC's PFAS removal efficiency, requiring the system to make long-term adjustment of their flow rates (Tshangana et al., 2025).

Although reactivation can extend the longevity of GAC, disposal should be considered when PFAS removal becomes inefficient, and one manufacturer recommends that GAC should not be reactivated more than 5 – 6 times (Norit, 2025). The most frequently used disposal method for spent GAC is incineration (USEPA, 2024n). However, this process can be expensive, energy-intensive, potentially create products of incomplete combustion, and is limited to a small number of approved waste incineration facilities (USDOE, 2023). Although disposal to landfill can be an option, an increasing number of landfills will not accept solids with PFAS contamination (ITRC, 2026).

Ion exchange (IX) resins

Ion exchange resins are polymer beads, 0.5 to 1.0 mm diameter in size, that can attract contaminants through ion interactions (UC Irvine, undated; ITRC, 2026). When contaminated water passes through a vessel containing IX resins, mobile ions are released into the water and exchanged with PFAS during an ion exchange reaction. PFAS then attach to the resin surface and remain there.

Positively charged anion-exchange resins are most effective for removing negatively charged PFAS, and additional specialized PFAS selective-resins are also available (US DOE, 2023). While IX resins can be customized for enhanced performance toward PFAS, other resins designed for perchlorate removal and arsenic removal can also show high adsorption of PFAS (USEPA, 2023d). Multiple studies with various water media have shown that certain IX resins can adsorb up to >99% of select short-chain and long-chain PFAS (USEPA, 2023d). However, breakthrough times for short-chain perfluoroalkyl acids (PFAAs) in IX resins are generally shorter than long-chain PFAAs (ITRC, 2026 - Section 12.2.1). Breakthrough times are also shorter for PFAAs that are carboxylates than those that are sulfonates (ITRC, 2026 - Section 12.2.1).

As of April 2025, at least 29 New Jersey public water treatment plants have installed IX resins for PFAS removal from drinking water. Previously, in 2022, NJDEP conducted an evaluation of drinking water facilities that had installed IX resin for PFAS removal. This evaluation showed that all five facilities assessed were able to reduce PFOA and PFOS below the New Jersey MCLs of 14 ng/L and 13 ng/L, respectively (NJDEP, 2022).

At this time, there is no full-scale deployment of IX resins for PFAS removal from wastewater in New Jersey POTWs, and no such deployments were identified elsewhere in the U.S. However, Michigan EGLE (2025) noted that IX resins are the second most utilized PFAS treatment technology by industrial users when paired with one or more additional treatment technologies. As noted above, Solvay Specialty Polymers, a New Jersey industrial facility that used PFAS in its fluoropolymer manufacturing process, treats its process wastewater to remove PFAS with IX resins, as well as GAC (Integral Consulting, 2025).

The typical design of IX resins uses pressure vessels, as IX resin media is usually utilized within gravity contactors. IX resins typically require about four to five minutes of EBCT for effective PFAS removal. As the EBCT needed is less than GAC, the pressure vessels are often smaller, and as a result, IX resins are often used when limited space is a significant constraint (Forrester and Bostardi, 2019). As with GAC, proper operation of IX resin treatment requires that the hydraulic loading rates being utilized are not too low or too high.

Pretreatment is a critical consideration in the design and operation of IX resins for PFAS treatment. For example, water that is high in iron, and manganese can cause significant loading on the IX resin which can then lead to fouling and premature media replacement (Purolite, 2024). Additionally, bag or cartridge filters are commonly installed before IX resins to prevent particulate matter from entering the resin bed (Town of Wellesley, Massachusetts, 2026). Damage to IX resins, resulting in decreased PFAS removal and ultimately leading to premature media replacement, can be caused by oxidants (LANXESS, 2024), which are commonly utilized by drinking water systems in pretreatment to address other contaminants like iron and manganese (von Guten, 2024). Therefore, the existing treatment scheme at a facility may need to be adjusted to ensure that pretreatment processes do not damage the IX resin. Alternatively, one manufacturer recommends additional pretreatment processes such as the addition of sodium bisulfite to remove oxidants prior to IX resin treatment (Purolite, 2024).

Similar to GAC, start-up of treatment with new IX resin media requires an initial rinsing process to ensure any residual compounds from manufacturing are flushed. Manufacturers offer buffered resins, which may require less rinsing volume needed to attain stabilized effluent parameters (Purolite, 2024). In addition, resin traps may be installed following the IX resin bed to capture resin beads in the effluent that would otherwise enter and potentially damage downstream treatment processes.

Like GAC, there are challenges with disposal of spent IX resin after its use to remove PFAS. Certain types of IX resins can be reused through the regeneration process (i.e., reuse after immersion in a brine or solvent for IX resins), decreasing the need for media replacement and disposal (Kempisty et al., 2024). However, the regeneration process transfers any removed PFAS from the resin media to a liquid waste stream, which then requires additional management and disposal consideration. Therefore, IX resins utilized for PFAS treatment are not typically regenerated, and no regenerable IX resin designs for PFAS removal are currently approved in New Jersey public drinking water systems. Options for disposal of IX resin after end of use include destruction via incineration at facilities approved to handle PFAS materials and disposal at landfills approved to handle PFAS materials. However, as mentioned above, an increasing number of landfills will not accept solids with PFAS contamination (ITRC, 2026).

Other types of adsorbents

Several New Jersey systems have been approved to utilize novel surface modified clay adsorbents in their permanent treatment systems, and these systems are currently conducting extensive pilot testing of this novel technology to ensure effective removal of PFAS. Plant-based adsorbents are also currently being pilot tested for the removal of PFAS in New Jersey drinking water systems. Some New Jersey drinking water systems using surface water sources are investigating and designing pilot studies to test the effectiveness of powdered activated carbon (PAC) to remove PFAS. While PAC may be effective at removing PFAS, the downstream operational impacts pose a significant limiting factor as the PAC must be settled out or otherwise removed. Additional research is needed to characterize these impacts.

Foam Fractionation

Foam fractionation involves a process in which gas (e.g., air or ozone) is injected into a vessel containing contaminated liquid, which then allows the contaminants to attach to the surfaces of bubbles and rise to the top of the liquid as foam (We et al., 2024). Research on the use of foam fractionation to remove PFAS has primarily focused on complex water matrices such as wastewater, landfill leachate, and aqueous film forming foam (AFFF)-impacted water (Miatke, 2025). In New Jersey, the Passaic Valley Sewerage Commission is currently performing pilot studies on foam fractionation for PFAS removal from wastewater (NJDEP, 2025

Foam fractionation tends to show better removal for long-chain PFAS than short-chain PFAS since the higher air-water sorption coefficients of long-chain PFAS allows for a better affinity towards foam (Buckley et al., 2022). While removal efficiencies up to >99% for certain long-chain PFAS have been reported (Smith et al., 2022), a lab-scale study of wastewater from mixed liquor suspension in activated sludge-based aerated bioreactors reported less than 20% removal of quantified PFAS with carbon chain lengths less than six (We et al., 2025).

In comparison to adsorbents or membrane-based treatment methods, fractionation is much less impacted by hardness, total organic carbon, and dissolved metals (ITRC, 2026). However, parameters that can affect foam fractionation performance include gas flow rate, foam height, bubble size, and addition of surfactants (We et al., 2024).

Although there is limited information on PFAS foam disposal methods, the volume of produced foam tends to be significantly lower than the volume of reverse osmosis (RO) concentrate (MPCA, 2023). Options for disposal include destruction via incineration at facilities approved to handle PFAS materials and disposal at landfills approved to handle PFAS materials (Miatke, 2025).

Membranes – Reverse Osmosis (RO) and Nanofiltration (NF)

Membrane-based technologies such as reverse osmosis (RO) and nanofiltration (NF) have also been shown to be effective PFAS removal technologies for drinking water (EPA, 2018). RO is a process that uses high pressure to push untreated water through a semi-permeable membrane with ~0.5 nm pores (Sanzana et al., 2025; Wang et al., 2023). This process results in two types of streams: treated water (permeate) and residual water containing removed PFAS (concentrate). In contrast, NF passes untreated water through a membrane with ~1 – 10 nm pores, and, like RO, results in permeate and concentrate streams. However, the reject water for NF contains lower PFAS concentrations than RO since NF has a larger pore size (Bargeman, 2023).

Studies on RO and NF applications for PFAS removal at pilot-scale (Liu et al., 2021) and full-scale (Appleman et al., 2013) drinking water treatment plants in the U.S. have shown successful removal of multiple types of PFAS to below method reporting levels (0.25 - 5 ng/L). In New Jersey, a small groundwater-sourced public drinking water system received approval for a full-scale pilot study of a RO treatment system. The concentrate, which contains highly concentrated PFAS, is then sent through a novel technology which applies an electrical current to force PFAS to be filtered through a membrane, which can be replaced when its capacity is exceeded. The effectiveness of this novel technology for removal of PFAS and other parameters will be monitored for the duration of the full-scale pilot study.

More research is needed for RO and NF in regard to full-scale applications, long-term operation, and causes of breakthrough. ITRC (2026) has noted concerns of fouling (or the buildup of unwanted substances onto the membrane), changes in water quality, and temperature as factors that could affect RO and NF performance. Researchers at the New Jersey Institute of Technology (NJIT) observed that, at lower pH levels, interactions with certain ions, and organic matter could decrease PFAS removal in two commercial RO and NF membranes (Ma et al., 2023). However, some of these concerns may be mitigated with carefully designed pre-treatment and treatment trains that utilize multiple treatment technologies, such as RO or NF combined with GAC or IX resins. However, cost and complexity of operations become a significant concern as these treatments are scaled (USEPA, 2024n). In addition, disposal options for the concentrate produced by membrane technologies remain a significant concern. Options include destruction via incineration at facilities approved to handle PFAS materials and disposal at landfills approved to handle PFAS materials (US DOE, 2023).

While the focus of this evaluation is treatment removal at public water supplies, it is noted that point of use (POU) membrane filtration devices, specifically RO filters, have been found to be effective for removal of PFAS from drinking water in the home (NSF, 2026). In a study conducted on North Carolina homes, POU under-sink filters that contained RO or dual-stage filters had almost complete PFAS removal and outperformed GAC filters (Herkert et al., 2020).

No information indicating use of RO for PFAS removal at POTWs was identified, but it has been applied to treatment of industrial wastewater to remove PFAS. PFAS manufacturing facilities, including Chemours in Fayetteville, NC and Solvay in Spinetta Marengo, Italy, have used RO as part of their industrial treatment systems (USEPA, 2020; FOSAN, 2023). However, additional tertiary treatment of wastewater is needed before RO, since RO membranes are susceptible to accumulation of other materials such as suspended solids (US DOE, 2023). At this time, there is limited research on possible wastewater treatment applications of NF.

Destruction

Destruction-based methods involve a physical, chemical, and/or biological process that can partially or fully break down PFAS. This section discusses some technologies that are in the later stages of development and may not yet be commercially available as a treatment option for water systems. A few technologies that are in the early stages of research are briefly discussed in the last subsection.

Electrochemical Oxidation (EO)

Electrochemical oxidation (EO) is a treatment approach that involves a vessel with contaminated water, conductive electrodes, and chemical interactions (Krause, Magnuson, and Crone, 2021). EO can break down carbon-fluorine bonds of PFAS molecules and then further degrade the molecules with available radicals (chemical species with unpaired electrons) (Li et al., 2025). At the lab-scale and pilot-scale, EO has been shown to effectively remove select PFAS precursors, short-chain PFAS, and long-chain PFAS (Chiang et al., 2018). One challenge for EO is the design of a low-cost and durable anode (Li et al., 2025). Other challenges include the possible formation of other chemical byproducts (such as chlorate and perchlorate), chemical reaction competition that reduces PFAS degradation, and buildup of calcium potentially causing scaling (Zeidabadi et al., 2023). Currently, most information on larger pilot-scale studies of PFAS removal comes from EO manufacturers. Such studies have shown EO being applied to the treatment of PFAS in drinking water, wastewater, landfill leachate, AFFF-impacted wastewater, RO concentrate, and IX resin regeneration solution (Axine Water Technologies, 2026; E2metrix, 2026; Hazen and Sawyer, 2024; Ovivo Inc., 2024).

Supercritical Water Oxidation (SCWO)

Supercritical water oxidation (SCWO) occurs when water has a pressure and temperature greater than 3200 psi (22.1 MPa) and 374°C respectively (Sahle-Demessie et al., 2022). At the supercritical point, water has both liquid and gas properties that allow for the degradation of contaminants (ITRC, 2026). At the laboratory and pilot-scales, research has shown SCWO removing over 99% of common types of PFAS such as PFOA and PFOS in AFFF-impacted water (Krause et al., 2021) and landfill leachate (Jama et al., 2020) in minutes. Challenges for SCWO include the formation of acids during the reaction (Berg et al., 2022) and the formation of fluoride salts during PFAS degradation (Sahle-Demessie and Krause, 2021). A study conducted by USEPA showed that three types of commercialized SCWO systems could remove more than 99% of PFAS from AFFF-impacted water despite each system having different operating parameters such as reaction residence time (6 – 60 sec) and temperature (590 – 595°C) (Krause et al., 2021). SCWO manufacturers have mostly discussed their systems' applications for complex water matrices such as AFFF-impacted water, landfill leachate, and wastewater (374water, 2026; Revive Environmental, 2026; Aquarden, 2024). However, SCWO could be applied to drinking water in terms of treatment of PFAS-concentrated byproducts such as used sorbents (i.e., GAC, IX resins) (Chiang et al., 2023).

Plasma

Plasma is a state of matter that is electrically conductive which is created after a gas receives charged ions (Foster, 2017). When applied to water treatment, plasma can create a series of physical and chemical reactions that allow for the degradation of contaminants such as PFAS (ITRC, 2026). Most lab and pilot-scale studies have evaluated plasma for PFAS degradation primarily in groundwater, included ground water impacted by AFFF-impacted, as well is in surface water impacted by AFFF. Depending on PFAS type and plasma reactor size, >99% of select PFAS degradation has been shown to occur within a few minutes or a few days (Vo et al., 2020; Holsen, 2022). Challenges for destruction of PFAS with plasma include increased pH, the need for addition of chemicals for improved degradation, and potential byproducts of incomplete destruction of PFAS, such as short-chain PFAS that may be formed from longer chain-PFAS (Meegoda et al., 2022).

NJDEP has collaborated with Purafide to evaluate how a lab-scale plasma reactor could degrade select PFAS from wastewater, landfill leachate, and leachate-impacted groundwater (Mujovic and Arias, 2025). While the data for wastewater after reactor treatment were not provided, data were provided for treatment of leachate-impacted groundwater and landfill leachate. In the leachate-impacted groundwater, removal percentages in 66 minutes were approximately 52% for PFOA, 77% for PFNA, and 95% for PFOA, when initial concentrations were 10,600, 9.87, and 89,900 ng/L, respectively. For landfill leachate, approximately 97 – 98% of PFOS, PFNA, and PFOA were removed in 99 minutes, with initial concentrations of 44, 137, and 2070 ng/L, respectively.

Other destruction-based methods

There are other destruction technologies that are mostly in the research stage. A few examples are provided below:

- Biodegradation: This process involves the breakdown of contaminants such as PFAS with small living organisms such as bacteria (IUPAC, 2026). Research on biodegradation of PFAS is limited to lab-scale studies. Most of the bacterial species being evaluated are members of the genus *Pseudomonas*. These bacteria appear to have better potential for the breakdown of short-chain than long-chain PFAS (Skinner et al., 2025).

- Hydrothermal alkaline treatment (HALT): This technology involves subcritical (<374^{o}C and approximately 25 MPa) and high pH water conditions for the degradation of PFAS (SERDP-ESTCP, 2026). It was developed by a research group from the Colorado School of Mines (Aquagga, 2026). At the pilot scale, a HALT reactor has been able to degrade select long-chain, short-chain, and ultra-short chain PFAS (Pinkard et al., 2024).

- Photocatalysis: This chemical reaction involves UV light and leads to the formation of reactive species that can degrade PFAS (Verma et al., 2024). This field of research is limited to mostly lab-scale studies and a few pilot-scale studies. A pilot-scale photocatalytic reactor was able to fully defluorinate a 0.1 mg/L PFOS – K (potassium) solution (Chong et al., 2026)

- Ultrasound/sonolysis: This approach utilizes high frequency sound waves for the destruction of PFAS (USDOE, 2023). This field of research is limited to lab-scale studies. One study showed up to 96.9% degradation of a 10 mg/L PFOS - K solution at 400 kHz (Wood et al., 2020).

Future Directions

Recent studies demonstrate that ultra-short chain PFAS, particularly trifluoracetic acid (TFA), can occur in drinking water at higher concentrations than other PFAS, and treatment removal of ultrashort PFAS from drinking water is a focus of current research. For example, Zheng et al. (2023) analyzed Indiana tap water samples (n = 324) for 47 PFAAs and found that TFA contributed 79 ng/L of the median total PFAA concentration of 100 ng/L. Additionally, TFA concentrations have been reported to have rapidly increasing in groundwater during the last several decades (Albers and Sültenfuss, 2024). Meanwhile, a few non-U.S. WWTP studies have shown the presence of perfluoropropionic acid (PFPrA) in wastewater at 1.1–40.7 ng/L (Kim et al., 2022).

There is limited research on the effectiveness of treatment technologies for ultra-short chain PFAS removal. Studies have reported that IX resins have partial capability and RO has full capability for ultra-short chain PFAS removal (Schueurer et al, 2017; Björnsdotter et al., 2020). Additional research suggests that material modifications of IX resins could enhance ultra-short chain PFAS removal. One study observed that the addition of a pentafluorostyrene segment to IX resins could remove 92.2 – 99.1% of difluoroacetic acid (DFA), PFPrA, perfluoro-2-methoxyacetic acid (PFMOAA), and perfluoro-2-methoxypropanoic acid (PMPA) when the initial concentration of each was 50 mg/L (He et al., 2025). When disposing of spent IX resins or RO concentrate containing TFA, it should be noted that incineration could lead to the release of fluoroform, a type of greenhouse gas (Arp et al., 2024). For destruction-based technologies, HALT has shown partial capability for degradation of ultra-short chain PFAS. A pilot-scale study that analyzed 15 types of PFAS noted that TFA and PFPrA continued to persist after exposure to HALT (Pinkard et al., 2024).

To ensure comprehensive PFAS removal, treatment systems should consider incorporating more than one type of treatment technology. For wastewater treatment, it is common to see a combination of GAC and IX resin vessels in the field (Integral Consulting, 2025; Murray and Mohan, 2025). For both drinking water and wastewater treatment, it could be helpful to pair an adsorption-based technology with a destruction-based technology. A few examples of applications include the treatment of spent IX resins with SCWO (374water, 2025) and treatment of foam from foam fractionation with electrochemical oxidation (Smith et al., 2023).

Conclusions

Conventional drinking water (e.g., coagulation, sedimentation, disinfection) and wastewater treatment technologies (e.g., bar screens, grit removal, clarifiers, filtration, aeration) are generally not effective for the removal of PFAS, and specific treatment designed for PFAS removal are needed. This assessment provides a brief overview of the available technologies that can be applied for PFAS treatment of drinking water and wastewater based both on information from the published literature and the knowledge that NJDEP has acquired since its PFAS MCLs were established.

Of the three major technology categories discussed in this assessment– adsorption, membranes, and destruction, adsorption-based technologies are currently the most frequently utilized for PFAS treatment in water systems. More specifically, GAC and IX resins have been studied extensively and have been deployed for both drinking water and wastewater treatment in New Jersey and elsewhere. In addition, emerging adsorbents made from plant-based materials or surface modified clay could be applied to various water media in the future. Alternative types of carbon such as PAC are being studied for drinking water treatment, primarily for surface water, but considerable pilot study is needed to evaluate effectiveness and implementation in full-scale water treatment applications. Other adsorption-based processes such as foam fractionation could be applied for wastewater treatment in the future as well.

Although many PFAS that may be present in water can be removed by adsorption technologies, differences in breakthrough times and removal efficiencies among PFAS must be considered to ensure adequate removal of all PFAS of interest. The main challenge for adsorbents in general is disposal of the material after it has been concentrated with PFAS. Some adsorbent materials used for PFAS removal reactivated (thermal treatment) or regenerated (chemical treatment) for reuse, but they must eventually be disposed. Options for adsorbents after end of use include destruction via incineration at facilities approved to handle PFAS materials and disposal at landfills approved to handle PFAS materials. However, an increasing number of landfills will not accept solids with PFAS contamination. Other adsorption-based processes such as foam fractionation could be applied for wastewater treatment in the future as well.

Membrane-based technologies could be an alternative for the removal of PFAS from drinking water, but their use for PFAS removal from wastewater could be limited by challenges such as membrane fouling and concentrate disposal. Both RO and NF appear to be promising and can remove select PFAS to levels below reporting limits. However, more research is needed on full-scale applications, long-term operation, and causes of breakthrough. Other challenges include disposal options for the PFAS concentrate and cost.

Destruction-based technologies could serve as the ideal final approach to ending the release and recirculation of PFAS through the environment. A few examples of destruction-based technologies applicable for PFAS removal include electrochemical oxidation, supercritical water oxidation, and plasma. However, more research is needed on long-term operation, identification of possible byproducts, and performance enhancement.

Ultra-short chain PFAS, particularly TFA, are a rising concern for treatment facilities. IX resins and RO could be possible technologies that can reduce these types of PFAS. However, more research is needed to understand ultra-short chain removal and optimization of available technologies. To guarantee a comprehensive removal of PFAS with varying sizes, more than one treatment technology should be included in the treatment train.

Although several PFAS treatment technologies are currently available on the market and others are in development, selection of effective treatment for the removal of PFAS requires careful consideration and design. When designing treatment systems for PFAS removal, water systems must assess the specific PFAS present in their source water and their influent concentrations, as well as their specific source water quality, volume of water treated, existing treatment, waste management, and other regulated and unregulated contaminants of concern. Every treatment facility has different water quality goals (e.g., target concentration of specific PFAS parameters, pH, water temperature, etc.) and site-specific constraints (e.g., cost, space, sewer availability), and installation of treatment technology for removal of PFAS could require significant allocation of resources. Therefore, any treatment technique selected should be carefully designed and tailored to the specific treatment facility where it will be used.

References

374water (2025). Destruction of PFAS-Laden Ion Exchange Resin using Supercritical Water Oxidation. https://374water.com/wp-content/uploads/2026/02/White-Paper_-Destruction-of-PFAS-Laden-Ion-Exchange-Resin-using-SCWO.pdf

374water (2026). What is Supercritical Water Oxidation? Accessed March 2026. https://374water.com/technology/

Abou Khalil, C., Jiang, M., Gerges, F., Curtis, E., Chernysheva, L., Kim, J., & Doudrick, K. (2026). A Critical Review and Meta-Analysis of the Occurrence and Fate of Per- and Polyfluoroalkyl Substances in Global Wastewater Treatment Plants. ACS ES&T Engineering. 6(2), 544 – 566. https://doi.org/10.1021/acsestengg.5c00648

Albers, C.N. & Sültenfuss, J. (2024). A 60-Year Increase in the Ultrashort-Chain PFAS Trifluoroacetate and Its Suitability as a Tracer for Groundwater Age. Environmental Science & Technology Letters. 11 (10), 1090-1095. https://doi.org/10.1021/acs.estlett.4c00525

Appleman, T. D., Higgins, C. P., Quiñones, O., Vanderford, B. J., Kolstad, C., Zeigler-Holady, J. C., & Dickenson, E. R. V. (2013). Treatment of poly- and perfluoroalkyl substances in U.S. full-scale water treatment systems. Water Research. 51, 246 – 255. https://doi.org/10.1016/j.watres.2013.10.067

Arp, H. P. H., Gredelj, A., Glüge, J., Scheringer, M., & Cousins, I. T. (2024). The Global Threat from the Irreversible Accumulation of Trifluoroacetic Acid (TFA). Environmental Science & Technology. 58 (45), 19925 – 19935. https://doi.org/10.1021/acs.est.4c06189

ATSDR (2000). Agency for Toxic Substances and Disease Registries. Health Consultation. Evaluation of per-and polyfluoroalkyl substances (PFAS) detected in private residential drinking water wells located within 1 mile of the Pease International Tradeport. February 24, 2022. https://www.atsdr.cdc.gov/HAC/pha/pease/PeaseAFB-HC-508.pdf

Aquarden (2024). SuperOx® – Complete Destruction of Toxins. https://aquarden.com/wp-content/uploads/2024/07/Aquarden_Brochure_2024-singlepages.pdf

Axine Water Technologies (2026). electraCLEAR™ – Redefining Electrochemical Oxidation. Accessed March 2026. https://axinewater.com/solutions/technology/

Bălan, S.A., Mathrani, V.C., Guo, D.F., & Algazi, A.M. (2021). Regulating PFAS as a Chemical Class under the California Safer Consumer Products Program. Environmental Health Perspectives. 129, 25001. https://ehp.niehs.nih.gov/doi/epdf/10.1289/EHP7431

Bargeman, G. (2023). Maximum allowable retention for low-salt-rejection reverse osmosis membranes and its effect on concentrating undersaturated NaCl solutions to saturation. Separation and Purification Technology. 317, 123854. https://doi.org/10.1016/j.seppur.2023.123854

Berg, C., Crone, B., Gullett, B., Higuchi, M., Krause, M. J., Lemieux, P. M., Martin, T., Shields, E. P., Struble, E., Thomas, E., & Whitehill, A. (2022). Developing innovative treatment technologies for PFAS-containing wastes. Journal of the Air & Waste Management Association. 72(6), 540–555. https://doi.org/10.1080/10962247.2021.2000903

Bil, W., Zeilmaker, M., Fragki, S., Lijzen, J., Verbruggen, E., & Bokkers, B. (2021). Risk Assessment of Per- and Polyfluoroalkyl Substance Mixtures: A Relative Potency Factor Approach. Environmental Toxicology and Chemistry. 40, 859-870. https://doi.org/10.1002/etc.4835

Bil, W., Zeilmaker, M.J., Bokkers, & B.G.H. (2022). Internal Relative Potency Factors for the Risk Assessment of Mixtures of Per- and Polyfluoroalkyl Substances (PFAS) in Human Biomonitoring. Environ Health Perspectives. 130, 77005. https://ehp.niehs.nih.gov/doi/epdf/10.1289/EHP10009

Bil, W., Ehrlich, V., Chen, G., Vandebriel, R., Zeilmaker, M., Luijten, M., Uhl, M., Marx-Stoelting, P., Halldorsson, T. I., & Bokkers, B. (2023). Internal relative potency factors based on immunotoxicity for the risk assessment of mixtures of per- and polyfluoroalkyl substances (PFAS) in human biomonitoring. Environment International. 171, 107727. https://www.sciencedirect.com/science/article/pii/S0160412022006547

Björnsdotter, M. K., Yeung, L., W. Y., Kärrman, A., & Jogsten, I. E. (2020). Challenges in the analytical determination of ultra-short-chain perfluoroalkyl acids and implications for environmental and human health. Analytical and Bioanalytical Chemistry. 412, 4785–4796. https://doi.org/10.1007/s00216-020-02692-8

Buckley, T., Karanam, K. Xu, X., Shukla, P., Firouzi, M., Rudolph, V. (2022). Effect of mono- and di-valent cations on PFAS removal from water using foam fractionation – A modelling and experimental study. Separation and Purification Technology. 286, 120508. https://doi.org/10.1016/j.seppur.2022.120508

CalEPA (2024). California Environmental Protection Agency. Public Health Goals. Perfluorooctanoic Acid and Perfluorooctane Sulfonic Acid in Drinking Water. March 2024. https://oehha.ca.gov/media/downloads/air/public-health-goal-document/pfoapfosphgfinaldraft040524.pdf

CA Assembly (2022). California Assembly Bill 178. https://legiscan.com/CA/text/AB178/id/2600061

Carollo Engineers. (2023). City of Thorton: WES BROWN WTP AND THORNTON WTP PFAS STUDY. July 2023. https://solicitations.thorntonco.gov/files/filerecords/view/solicitationattachment/21135/attachment-a---thornton-pfas-study.pdf

CA Water Board (2024a). California State Water Resources Control Board. Comments on Analytical Methods for Unregulated Contaminant Monitoring Rule 6. Submitted to USEPA. April 5, 2024. Posted at https://www.regulations.gov/comment/EPA-HQ-OW-2023-0469-0087

CA Water Board (2024b). California State Water Resources Control Board. Broad-Spectrum Per- and Polyfluoroalkyl Substances (PFAS) Method Comparison Study Results and Selection of Broad-Spectrum Methods to Support Statewide Monitoring for the Class of PFAS. April 24, 2024. https://www.waterboards.ca.gov/pfas/docs/broad-spectrum-pfas-method-comparison-study-summary-combined.pdf

CFPUA (2026). Cape Fear Public Utility Authority. Drinking Water Quality. Accessed March 2026. https://www.cfpua.org/692/Drinking-Water-Quality

CFR (2026). Code of Federal Regulations. Title 40: Chapter I – Subchapter N—Part 403—§ 403.3. Last updated March 3, 2026. https://www.ecfr.gov/current/title-40/chapter-I/subchapter-N/part-403/section-403.3

Chiang, D., Laing, S., Casson, R., Mora, R., & Q. Huang. (2018). Applications of Electrochemical Oxidation for PFAS Destruction in Water, Liquid and Solid Wastes. Battelle Conference, Palm Springs, CA. https://www.battelle.org/docs/default-source/conferences/chlorinated-conference/proceedings/2018-chlorinated-conference-proceedings/a9-pfas-remediation/1176.pdf?sfvrsn=42168188_0

Chiang, S. D., Saba, M., Leighton, M., Ballenghien, D., Hatler, D., Gal, J., & Deshusses, M. A. (2023). Supercritical water oxidation for the destruction of spent media wastes generated from

PFAS treatment. Journal of Hazardous Materials. 460, 132264. https://doi.org/10.1016/j.jhazmat.2023.132264

Chong, M., Zhou, Q., Xu, J., Wu, Z., Zhu, E., Li, W. Zhang, L., Guo, Y., & Zu, Y. (2026). Complete defluorination of PFASs via photocatalytic reduction in water. Nature Communications. https://doi.org/10.1038/s41467-026-69933-9

Colorado Water Quality Control Commission (2020). Water Quality Control Commission. Policy 20-1. Policy for Interpreting the Narrative Water Quality Standards for Per- and Polyfluoroalkyl Substances (PFAS). 5 CCR 1002-31, Section 31.11(1)(a)(iv) and 5 CCR 1002-41, Section 41.5(A)(1). Approved: July 14, 2020. Expires: July 31, 2025. https://drive.google.com/file/d/119FjO4GZVaJtw7YFvFqs9pmlwDhDO_eG/view?pli=1

Cousins, I. T., DeWitt, J. C., Glüge, J., Goldenman, G., Herzke, D., Lohmann, R., Ng, C. A., Scheringer, M., & Wang, Z. (2020a). The high persistence of PFAS is sufficient for their management as a chemical class. Environmental Science. Processes & Impacts. 22, 2307–2312. https://doi.org/10.1039/d0em00355g

Cousins, I. T., DeWitt, J. C., Glüge, J., Goldenman, G., Herzke, D., Lohmann, R., Miller, M., Ng, C. A., Scheringer, M., Vierke, L., & Wang, Z. (2020b). Strategies for grouping per- and polyfluoroalkyl substances (PFAS) to protect human and environmental health. Environmental Science. Processes & Impacts. 22, 1444–1460. https://pubs.rsc.org/en/content/articlehtml/2020/em/d0em00147c

Delaware House of Representatives (2021). 151st General Assembly. House Bill No. 8. An Act to amend Title 29 of the Delaware Code relating to drinking water. https://legiscan.com/DE/text/HB8/id/2413483

Denmark Ministry of the Environment (2023). Decree on water quality and supervision of water supply facilities. https://www.retsinformation.dk/eli/lta/2023/1023

DWQI (2015a). New Jersey Drinking Water Quality Institute. Health-Based Maximum Contaminant Level Support Document: Perfluorononanoic Acid (PFNA). June 22, 2015. https://www.nj.gov/dep/watersupply/pdf/pfna-health-effects.pdf

DWQI (2015b). New Jersey Drinking Water Quality Institute. Recommendation on Perfluorinated Compound Treatment Options for Drinking Water. June 2015. https://www.state.nj.us/dep/watersupply/pdf/pfna-pfc-treatment.pdf

DWQI (2016). New Jersey Drinking Water Quality Institute. Addendum to Appendix C: Recommendation on Perfluorinated Compound Treatment Options for Drinking Water New Jersey Drinking Water Quality Institute Treatment Subcommittee. August 2016. https://www.nj.gov/dep/watersupply/pdf/pfoa-appendixc.pdf

DWQI (2017a). New Jersey Drinking Water Quality Institute. Health-Based Maximum Contaminant Level Support Document: Perfluorooctanoic Acid (PFOA). February 15, 2017. https://www.state.nj.us/dep/watersupply/pdf/pfoa-appendixa.pdf

DWQI (2017b). New Jersey Drinking Water Quality Institute. Second Addendum to Appendix C: Recommendation on Perfluorinated Compound Treatment Options for Drinking Water. November 2017b. https://www.state.nj.us/dep/watersupply/pdf/pfos-recommendation-appendix-c.pdf

DWQI (2018a). New Jersey Drinking Water Quality Institute. Health-Based Maximum Contaminant Level Support Document: Perfluorooctane Sulfonate (PFOS). June 5, 2018. https://www.state.nj.us/dep/watersupply/pdf/pfos-recommendation-appendix-a.pdf

DWQI (2022). New Jersey Drinking Water Quality Institute. Review of Interim USEPA Health Advisories for PFOA and PFOS and Other Relevant Information. December 2, 2022. https://www.nj.gov/dep/watersupply/pdf/dwqi-health-effects-pfas-report.pdf

DWQI (2025). New Jersey Drinking Water Quality Institute. Health Effects Subcommittee review of internal assessment report for regulating PFAS as an entire class or subclass/mixture. Memorandum from J. Gleason, Health Effects Subcommittee chair, to Phoebe Stapleton, DWQI chair. July 1, 2025. https://dspace.njstatelib.org/items/d3d30e37-91b9-42cb-a107-7d909992a6e2

E2metrix. (2026). Obreak^{TM} Electrooxidation. Accessed March 2026. https://e2metrix.com/products-solutions/onsite-pfas-destruction-electrochemical-oxidation-eo/

ECHA (2020). European Chemicals Agency. Consultation on a proposed restriction on the manufacture, placing on the market and use of per- and polyfluoroalkyl substances (PFAS) https://echa.europa.eu/documents/10162/cad38c27-ede8-2268-00c6-939ea066743c

ECOS (2025). Environmental Council of the States. Compendium of State PFAS Actions. April 2025. https://www.ecos.org/wp-content/uploads/2025/04/ECOS-PFAS-Compendium-FINAL.pdf

EU (2020). Directive (EU) 2020/2184 of the European Parliament and of the Council of 16 December 2020 on the quality of water intended for human consumption (recast). https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32020L2184

EU (2024). European Union. Technical guidelines regarding methods of analysis for monitoring of per- and polyfluoroalkyl substances (PFAS) in water intended for human consumption (C/2024/4910). Official Journal of the European Union. July 8, 2024. https://eur-lex.europa.eu/eli/C/2024/4910/oj

Eurofins (undated). PFAS Analyte List. https://www.eurofinsus.com/environment-testing/pfas-testing/pfas-analyte-lists/

Forrester, E. & Bostardi, C. (2019). PFAS Treatment: GAC vs IX. Calgon Carbon. https://www.calgoncarbon.com/app/uploads/Calgon-PFAS-Webinar-4.26.2019.pdf

FOSAN (2023). Foundation for the Study of Food and Nutrition. Solvay, activated carbon to contain PFAS. https://www.fosan.org/solvay-carboni-attivi-per-contenere-i-pfas/

Greico, S. A. (2021). Implementing Granular Activated Carbon Systems: Important Design And Start-Up Considerations. Water Online. https://www.wateronline.com/doc/implementing-granular-activated-carbon-systems-important-design-and-start-up-considerations-0001

Hammel, E., Webster, T. F., Gurney, R., & Heiger-Bernays, W. (2022). Implications of PFAS definitions using fluorinated pharmaceuticals. iScience*. 25*(4), 104020. https://www.sciencedirect.com/science/article/pii/S2589004222002905

Harrill, A. H., Hagiwara, S., Weitekamp, C. A., Stanish, P. C., Wall, J. T., Sayre, R. R., Davidson-Fritz, S. E., Vitense, K., Chang, D. T., Devito, M. J., Gonzales, C. J., Groover, M., Hughes, M. F., Judson, R. S., Lambert, J. C., Lowe, C. N., Mutlu, E., Friedman, K. P., Watkins, A. M., Williams, A. J., … Thomas, R. S. (2026). Database-calibrated toxicity values for human health assessment based on existing toxicology data for one thousand chemicals. Journal of toxicology and environmental health. Part B, Critical reviews. 29(2), 128–167. https://doi.org/10.1080/10937404.2025.2552108

Hazen and Sawyer (2024). Electrochemical Oxidation Pilot Study Explores New Frontiers for PFAS Destruction. https://www.hazenandsawyer.com/projects/electrochemical-oxidation-pilot-study-explores-new-frontiers-for-pfas-destruction

He, Y., Tan, X., Chunrong, Y., Liu, K., Zhou, C., Zhu, Y., Leung, L., Breske, S., Hopkins, T. E., Tottszer, A., Matheson, A., Whittaker, A. K., & Zhang, C. (2025). Capturing PFAS with Partly Fluorinated Macromolecules: The Influence of the Fluorinated Group Structure. Macromolecules. 58 (14), 7050–7061. https://doi.org/10.1021/acs.macromol.5c01012

Health Canada (2024). Objective for Canadian Drinking Water Quality Per- and Polyfluoroalkyl Substances. https://www.canada.ca/content/dam/hc-sc/documents/services/publications/healthy-living/objective-drinking-water-quality-per-polyfluoroalkyl-substances/objective-for-canadian-drinking-water-quality-en-final.pdf

HIDOH (2024). Hawaii Department of Health. Interim PFAS Guidance. Attachment 1 of *Interim Soil and Water Environmental Action Levels (EALs) for Perfluoroalkyl and Polyfluoroalkyl Substances (PFASs)*. April 12, 2024. https://health.hawaii.gov/heer/files/2024/04/PFAS-Update-signed-April-2024.pdf

Inside PFAS Policy (2024). Amid Struggle, Maine Narrows PFAS Reporting, Reworks Product Bans. April 26, 2024. https://insideepa.com/pfas-news/amid-struggle-maine-narrows-pfas-reporting-reworks-product-bans

Integral Consulting (2025). Focused Preliminary Assessment PFAS and Alternative PFAS Solvay Specialty Polymers USA, LLC (now known as Syensqo Specialty Polymers USA, LLC) 10 Leonard Lane West Deptford, NJ 08086 Program Interest No: 015010. September 2025. https://www.syensqo.com/sites/g/files/alwlxe161/files/2025-10/202509-Final-PA-Report.pdf

ITRC (2026). Interstate Technology & Regulatory Council. PFAS Technical and Regulatory Guidance Document and Fact Sheets, PFAS-1. Washington, D.C.: Interstate Technology & Regulatory Council, PFAS Team. https://pfas-1.itrcweb.org/ Last updated January 2026.

IUPAC. (2026). International Union of Pure and Applied Chemistry. 'biodegradation' in IUPAC Compendium of Chemical Terminology, 5th ed. Accessed March 2026. https://doi.org/10.1351/goldbook.B00656

Jama, Y., Lindholst, S., Andreasen, R. R., Andersen, H. R., Kokkoli, A., Svendsen, T., Cai, Z., & Kragelund, C. (2020). PFAS removal from percolate by super critical water oxidation (SCWO). 14th DWF Water Research Conference. University of Copenhagen. https://backend.orbit.dtu.dk/ws/portalfiles/portal/206539723/DWF_Abstract_catalogue_and_time_table_2020.pdf

Kempisty, D. M., Gordon, C., Haxen, J., Mowla, O., Nickelsen, M. G., & Woodard, S. (2024). THE TREATMENT OF PFAS-IMPACTED GROUNDWATER USING NOVEL REGENERABLE ION EXCHANGE RESIN: A FIVE-YEAR CASE STUDY. Australian Water Association. 10(3). https://montrose-env.com/wp-content/uploads/2017/09/RIEX_Water_E-journal_August_2024-1.pdf

Kim, J., Xin, X., Mamo, B. T., Hawkins, G. L., Li, K., Chen, Y., Huang, Q., & Huang, C. H. (2022) Occurrence and fate of ultrashort-chain and other per-and polyfluoroalkyl substances (PFAS) in wastewater treatment plants. ACS ES&T Water. 2 (8), 1380– 1390. https://doi.org/10.1021/acsestwater.4c00541

Kim, J., Xin, X., Hawkins, G. L., Huang, Q., & Huang, C. (2024). Occurrence, Fate, and Removal of Per- and Polyfluoroalkyl Substances (PFAS) in Small- and Large-Scale Municipal Wastewater Treatment Facilities in the United States. ACS EST Water. 4 (12), 5428–5436. https://doi.org/10.1021/acsestwater.4c00541

Kirchen, F., Fundneider, T., & Lackner, S. (2024). Implications of the operation of continuous granular activated carbon filters on the effluent quality. Water Science Technology. 89(11), 3079 – 3092. https://doi.org/10.2166/wst.2024.178

Kirkwood-Donelson, K. I., Dodds, J. N., Schnetzer, A., Hall, N., & Baker, E. S. (2023). Uncovering per- and polyfluoroalkyl substances (PFAS) with nontargeted ion mobility spectrometry-mass spectrometry analyses. Science Advances. 9(43), eadj7048. https://www.science.org/doi/pdf/10.1126/sciadv.adj7048

Krause, M., Magnuson, M., & Crone, B. (2021) Potential PFAS destruction technology: electrochemical oxidation. United States Environmental Protection Agency Research Brief. https://www.epa.gov/sites/default/files/2021-01/documents/pitt_research_brief_electrochemical_oxidation_final_jan_25_2021_508.pdf

Krause, M. J., Thoma, E., Sahle-Demessie, E., Crone, B., Whitehill, A., Shields, E., & Gullett, B. (2021). Supercritical Water Oxidation as an Innovative Technology for PFAS Destruction. Journal of Environmental Engineering (New York, N.Y.). 148(2), 1–8. https://doi.org/10.1061/(asce)ee.1943-7870.0001957

Kwiatkowski, C. F., Andrews, D. Q., Birnbaum, L. S., Bruton, T. A., DeWitt, J. C., Knappe, D. R. U., Maffini, M. V., Miller, M. F., Pelch, K. E., Reade, A., Soehl, A., Trier, X., Venier, M., Wagner, C. C., Wang, Z., & Blum, A. (2020). Scientific Basis for Managing PFAS as a Chemical Class. Environmental Science & Technology Letters. 7, 532–543. https://pubs.acs.org/doi/10.1021/acs.estlett.0c00255

LANXESS (2024). LANXESS Deutschland GmbH. Efficient PFAS Removal with Selective Lewatit®: Ion Exchange Resins Product Information and Operational Guidelines. https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwjaxvrr7Y6TAxUvjokEHbjZM34QFnoECA0QAQ&url=https%3A%2F%2Flanxess.com%2F-%2Fmedia%2Fproject%2Flanxess%2Fcorporate-internet%2Fproducts-and-solutions%2Fbrands%2Flewatit%2Fservice-center-product-literature%2Fbrochure_lewatit_pfas_removal_en_2024.pdf&usg=AOvVaw0UsIHs_bVM0i4Ecb5qOAt4&opi=89978449

Li, G., Peng, M., Huang, Q., Huang, C., Chen, Y., Hawkins, G., & Li, K. (2025). A review on the recent mechanisms investigation of PFAS electrochemical oxidation degradation: mechanisms, DFT calculation, and pathways. Frontiers in Environmental Engineering. 4. https://doi.org/10.3389/fenve.2025.1568542

Liu, C. J., Strathmann, T. J., & Bellona, C. (2021). Rejection of per- and polyfluoroalkyl substances (PFASs) in aqueous film-forming foam by high-pressure membranes. Water Research. 188, 116456. https://doi.org/10.1016/j.watres.2020.116546

Ma, Q., Lei, Q., Liu, F., Song, Z., Khusid, B., & Zhang, W. (2023). Evaluation of commercial nanofiltration and reverse osmosis membrane filtration to remove per-and polyfluoroalkyl substances (PFAS): Effects of transmembrane pressures and water matrices. Water Research. 96 (2), e10983. https://doi.org/10.1002/wer.10983

Maine legislature (2021). S.P. 64 - L.D. 129. Resolve, To Protect Consumers of Public Drinking Water by Establishing Maximum Contaminant Levels for Certain Substances and Contaminants. Approved by Governor. June 21, 2021. https://www.mainelegislature.org/legis/bills/getPDF.asp?paper=SP0064&item=3&snum=130

Mayerberger, E., Rodriguez, A., Townsend, E., DiStefano, R., Alward, R., & Matthis, J. (2025). Destruction of PFAS During Thermal Reactivation of Granular Activated Carbon Used in Potable Water Treatment. Remediation Journal. 35(4). https://doi.org/10.1002/rem.70030

McCord, J. P., Strynar, M. J., Washington, J. W., Bergman, E. L., & Goodrow, S. M. (2020). Emerging Chlorinated Polyfluorinated Polyether Compounds Impacting the Waters of Southwestern New Jersey Identified by Use of Nontargeted Analysis. Environmental Science & Technology Letters. 7(12), 903–908. https://pubs.acs.org/doi/10.1021/acs.estlett.0c00640

McDonough, C. A., Guelfo, J. L., & Higgins, C. P. (2019). Measuring Total PFASs in Water: The Tradeoff between Selectivity and Inclusivity. Current Opinion in Environmental Science & Health. 7, 13–18. https://www.sciencedirect.com/science/article/abs/pii/S2468584418300515

MADEP (2019). Technical Support Document - Per- and Polyfluoroalkyl Substances (PFAS): An Updated Subgroup Approach to Groundwater and Drinking Water Values. December 26, 2019. https://www.mass.gov/doc/per-and-polyfluoroalkyl-substances-pfas-an-updated-subgroup-approach-to-groundwater-and/download

MDH (2020). Minnesota Department of Health. Evaluating Concurrent Exposures to Multiple Chemicals. Updated October 3, 2022. Accessed May 7, 2024. https://www.health.state.mn.us/communities/environment/risk/guidance/gw/additivity.html#:~:text=The%20MDH%20Water%20Guidance%20and,based%20guidance%20for%20that%20chemical

MDH (2024a). Minnesota Department of Health. Toxicological Summary for: Perfluorooctanoate. January 2024. https://www.health.state.mn.us/communities/environment/risk/docs/guidance/gw/pfoa2024.pdf

MDH (2024b). Minnesota Department of Health. Toxicological Summary for: Perfluorooctane sulfonate. February 2024. https://www.health.state.mn.us/communities/environment/risk/docs/guidance/gw/pfos.pdf

MDH (2024c). Minnesota Department of Health. Human Health-Based Water Guidance Table. Last updated May 6, 2024. https://www.health.state.mn.us/communities/environment/risk/guidance/gw/table.html

MEDEP (2024). Maine Department of Environmental Protection. PFAS in Products. Accessed May 7, 2024. https://www.maine.gov/dep/spills/topics/pfas/PFAS-products/

Miatke, B. (2025). Foam Fractionation Overview and Applications for PFAS Water Treatment. New England Water Environment Association (NEWEA) Spring Conference. https://www.newea.org/wp-content/uploads/2025/05/6_SM25_BMiatke.pdf

Meegoda, J. N., Bezerra de Souza, B., Casarini, M. M., & Kewalramani, J. A. (2022). A Review of PFAS Destruction Technologies. International Journal of Environmental Research and Public Health. 19(24), 16397. https://doi.org/10.3390/ijerph192416397

MI EGLE (2025). Michigan Department of Environment, Great Lakes, and Energy. MICHIGAN INDUSTRIAL PRETREATMENT PROGRAM (IPP) PFAS INITIATIVE: Identified Industrial Sources of PFOS to Municipal Wastewater Treatment Plants. https://www.michigan.gov/-/media/Project/Websites/egle/Documents/Programs/WRD/IPP/pfas-ipp-intiative-identified-sources.pdf?rev=5dece57600dc4982a38ebc67a5b12471

MPCA (undated). PFAS in Product. Accessed May 7, 2024. https://www.pca.state.mn.us/get-engaged/pfas-in-products

MPCA. (2023). Minnesota Pollution Control Agency. Evaluation of Current Alternatives and Estimated Cost Curves for PFAS Removal and Destruction from Municipal Wastewater, Biosolids, Landfill Leachate, and Compost Contact Water. https://www.pca.state.mn.us/sites/default/files/c-pfc1-26.pdf

Murray, C. C., Marshall, R. E., Liu, C. J., Vatankhah, H., & Bellona, C. L. (2021). PFAS treatment with granular activated carbon and ion exchange resin: Comparing chain length, empty bed contact time, and cost. Journal of Water Process Engineering. 44, 102342. https://doi.org/10.1016/j.jwpe.2021.102342

Murray, C. & Mohan, G.R. (2025). Beyond the PFAS treatment Barrier: Key Lessons from an 18-Month Pilot on PFAS removal from Wastewater. Water Environment Federation. Conference Proceeding. https://files.aievolution.com/prd/wef2501/events/33389/1430_3_MURRAY_1163.pdf

Mustafa, K., de Falco, G., Fernando, E., Boufadel, M. C., Zhang, Z., & Sarkar, D. (2025a). Assessing PFAS and Their Precursor Transformation in a Landfill Leachate-Impacted Wastewater Treatment Plant. Water Environment Research. 97, 70172. https://doi.org/10.1002/wer.70172

Mustafa, K., de Falco, G., Zhang, Z., Fernando, E., Boufadel, M. C., & Sarkar, D. (2025b). From Home to Hazard: Tracking PFAS From Residential Wastewater Through Wastewater Treatment Sludge to Sludge-Derived Ash. Water Environment Research. 97, 70214. https://doi.org/10.1002/wer.70214

Nakazawa, Y., Kosaka, K., Yoshida, N., Asami, M., & Matsui, Y. (2023). Long-term removal of perfluoroalkyl substances via activated carbon process for general advanced treatment purposes. Water Research. 245, 120559. https://doi.org/10.1016/j.watres.2023.120559

Neuwald, I. J., Hübner, D., Wiegand, H. L., Valkov, V., Borchers, U., Nödler, K., Scheurer, M., Hale, S. E., Arp, H. P. H., & Zahn, D. (2022). Ultra-Short-Chain PFASs in the Sources of German Drinking Water: Prevalent, Overlooked, Difficult to Remove, and Unregulated. Environmental Science & Technology. 56(10), 6380–6390. https://pubs.acs.org/doi/10.1021/acs.est.1c07949

Newton, D. and Linck, W. (2025). PFAS Broad Spectrum Project – California Water Boards. Presented at New Jersey PFAS Summit. New Jersey Institute of Technology, Newark, NJ. October 10, 2025. Posted at: https://dep.nj.gov/wp-content/uploads/pfas-summit/pfas-summit-day-2.pptx

NJDEP (2004). New Jersey Department of Environmental Protection. Opportunity for Public Comment on possible regulatory strategies to address the occurrence of unregulated organic contaminants in drinking water. (Notice requesting public comment published in New Jersey Register 36 (3), February 2, 2004) https://hdl.handle.net/10929/154235

NJDEP (2007). Determination of Perfluorooctanoic Acid (PFOA) in Aqueous Samples, Final Report, January 2007. http://www.nj.gov/dep/watersupply/final_pfoa_report.pdf

NJDEP (2014). New Jersey Department of Environmental Protection. Occurrence of Perfluorinated Chemicals in Untreated New Jersey Drinking Water Sources Final Report. April 2014. http://www.nj.gov/dep/watersupply/pdf/pfc-study.pdf

NJDEP SAB (2020). New Jersey Department of Environmental Protection Science Advisory Board. Approaches for Addressing Drinking Water and Wastewater Contaminants of Emerging Concern (CECs) in a Broader Context: Identification, Ranking and Treatment Removal. April 22, 2020. https://dep.nj.gov/wp-content/uploads/sab/sab-cec-2020.pdf

NJDEP (2021). New Jersey Department of Environmental Protection. Technical Support Document: Interim Specific Ground Water Quality Criterion for Chloroperfluoropolyether Carboxylates (CAS Numbers 220182-27-4, 220207-15-8, 330809-92-2, and 329238-24-6). October 20, 2021. https://dep.nj.gov/wp-content/uploads/dsr/clpfpecas-tsd.pdf

NJDEP (2022). New Jersey Department of Environmental Protection. Public comment on: *PFOS and PFOA in Drinking Water, Draft background document for development of World Health Organization (WHO) Guidelines for Drinking Water Quality*. Submitted November 11, 2022. https://dep.nj.gov/wp-content/uploads/dsr/njdep-comments-who-pfas-guidelines.pdf

NJDEP (2023). New Jersey Department of Environmental Protection. Interim Specific Ground Water Quality Criterion (ISGWQC) for hexafluoropropylene oxide dimer acid (HFPO-DA) and its ammonium salt (GenX chemicals). Memorandum from G. Post to M. Kuserk. May 24, 2023. Amended July 17, 2025. https://dep.nj.gov/wp-content/uploads/dsr/hfpo-da-genx-tsd.pdf

NJDEP (2025). PFAS Summit Day 2. New Jersey Department of Environmental Protection. October 9, 2025. https://dep.nj.gov/pfas-summit/pfas-summit-materials/

NJDEP (2026). New Jersey Department of Environmental Protection. Per- and Polyfluoroalkyl Substances (PFAS) Research. Last updated March 12, 2026. https://dep.nj.gov/dsr/pfas/

NJDOH (2024). New Jersey Department of Health. Drinking Water Facts: Per- and Polyfluoroalkyl Substances (PFAS) in Drinking Water. https://www.nj.gov/health/ceohs/documents/pfas_drinking%20water.pdf Last updated April 2024.

Norit (2025). NORIT® GAC 400. https://norit.com/hubfs/2025_NRT_Product%20Bulletin_GAC%20400_06.09.2025.pdf?hsLang=en

NSF (2026). National Sanitation Foundation. PFAS in Drinking Water. https://www.nsf.org/consumer-resources/articles/pfas-drinking-water

OECD (2021). Organisation for Economic Co-operation and Development. Reconciling Terminology of the Universe of Per- and Polyfluoroalkyl Substances: Recommendations and Practical Guidance. Series on Risk Management. No.61. https://one.oecd.org/document/ENV/CBC/MONO(2021)25/En/pdf

OHA (undated). Oregon Health Authority Per- and Polyfluoroalkyl Substances (PFAS). Accessed May 7, 2024. https://www.oregon.gov/oha/PH/HEALTHYENVIRONMENTS/DRINKINGWATER/OPERATIONS/Pages/PFAS.aspx

Ovivo Inc. (2024). Ovivo completes the acquisition of E2metrix to offer an integrated solution for destruction of PFAS in water and wastewater. PR Newswire. https://www.prnewswire.com/news-releases/ovivo-completes-the-acquisition-of-e2metrix-to-offer-an-integrated-solution-for-destruction-of-pfas-in-water-and-wastewater-302062431.html

Pelch, K. E., McKnight, T., & Reade, A. (2023). 70 analyte PFAS test method highlights need for expanded testing of PFAS in drinking water. Science of the Total Environment. 876, 162978. https://doi.org/10.1016/j.scitotenv.2023.162978

Pinkard, B., Smith, S. M., Vorarath, P., Smrz, T., Schmick, S., Dressel, L., Bryan, C., Czerski, M., de Marne, A., Halevi, A., Thomsen, C., & Woodruff, C. (2024). Degradation and Defluorination of Ultra Short-, Short-, and Long-Chain PFASs in High Total Dissolved Solids Solutions by Hydrothermal Alkaline Treatment–Closing the Fluorine Mass Balance. ACS ES&T Engineering. 4(11), 2810 – 2818. https://doi.org/10.1021/acsestengg.4c00378

Post, G.B., Louis, J.B., Lippincott, R.L., & Procopio, N.A. (2013). Occurrence of perfluorinated chemicals in raw water from New Jersey public drinking water systems. Environmental Science & Technology. 47(23), 13266-13275. https://pubs.acs.org/doi/10.1021/es402884x

Post, G.B. (2014). DEP & DWQI Work to Date on Perfluorinated Chemicals (PFCs). New Jersey Drinking Water Quality Institute. April 29, 2014. PowerPoint presentation. https://www.nj.gov/dep/watersupply/pdf/dep-dwqi-work-to-date-pfoa20140429.pdf

Post, G.B., Gleason, J.A., & Cooper, K.R. (2017). Key scientific issues in developing drinking water guidelines for perfluoroalkyl acids: Contaminants of emerging concern. PLoS Biology. 15(12), e2002855. https://journals.plos.org/plosbiology/article/file?id=10.1371/journal.pbio.2002855&type=printable

Pinkard, B., Smith, S. M., Vorarath, P., Smrz, T., Schmick, S., Dressel, L., Bryan, C., Czerski, M., de Marne, A., Halevi, A., Thomsen, C., & Woodruff, C. (2024). Degradation and Defluorination of Ultra Short-, Short-, and Long-Chain PFASs in High Total Dissolved Solids Solutions by Hydrothermal Alkaline Treatment–Closing the Fluorine Mass Balance. ACS ES&T Engineering. 4(11), 2810 – 2818. https://doi.org/10.1021/acsestengg.4c00378

Purolite (2024). PFAS-Selective Single-Use Ion Exchange Resin for Drinking Water Systems. https://www.purolite.com/dam/jcr:e7dc9abb-abeb-4363-b46a-e44f1ae4ce18/PFAS-Selective-Single-Use-IX%20Resin.pdf

Revive Environmental (2026). PFAS Annihilator®. Accessed March 2026. https://revive-environmental.com/pfas-annihilator/

RIDOH (2023). Rhode Island Department of Health. Advance Notice Of Proposed Rulemaking. Title of Rule: Public Drinking Water (216-RICR-50-05-1). https://risos-apa-production-public.s3.amazonaws.com/DOH/13079/PBN_13079_20231120151949736.pdf

Sadik, O & Osonga, F. (2025). Development of electrochemical treatment technologies for PFAS, PFOS and 1,4-Dioxane in New Jersey Drinking Water and Regional Wastewater Treatment Plants. https://hdl.handle.net/10929/145641

Safer States (2024). PFAS Definition Factsheet: Why a Strong PFAS Definition Matters. https://www.saferstates.org/resource/pfas-definition-factsheet/

Sahle-Demessie, E. & Krause, M. (2021). Potential PFAS destruction technology: supercritical water oxidation. https://www.epa.gov/sites/production/files/2021-01/documents/pitt_research_brief_scwo_final_jan_25_2021_508.pdf

Sahle-Demessie, Berg, E. C., Shields, E., Jackson, S., George, I., Liberty, K., & Follin, J. (2022). Industrial SCWO for the Treatment of PFAS/AFFF Within a Water Matrix. https://cfpub.epa.gov/si/si_public_record_Report.cfm?dirEntryId=357639&Lab=CESER

Sanzana, S., Fenti, A., Iovino, P., & Panico, A. (2025). A review of PFAS remediation: Separation and degradation technologies for water and wastewater treatment. Journal of Water Processing. 74, 107793. https://doi.org/10.1016/j.jwpe.2025.107793

Scheurer, M., Nödler, K., Freeling, F., Janda, J., Happel, O., Riegel, M., Müller, U., Storck, F. R., Fleig, M., Lange, F. T., Brunsch, A., & Brauch, H-J. (2017). Small, mobile, persistent: Trifluoroacetate in the water cycle: Overlooked sources, pathways, and consequences for drinking water supply. Water Research. 126, 460 - 471. https://doi.org/10.1016/j.watres.2017.09.045

SERDP-ESTCP. (2026). PFAS Destruction Technology Demonstrations. Strategic Environmental Research and Development Program (SERDP)- Environmental Security Technology Certification Program (ESTCP). January 29, 2026. https://serdp-estcp.mil/webinars/details/769989f0-28df-43c4-b69c-29a005d98184

Smith, S. J., Wiberg, K., McCleaf, P., & Ahrens, L. (2022). Pilot-Scale Continuous Foam Fractionation for the Removal of Per- and Polyfluoroalkyl Substances (PFAS) from Landfill Leachate. ACS EST Water. 2(5), 841–851. https://doi.org/10.1021/acsestwater.2c00032

Smith, S. J., Lauria, M., Ahrens, L., McCleaf, P., Hollman, P., Seroka, S. B., Hamers, T., Arp, H. P. H., & Wiberg, K. (2023). Electrochemical Oxidation for Treatment of PFAS in Contaminated Water and Fractionated Foam–A Pilot-Scale Study. ACS ES&T Water. 3(4), 1201-1211. https://doi.org/10.1021/acsestwater.2c00660

Smith, M. N., Stump, S., van Bergen, S. K., Davies, H. G., Fanning, E., Eaton, R., Manahan, C. C., Sergent, A., & Zarker, K. (2024). A Hazard-Based Framework for Identifying Safer Alternatives to Classes of Chemicals: A Case Study on Phthalates in Consumer Products. Environmental Health Perspectives. 132, 45002. https://ehp.niehs.nih.gov/doi/epdf/10.1289/EHP13549

Sun, M., Arevalo, E., Strynar, M., Lindstrom, A., Richardson, M., Kearns, B., Pickett, A., Smith, C., and Knappe, D.R.U. (2016). Legacy and Emerging Perfluoroalkyl Substances Are Important Drinking Water Contaminants in the Cape Fear River Watershed of North Carolina. Environmental Science & Technology Letters. 3, 415-419. https://pubs.acs.org/doi/10.1021/acs.estlett.6b00398

Town of Wellesley, Massachusetts (2026). Frequently Asked Questions: DPW-PFAS. Accessed March 2026. https://wellesleyma.gov/m/faq?cat=28#question-198

Tshangana, C.S., Nhlengethwa, S.T., Glass, S. Denison, S., Kuvarega, A. T., Nkambule, T. T. I., Mamba, B. B., Alvarez, P. J. J., & Muleja, A. A. (2025). Technology status to treat PFAS-contaminated water and limiting factors for their effective full-scale application. npj Clean Water. 8, 41. https://doi.org/10.1038/s41545-025-00457-3

US DOE (2023). United States Department of Energy. DOE Commercial Potential Evaluation (CPE) Report // PFAS in Wastewater. https://science.osti.gov/-/media/sbir/pdf/Application_Resources/2023/CPE-PFAS-Final-Report.pdf

USEPA (1989). United States Environmental Protection Agency. Risk Assessment Guidance for Superfund Volume I Human Health Evaluation Manual (Part A). Interim Final. EPA/540/1-89/002. https://www.epa.gov/sites/production/files/2015-09/documents/rags_a.pdf

USEPA (2000). United States Environmental Protection Agency. Supplementary Guidance for Conducting Health Risk Assessment of Chemical Mixtures. EPA/630/R-00/002. EPA, Risk Assessment Forum, Washington, DC. https://ofmpub.epa.gov/eims/eimscomm.getfile?p_download_id=4486

USEPA (2009). United States Environmental Protection Agency. Long-Chain Perfluorinated Chemicals (PFCs) Action Plan. December 30, 2009. https://www.epa.gov/sites/default/files/2016-01/documents/pfcs_action_plan1230_09.pdf

USEPA (2018). United States Environmental Protection Agency. Reducing PFAS in Drinking Water with Treatment Technologies. August 23, 2018. https://www.epa.gov/sciencematters/reducing-pfas-drinking-water-treatment-technologies

USEPA (2020). United States Environmental Protection Agency. NPDES Permit No. NC0003573 - Attachment 5 Chemours, Att. J.2 Reverse Osmosis Engineering Report and Data Analysis. https://www.bing.com/ck/a?!&&p=68ed0b27d1ec168a246af9e6c3527f3c6f42a9e9ed97b5166f655c68302080ddJmltdHM9MTc2NTg0MzIwMA&ptn=3&ver=2&hsh=4&fclid=3be4afaf-14be-66cb-350e-b913157a67db&psq=Attachment+5+Chemours%2c+Att.+J.2+Reverse+Osmosis+Engineering+Report+and+Data+Analysis&u=a1aHR0cHM6Ly9kb3dubG9hZHMucmVndWxhdGlvbnMuZ292L0VQQS1IUS1PVy0yMDIxLTA1NDctMDQ1NS9hdHRhY2htZW50XzYucGRm

USEPA (2021a). United States Environmental Protection Agency. National PFAS Testing Strategy: Identification of Candidate Per- and Polyfluoroalkyl Substances (PFAS) for Testing. October 2021. https://www.epa.gov/system/files/documents/2021-10/pfas-natl-test-strategy.pdf

USEPA (2021b). United States Environmental Protection Agency. External Peer Review Draft. Draft Framework for Estimating Noncancer Health Risks Associated with Mixtures of Per- and Polyfluoroalkyl Substances (PFAS). 822D-21-003. November 2021. Posted at: https://sab.epa.gov/ords/sab/f?p=114:19:11488469483433:::19:P19_ID:975#materials

USEPA (2021c). United States Environmental Protection Agency. Multi-Industry Per- and Polyfluoroalkyl Substances (PFAS) Study – 2021 Preliminary Report. https://www.epa.gov/system/files/documents/2021-09/multi-industry-pfas-study_preliminary-2021-report_508_2021.09.08.pdf

USEPA (2022a). United States Environmental Protection Agency. Drinking Water Contaminant Candidate List 5—Final. Federal Register. 87 (281), 68060-68085. November 14, 2022. https://www.govinfo.gov/content/pkg/FR-2022-11-14/pdf/2022-23963.pdf

USEPA (2022b). United States Environmental Protection Agency. Interim Drinking Water Health Advisory: Perfluorooctanoic Acid (PFOA). CASRN 335-67-1. EPA/822/R-22/003. June 2022. https://www.epa.gov/system/files/documents/2022-06/interim-pfoa-2022.pdf

USEPA (2022c). United States Environmental Protection Agency. Interim Drinking Water Health Advisory: Perfluorooctane Sulfonic Acid (PFOS). CASRN 1763-23-1. EPA/822/R22/004. June 2022. https://www.epa.gov/system/files/documents/2022-06/interim-pfos2022.pdf

USEPA SAB (2022). United States Environmental Protection Agency Science Advisory Board. Review of EPA's Analyses to Support EPA's National Primary Drinking Water Rulemaking for PFAS. EPA-SAB-22-008. August 22, 2022. Posted at https://sab.epa.gov/ords/sab/f?p=100:12:8777962449060

USEPA (2023a). United States Environmental Protection Agency. Toxic Substances Control Act Reporting and Recordkeeping Requirements for Perfluoroalkyl and Polyfluoroalkyl Substances. Fed. Reg. 88 (195): 70516-70559. October 11, 2023. https://www.govinfo.gov/content/pkg/FR-2023-10-11/pdf/2023-22094.pdf

USEPA (2023b). United States Environmental Protection Agency. IRIS Toxicological Review of Perfluorohexanesulfonic Acid (PFHxS) and Related Salts (Public Comment and External Review Draft). EPA-635-R-23-056. Washington, DC. https://ordspub.epa.gov/ords/eims/eimscomm.getfile?p_download_id=547143

USEPA (2023c). United States Environmental Protection Agency. PFAS Drinking Water Methods: Past, Present, and Future. Small Drinking Water Systems Webinar. Presented by: Daniel R. Tettenhorst, Jenifer L. Jones, William A. Adams, and Steve Wendelken. October 31, 2023. https://cfpub.epa.gov/si/si_public_file_download.cfm?p_download_id=548207&Lab=CESER

USEPA. (2023d). United States Environmental Protection Agency. Drinking Water Treatability Database (DWTD)- Per- and Polyfluoroalkyl Substances / Ion Exchange. https://tdb.epa.gov/tdb/contaminantprocess?treatmentProcId=263654386&id=11020&treatmentName=Ion%20Exchange&contProcId=14350

USEPA (2024a). United States Environmental Protection Agency. PFAS National Primary Drinking Water Regulation. Federal Register 89 (82): 32532-32757. April 26, 2024. https://www.govinfo.gov/content/pkg/FR-2024-04-26/pdf/2024-07773.pdf

USEPA (2024b). United States Environmental Protection Agency. Final Human Health Toxicity Assessment for Perfluorooctanoic Acid (PFOA) and Related Salts. EPA Document No. 815R24006. April 2024. https://www.epa.gov/system/files/documents/2024-04/main_final-toxicity-assessment-for-pfoa_2024-04-09-refs-formatted.pdf

USEPA (2024c). United States Environmental Protection Agency. Final Human Health Toxicity Assessment for Perfluorooctane Sulfonic Acid (PFOS) and Related Salts. EPA Document No. 815R24007. April 2024. https://www.epa.gov/system/files/documents/2024-04/main_final-toxicity-assessment-for-pfos_2024-04-09-refs-formatted_508c.pdf

USEPA (2024d). United States Environmental Protection Agency. IRIS Toxicological Review of Perfluorononanoic Acid (PFNA) and Related Salts. EPA/635/R-24/031a. External Review Draft. https://ordspub.epa.gov/ords/eims/eimscomm.getfile?p_download_id=548669

USEPA (2024e). United States Environmental Protection Agency. Standard Methods for Development of EPA Transcriptomic Assessment Products (ETAPs). EPA/600/X-23/083. March 2024. https://cfpub.epa.gov/si/si_public_file_download.cfm?p_download_id=548702&Lab=CCTE

USEPA (2024f). United States Environmental Protection Agency. Unregulated Contaminant Monitoring Rule; Methods Request and Webinar. Federal Register 89 (27): 8584-8598. February 8, 2024. https://www.govinfo.gov/content/pkg/FR-2024-02-08/pdf/2024-02247.pdf

USEPA (2024g). United States Environmental Protection Agency. Frequent Questions about PFAS Methods for NPDES Permits. Updated January 31, 2024. https://www.epa.gov/cwa-methods/frequent-questions-about-pfas-methods-npdes-permits

USEPA (2024h). United States Environmental Protection Agency. Method 1621. Determination of Adsorbable Organic Fluorine (AOF) in Aqueous Matrices by Combustion Ion Chromatography (CIC). January 2024. https://www.epa.gov/system/files/documents/2024-01/method-1621-for-web-posting.pdf

USEPA (2024i). United States Environmental Protection Agency. CWA Analytical Methods for Per- and Polyfluorinated Alkyl Substances (PFAS). Updated April 18, 2024. https://www.epa.gov/cwa-methods/cwa-analytical-methods-and-polyfluorinated-alkyl-substances-pfas

USEPA (2024j). United States Environmental Protection Agency. Method 1633A. Analysis of Per- and Polyfluoroalkyl Substances (PFAS) in Aqueous, Solid, Biosolids, and Tissue Samples by LC-MS/MS. December 2024. https://www.epa.gov/system/files/documents/2024-12/method-1633a-december-5-2024-508-compliant.pdf

USEPA (2024k). United States Environmental Protection Agency. IRIS Toxicological Review of Perfluorohexanesulfonic Acid (PFHxS) and Related Salts. EPA/635/R-25/012Fa. Washington, DC. https://iris.epa.gov/static/pdfs/0705tr.pdf

USEPA (2024l). United States Environmental Protection Agency. IRIS Toxicological Review of Perfluorodecanoic Acid and Related Salts. EPA- EPA/635/R-24/172Fa. Washington, DC. Linked from https://iris.epa.gov/document/&deid=361797

USEPA (2024m). United States Environmental Protection Agency. EPA Transcriptomic Assessment Product (ETAP) for Perfluoro-3-Methoxypropanoic Acid. https://cfpub.epa.gov/si/si_public_record_Report.cfm?dirEntryId=360638&Lab=CCTE

USEPA (2024n). United States Environmental Protection Agency. Best Available Technologies and Small System Compliance Technologies for Per- and Polyfluoroalkyl Substances (PFAS) in Drinking Water. March 2024. https://www.epa.gov/system/files/documents/2024-04/2024-final-pfas-bat-ssct_final-508.pdf

USEPA (2025a). United States Environmental Protection Agency. USEPA BOSC DCAP Panel: January 16-17, 2025. https://www.epa.gov/bosc/bosc-dcap-panel-january-16-17-2025 Last updated March 26, 2025.

USEPA (2025b). United States Environmental Protection Agency. Clean Water Act Methods Update Rule 22 for the Analysis of Contaminants in Effluent. Proposed Rule. FR 90 (12), 6967-7037. January 21, 2015. https://www.federalregister.gov/documents/2025/01/21/2024-29239/clean-water-act-methods-update-rule-22-for-the-analysis-of-contaminants-in-effluent

USEPA (2026). United States Environmental Protection Agency. Occurrence Data from the Unregulated Contaminant Monitoring Rule. https://www.epa.gov/dwucmr/occurrence-data-unregulated-contaminant-monitoring-rule Last updated February 12, 2026.

Verma, S., Mezgebe, B., Hejase, C. A., Sahle-Demessie, E., & Nadagouda, M. N. (2024). Photodegradation and photocatalysis of per- and polyfluoroalkyl substances (PFAS): A review of recent progress. Next Materials. 2, 100077. https://doi.org/10.1016/j.nxmate.2023.100077

von Guten, U. (2024). Oxidation processes and me. Water Research. 253, 121148. https://doi.org/10.1016/j.watres.2024.121148

VT ANR (2020). Vermont Agency of Natural Resources. Notice of Decision Not To Adopt A Maximum Contaminant Level Regulating PFAS as a Class in Public Drinking Water Systems. April 2021. https://dec.vermont.gov/sites/dec/files/PFAS/PFAS-MCL-Final-Decision.pdf

VT DEC (2020). Vermont Department of Environmental Conservation. Per and Polyfluoroalkyl Substances (PFAS) & Drinking Water. https://dec.vermont.gov/water/drinking-water/water-quality-monitoring/pfas#:~:text=In%202019%2C%20Act%2021%20(S,PFAS%20levels%20in%20drinking%20water

VT DOH (2018). Vermont Department of Health. Drinking Water Health Advisory for Five PFAS (per- and polyfluorinated alkyl substances). July 10, 2018. https://www.healthvermont.gov/sites/default/files/documents/pdf/ENV_DW_PFAS_HealthAdvisory.pdf

Wang, Z., DeWitt, J. C., Higgins, C. P., & Cousins, I. T. (2017). A Never-Ending Story of Per- and Polyfluoroalkyl Substances (PFASs)?. Environmental Science & Technology. 51(5), 2508–2518. https://pubs.acs.org/doi/10.1021/acs.est.6b04806

Wang, L., He, J., Heiranian, M., Fan, H., Song, L., Li, Y., Elimelech, M. (2023). Water transport in reverse osmosis membranes is governed by pore flow, not a solution-diffusion mechanism. Science Advances. 9(15). https://doi.org/10.1126/sciadv.adf8488

Washington, J. W., Rosal, C. G., McCord, J. P., Strynar, M. J., Lindstrom, A. B., Bergman, E. L., Goodrow, S. M., Tadesse, H. K., Pilant, A. N., Washington, B. J., Davis, M. J., Stuart, B. G., Jenkins, T. M. (2020). Nontargeted mass-spectral detection of chloroperfluoropolyether carboxylates in New Jersey soils. Science (New York, N.Y.). 368(6495), 1103–1107. https://www.science.org/doi/10.1126/science.aba7127

We, A., Zamyadi, A., Stickland, A. D., Clarke, B. O., & Freguia, S. (2024). A review of foam fractionation for the removal of per- and polyfluoroalkyl substances (PFAS) from aqueous matrices. Journal of Hazardous Materials. 465, 133182. https://doi.org/10.1016/j.jhazmat.2023.133182

We, A., Stickland, A. D., Clarke, B. O., & Freguia, S. (2025). PFAS removal through foam harvesting during wastewater aeration. Journal of Hazardous Materials. 491, 137936. https://doi.org/10.1016/j.jhazmat.2025.137936

Willett, A. (2023). Drinking Water Treatment System Design for PFAS Removal with FLUORO-SORB Adsorbent. Langan Engineering. https://www.newea.org/wp-content/uploads/2023/09/CEC23_AWillett.pdf

Williams, A. J., Gaines, L. G. T., Grulke, C. M., Lowe, C. N., Sinclair, G. F. B., Samano, V., Thillainadarajah, I., Meyer, B., Patlewicz, G., Richard, A. M. (2022). Assembly and curation of lists of per- and polyfluoroalkyl substances (PFAS) to support environmental science research. Frontiers in Environmental Science. 10, 1–13. https://www.frontiersin.org/articles/10.3389/fenvs.2022.850019/full

Wood, R. J., Sidnell, T., Ross, I., McDonough, J., Lee, J., & Bussemaker, M. J. (2020). Ultrasonic degradation of perfluorooctane sulfonic acid (PFOS) correlated with sonochemical and sonoluminescence characterization. Ultrasonics Sonochemistry. 68, 105196. https://doi.org/10.1016/j.ultsonch.2020.105196

WQA (2013). Water Quality Association. GRANULAR ACTIVATED CARBON (GAC) FACT SHEET. https://wqa.org/wp-content/uploads/2022/09/2016_GAC.pdf

Zeidabadi, F. A., Esfahani, E. B., & Mohseni, M. (2023). Effects of water matrix on per- and polyfluoroalkyl substances (PFAS) treatment: Physical-separation and degradation processes – A review. Journal of Hazardous Materials Advances. 10, 100322. https://doi.org/10.1016/j.hazadv.2023.100322

Zheng, G., Eick, S. M., & Salamova, A. (2023). Elevated Levels of Ultrashort- and Short-Chain Perfluoroalkyl Acids in US Homes and People. Environmental Science & Technology. 57 (42), 15782 – 15793. https://doi.org/10.1021/acs.est.2c06715