PFAS in the Commonwealth of Massachusetts

FINAL REPORT OF THE PFAS INTERAGENCY TASK FORCE

APRIL 2022

LETTER FROM THE CO-CHAIRS

As we continue to face the challenges of the COVID-19 pandemic and the climate crisis, it is more urgent than ever to address issues of emerging public health and environmental concern. Per- and polyfluoroalkyl substances (PFAS), colloquially known as "forever chemicals," are a class of environmentally persistent chemicals associated with a range of adverse health effects. PFAS are widely used in industrial applications and in end products, such as non-stick cookware, water-repellent clothing, and firefighting foam. Due to their widespread use and disposal, PFAS have been detected in our drinking water, groundwater, rivers, soil, wastewater, and other environmental media that can put our health at risk.

As legislators, we first learned about PFAS when the chemicals were detected in the drinking water supplies of several towns we represent. As our communities grappled with the aftermath of PFAS detection, it became clear that municipalities alone could not shoulder the significant financial challenges of remediating PFAS in drinking water. We also saw the need for a consistent approach to mitigating and remediating PFAS contamination that could leverage best practices and shared resources.

The experiences of our communities served as the catalyst for the creation of the PFAS Interagency Task Force. We proposed legislation to establish the Task Force with the purpose of convening legislators, agency officials, PFAS experts, and other stakeholders to develop a policy framework that addresses PFAS along their entire lifecycle, not just after our drinking water has been contaminated. State leadership has demonstrated commitment to tackling the urgent issue of PFAS contamination in the Commonwealth by passing our bill as part of the FY21 budget and allocating millions of dollars for PFAS testing and remediation.

The Task Force is proud to share its findings from nine public hearings and written testimony submitted by members of the public. It was crucial for the Task Force to hear from a range of voices, and we thank all those who shared their stories and expertise with us. The Task Force proposes a comprehensive set of recommendations that build upon existing efforts to detect and remediate PFAS, prevent PFAS contamination at the source, broaden the scope of PFAS regulation, and support impacted communities.

The extent of PFAS contamination is vast, and the time to act is now. We invite you to join our efforts to protect the people of the Commonwealth and our environment.

Rep. Kate Hogan
Third Middlesex
Speaker Pro Tempore

Sen. Julian Cyr
Cape and Islands
Assistant Majority Whip

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EXECUTIVE SUMMARY

Per- and polyfluoroalkyl substances (PFAS) are a class of synthetic chemicals that have been detected in drinking water supplies across the Commonwealth of Massachusetts. To help protect residents from the adverse health effects associated with PFAS, the state established the PFAS Interagency Task Force through the Fiscal Year 2021 Budget. Throughout 2021, the Task Force held nine public hearings to investigate PFAS detection in multiple environmental media, known and potential exposure pathways, associated health and environmental impacts, possible sources of contamination, state and federal action, costs and challenges, and potential solutions. The Task Force, which is composed of state officials and experts, heard testimony from a wide range of stakeholders, including researchers, advocacy groups, community members, municipal officials, state agencies, public water systems, industry groups, and legislators. Based on its findings, the Task Force recommends the following set of measures for the Commonwealth of Massachusetts to implement in order to protect public health and the environment from PFAS contamination.

FUND PFAS DETECTION AND REMEDIATION

Given the adverse health effects and environmental impacts associated with PFAS, it is critical for the state to accurately assess the full extent of PFAS contamination. This will require appropriating funds for the Massachusetts Department of Environmental Protection (MassDEP) and the Massachusetts Department of Public Health (DPH) to conduct PFAS testing in drinking water, groundwater, surface water, wastewater, residuals, soil, air, fish tissue, and other environmental media. These funds would also support testing and investigation in locations with known or suspected PFAS releases to identify sources of contamination.

As a result of the maximum contaminant level (MCL) that MassDEP established for six PFAS in drinking water, known as PFAS6, the state now requires treatment of drinking water supplies in instances where these specific PFAS exceed the MCL of 20 parts per trillion (ppt). MassDEP also established cleanup standards for PFAS6 in groundwater and soil. The state could provide assistance to municipalities, public water systems, and homeowners facing the high cost of PFAS remediation by appropriating funds to the Clean Water Trust and establishing a PFAS Remediation Fund to distribute grants.

SUPPORT ENVIRONMENTAL JUSTICE COMMUNITIES

Environmental Justice (EJ) communities are minority, low-income, tribal or indigenous populations that may be disproportionately impacted by environmental and health hazards. EJ communities may have heightened exposure to PFAS through a variety of pathways, such as subsistence fishing in waterbodies with elevated levels of PFAS, but have fewer resources to address PFAS contamination. The state could provide additional support to EJ communities through the Clean Water Trust's Drinking Water State Revolving Fund Disadvantaged Communities program by increasing the loan forgiveness percentage for eligible projects. DPH could conduct outreach in EJ communities to ensure residents have information on PFAS in accessible language.

PHASE OUT PFAS IN CONSUMER PRODUCTS

While it is important to address the immediate impacts of PFAS contamination by funding testing and remediation, it would be ineffective for the state to continue treating PFAS contamination without also addressing the issue further upstream. The state could reduce PFAS exposure and contamination by regulating the sale of consumer products that contain intentionally added PFAS. This includes phasing out the sale of these products by 2030, identifying priority products for an earlier phase-out, enacting PFAS disclosure requirements for manufacturers of consumer products for sale in Massachusetts, and implementing PFAS labeling requirements. Priority products could include textiles, food packaging, and children's products.

To reduce the risk of regrettable substitutions, the state could take a class-based approach to regulating PFAS in consumer products and define PFAS as "fluorinated organic chemicals containing at least one fully fluorinated carbon atom." DPH, in consultation with MassDEP, could grant temporary exemptions to consumer products that do not currently have PFAS alternatives and that the agencies have determined to be environmentally preferable products or essential to the health and safety of the Commonwealth. The state could provide research grants to support the identification and development of safe PFAS alternatives in consumer products that have been granted temporary exemptions.

EXPAND PFAS REGULATION

Currently, the Massachusetts MCL for six PFAS in drinking water is 20 ppt and cleanup standards for the same six PFAS in groundwater and soil are 20 ppt and 0.3 to 2 parts per billion, respectively. Known as "PFAS6," the six regulated PFAS are PFOS, PFOA, PFHxS, PFNA, PFHpA, and PFDA. There is a growing body of research on adverse health effects associated with PFAS that are not currently regulated in Massachusetts. MassDEP will review its drinking water standards over the next two years and will consider establishing standards for additional PFAS. MassDEP is evaluating additional avenues of PFAS exposure and is encouraged to develop standards in those areas.

MassDEP requires wastewater treatment plants to screen for 16 PFAS and is conducting technical work and stakeholder engagement to establish interim screening levels for PFAS in residuals. To reduce the amount of PFAS entering groundwater and wastewater treatment plants, the state could incorporate PFAS conditions in groundwater discharge permits for industrial wastewater and establish limits to PFAS in effluent for industrial surface water discharge permits.

ENCOURAGE PRIVATE WELL PFAS TESTING AND REMEDIATION

Residents who rely on private wells for drinking water are uniquely vulnerable to PFAS contamination in groundwater. Homeowners may have limited resources to conduct regular PFAS testing and install treatment systems. As a result, they may experience extended exposure to PFAS. Homeowners may also be reluctant to test their wells for PFAS due to liability concerns. The state could identify strategies to reduce the cost of testing and municipalities could institute a PFAS testing requirement for PFAS during the transfer of property with a private well and with new well permits. The state could develop a loan program to support private well PFAS remediation.

SUPPORT FIREFIGHTERS AND LOCAL FIRE DEPARTMENTS

Due to the use of PFAS in aqueous film-forming foams (AFFF) and firefighter personal protective equipment, also known as turnout gear, firefighters can experience elevated exposure to PFAS. Local fire departments currently lack the funds to collect and dispose of AFFF, clean up storage facilities and equipment exposed to AFFF, and buy safer alternative foams. The state could assess the current inventory of AFFF, fund a second round of MassDEP's AFFF Take-Back Program that includes cleanup of facilities and equipment and replacement of AFFF with fluorine free foam, and direct the Department of Fire Services to develop standards for equipment cleanup. The state could prohibit the use of AFFF for firefighting training and maintenance, support efforts to reduce the use of AFFF in emergency responses, and require fire departments to notify MassDEP of releases of AFFF.

Only textiles containing PFAS can meet the current standards for firefighter turnout gear, which can lead to elevated PFAS exposure among firefighters. Manufacturers have developed low-PFAS turnout gear that does not contain PFAS in the outer shell but still contains PFAS in the moisture barrier. The state could take steps to protect firefighters from PFAS exposure by requiring manufacturers to disclose the inclusion of PFAS in turnout gear, supporting efforts to review turnout gear standards, identifying efficacious alternatives, and once there are viable alternatives in the marketplace, banning the sale of turnout gear with PFAS.

Firefighters experience higher rates of cancer diagnosis and cancer-related deaths compared to the general population. The Department of Fire Services and the Massachusetts Fire Academy offer cancer awareness trainings and cancer screening referrals to eligible firefighters. The state could increase funding for the program to offer screenings for cancers associated with PFAS exposure, which are frequently not covered by health insurance. The state may also direct the Massachusetts Cancer Registry to retroactively standardize “firefighter” as an occupation and collect data on occupational exposure to PFAS.

ADDRESS PFAS CONTAMINATION ACCOUNTABILITY

While private wells are regulated by local boards of health, MassDEP regulates the unpermitted release of oil and hazardous material, including PFAS6, into the environment under the state superfund law, Chapter 21E of the Massachusetts General Laws, and the Massachusetts Contingency Plan. Homeowners may face significant legal and fiscal responsibilities if their property is determined by MassDEP to be the source of PFAS contamination. Although MassDEP considers this to be an unusual circumstance, the potential liability may deter homeowners from testing their private wells for PFAS.

Fire departments are also concerned about potential liability for the release of AFFF during emergency responses and past training events. While MassDEP has discretionary authority in issuing Notices of Responsibility under Chapter 21E, fire departments may be subject to liability claims from third parties. The state may consider identifying paths for adopting reasonable limitations for liability claims against homeowners and municipalities for PFAS contamination.

The cost of PFAS detection and remediation has primarily fallen on those who have not contributed to PFAS contamination – individuals, communities, public water systems, and states – while manufacturers continue to profit from the production and use of PFAS. Towns in Massachusetts have begun filing lawsuits against PFAS manufacturers to seek monetary damages for costs related to PFAS contamination. In the past decade, other states have settled PFAS pollution claims against PFAS manufacturers and have used settlement funds to assist communities impacted by PFAS contamination. Massachusetts may continue evaluating potential claims against PFAS manufacturers to seek remediation costs and other damages for PFAS contamination.

In response to the use of AFFF at military installations, the Department of Defense (DOD) is investigating known or suspected releases of PFAS at military installations and initiating remedial actions for PFAS cleanup. DOD has initiated response actions when PFAS levels exceed the U.S. Environmental Protection Agency's lifetime health advisory of 70 ppt for PFOS and PFOA. This health advisory is significantly higher than the Massachusetts MCL of 20 ppt for PFAS6. In 2021, DOD issued guidance that recognizes the role of state MCLs in DOD's removal actions. MassDEP could work with DOD to implement this guidance to initiate removal actions when PFAS levels in drinking water exceed the Massachusetts MCL as a result of PFAS contamination from military activity.

ENHANCE PUBLIC AWARENESS OF PFAS

An important component of protecting the public from PFAS contamination is to educate Massachusetts residents on how they may be exposed to and impacted by PFAS. Currently, public water systems and municipalities issue public education and public notice announcements upon detection of PFAS6 in drinking water exceeding the MCL. The state could take a more proactive approach to educating the public by directing MassDEP and DPH to build upon existing outreach efforts to jointly conduct public education and awareness campaigns. Additionally, DPH's existing partnerships with health care providers to increase outreach and education could be further leveraged to provide guidance to additional health providers about how best to assess and discuss PFAS exposure and health risks with patients.

TASK FORCE STATUTORY CHARGE

The PFAS Interagency Task Force was established by Outside Section 98 of the Fiscal Year 2021 Budget, which Governor Baker signed into law on December 11, 2020.

> *There shall be an interagency task force to review and investigate water and ground contamination of per- and polyfluoroalkyl substances across the commonwealth. The task force shall consist of 19 members: 3 members who shall be appointed by the senate president, 1 of whom shall serve as co-chair; 1 of whom shall be a scientist with expertise in per- and polyfluoroalkyl substance-contaminated water; 1 member who shall be appointed by the minority leader of the senate; 3 members who shall be appointed by the speaker of the house of representatives, 1 of whom shall serve as co-chair; 1 member who shall be appointed by the minority leader of the house of representatives; 1 of whom shall be a physician trained in environmental medicine; the attorney general or their designee; the secretary of energy and environmental affairs or their designee; the secretary of public safety and security or their designee; the commissioner of environmental protection or their designee; the commissioner of public health or their designee; the commissioner of agricultural resources or their designee; the director of the Massachusetts emergency management agency or their designee; the state fire marshal or their designee; the executive director of the Massachusetts Municipal Association, Inc. or their designee; the executive director of the Massachusetts Water Resources Authority or their designee; and the executive director of the Massachusetts Water Works Association, Inc. or their designee.*
>
> *The task force shall: (i) gather and review information regarding known locations of per- and polyfluoroalkyl substances detection and create response plan strategies; (ii) identify significant data gaps in the knowledge of per- and polyfluoroalkyl substances and develop recommendations to address the gaps; (iii) identify opportunities for public education regarding per- and polyfluoroalkyl substances contamination and the effects of its exposure on public health and the environment; (iv) identify the sources of per- and polyfluoroalkyl substances contamination and exposure pathways that pose the greatest risk to public health and the environment; (v) examine the benefits and burdens of various treatment and disposal options for per- and polyfluoroalkyl substances contaminated media; (vi) assess how state agencies can most effectively use their existing*

> *authority and resources to reduce or eliminate priority risks from per- and polyfluoroalkyl substances contamination; (vii) determine the inventory and use of fluorinated aqueous forming foam in firefighting and fire training activities and evaluate effective non-fluorinated alternatives; (viii) examine data regarding per- and polyfluoroalkyl substances contamination in freshwater fish and marine organisms and determine whether further examination is warranted; (ix) examine and estimate the cost to mitigate per- and polyfluoroalkyl substances contamination in known locations across the commonwealth; and (x) examine ways to limit exposure of Massachusetts residents to per- and polyfluoroalkyl substances through food packaging.*
>
> *The task force shall file a report of its findings and recommendations, together with drafts of legislation necessary to carry those recommendations into effect, by filing the same with the clerks of the senate and the house of representatives, the chairs of the senate and house committees on ways and means, the senate and house chairs of the joint committee on environment, natural resources and agriculture, the senate and house chairs of the joint committee on public health, the senate and house chairs of the joint committee on the judiciary and the senate and house chairs of the joint committee on public safety and homeland security not later than December 31, 2021.*

The PFAS Task Force report deadline was extended to June 30, 2022, per an amendment in the supplementary budget bill, H.4578 - An Act making appropriations for fiscal year 2022 to provide for supplementing certain existing appropriations and for certain other activities and projects.

> *SECTION 65. The interagency task force established in section 98 of chapter 227 of the acts of 2020 to review and investigate water and ground contamination of per- and polyfluoroalkyl substance is hereby revived and continued to June 30, 2022. The task force shall submit a report of its findings and recommendations, together with any drafts of legislation necessary to carry those recommendations into effect, by filing the same with the clerks of the senate and house of representatives, the senate and house committees on ways and means, the joint committee on environment, natural resources and agriculture, the joint committee on public health, the joint committee on the judiciary and the joint committee on public safety and homeland security not later than June 30, 2022.*

TASK FORCE MEMBERS

HOUSE CHAIR

Rep. Kate Hogan
Third Middlesex District
Speaker Pro Tempore

SENATE CHAIR

Sen. Julian Cyr
Cape and Islands District
Assistant Majority Whip

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PFAS OVERVIEW

BACKGROUND

Per- and polyfluoroalkyl substances (PFAS) are a class of several thousand human-made chemicals. Estimates for the number of chemicals in this class range from 4,000 to over 12,000.[1] PFAS have been widely applied in commercial and industrial settings and several PFAS have been associated with adverse human health effects. On a molecular level, PFAS consist of a carbon chain in which one or more of the carbon-hydrogen bonds have been replaced by bonds to fluorine atoms.[2,3,4] PFAS with all of their carbons fully fluorinated are called perfluoroalkyl substances and PFAS with partially fluorinated carbon chains are called polyfluoroalkyl substances.[5] Unlike a carbon-hydrogen bond, a carbon-fluorine (C-F) bond is highly stable, extraordinarily strong, and rarely found in non-synthetic compounds.

As a result of their chemical structure, many PFAS exhibit qualities of water-repellency and oil-repellency, water solubility, environmental persistence, and bioaccumulation. Because C-F bonds remain strong, even under heat and chemical exposure, PFAS do not easily break down. This bond stability contributes to the persistence of PFAS in the environment and living organisms. While PFAS repel oil and water in their uncharged state, their chemical head groups easily deprotonate to form charged molecules that persist and accumulate in water and water-rich environments. As a result, PFAS are capable of persisting and accumulating without degradation in freshwater and marine ecosystems, as well as drinking water, groundwater, and wastewater. For some PFAS, the time required for a human or animal body to expel half of a chemical's total concentration, known as elimination half-life, is on the scale of years to decades.[6]

Highly stable C-F bonds provide PFAS with a number of industrially and commercially useful properties. PFAS remain stable when exposed to a wide range of temperatures, highly reactive chemicals, and acidic and oxidizing environments.[7] When applied to materials, PFAS are capable of lowering surface tension and repelling oil and water, which has contributed to their widespread use in commercial and industrial applications that require long-lasting water-resistance or oil-resistance. Commercially, PFAS are used as water-resistant components of textiles, cosmetics, household products, food packaging, and other single-use plastics. Industrially, PFAS are present in surfactants, emulsifiers, paints, non-stick coatings, and various stages of commercial production.

GROUPING METHODS

While the basic chemical structure of PFAS consists of a carbon chain in which one or more of the carbons are also bonded to fluorine atoms, these carbon chains can vary in length, branching, and chemical functional groups. These carbon chains can be linear, defined by carbons that bond to two or fewer other carbons to generate a single chain, or branched, which is defined by one or more carbons bonded to one or more other carbons to generate multiple branches from a single chain. Other PFAS may have additional functional groups, such as epoxides, which alter their chemistry.

These chemical distinctions influence various properties of PFAS, as well as their production, use, phase-out, and regulation. Chemical manufacturers and the U.S. Environmental Protection Agency (EPA) have used distinctions between short-chain and long-chain PFAS and between linear and branched-chain PFAS to define categories of PFAS. Researchers, regulatory bodies, and industry have typically defined long-chain PFAS as PFAS with six or more carbons linked together in at least one chain and short-chain PFAS as fewer than six carbons linked together in at least one chain.[8] EPA has partnered with industry stakeholders to voluntarily phase out perfluorooctane sulfonic acid (PFOS) and perfluorooctanoic acid (PFOA). PFOS and PFOA are long-chain PFAS associated with adverse health effects and are known as "legacy PFAS." Industry stakeholders have since replaced legacy PFAS with short-chain compounds and compounds with ether groups and other functional groups.[9] These compounds are often included in the category of "novel PFAS." While these short-chain PFAS compounds are thought by some to accumulate in human tissues less than long-chain compounds, ongoing studies indicate that these short-chain PFAS may also be associated with adverse health impacts, such as immunotoxicity.[10,11]

Aside from chain length, there are other methods to group PFAS into categories and subcategories. These grouping methods include chemical structure and properties, risk assessment, and applications. Grouping PFAS by essential and non-essential use has been proposed as a framework for regulating PFAS in the European Union and is currently being used in Maine and California. See Appendix C for an overview of the grouping methods, their defining characteristics, required data types, advantages and disadvantages, and situations in which it may be best applied. It may be challenging to conduct direct comparisons between these grouping methods as they were developed for different contexts and rely on different data.[12] Each method has the potential to reduce the research and regulatory resources required to assess chemicals on an individual basis.

INDUSTRIAL ORIGINS

PFOS and PFOA were first synthesized in 1938 and have been in use since the 1940s. E. I. du Pont de Nemours and Company and the 3M Company were the primary manufacturers of PFOS and PFOA up until the early 2000s.[13] The history of DuPont and 3M's knowledge of the toxic, persistent, and bioaccumulative effects of PFOS and PFOA in humans, animals, and the environment became public record as part of personal and class action litigation in West Virginia, Ohio, and Minnesota.[14] Beginning in 2000, 3M voluntarily phased out PFOS, precursors that could break down into PFOS, and its six-carbon and ten-carbon homologues.[15] DuPont later joined EPA's PFOA Stewardship program in 2006 with the goal of complete emissions phase-out of PFOA and its precursors by 2015. See Appendix D for a description of PFAS precursors.[16]

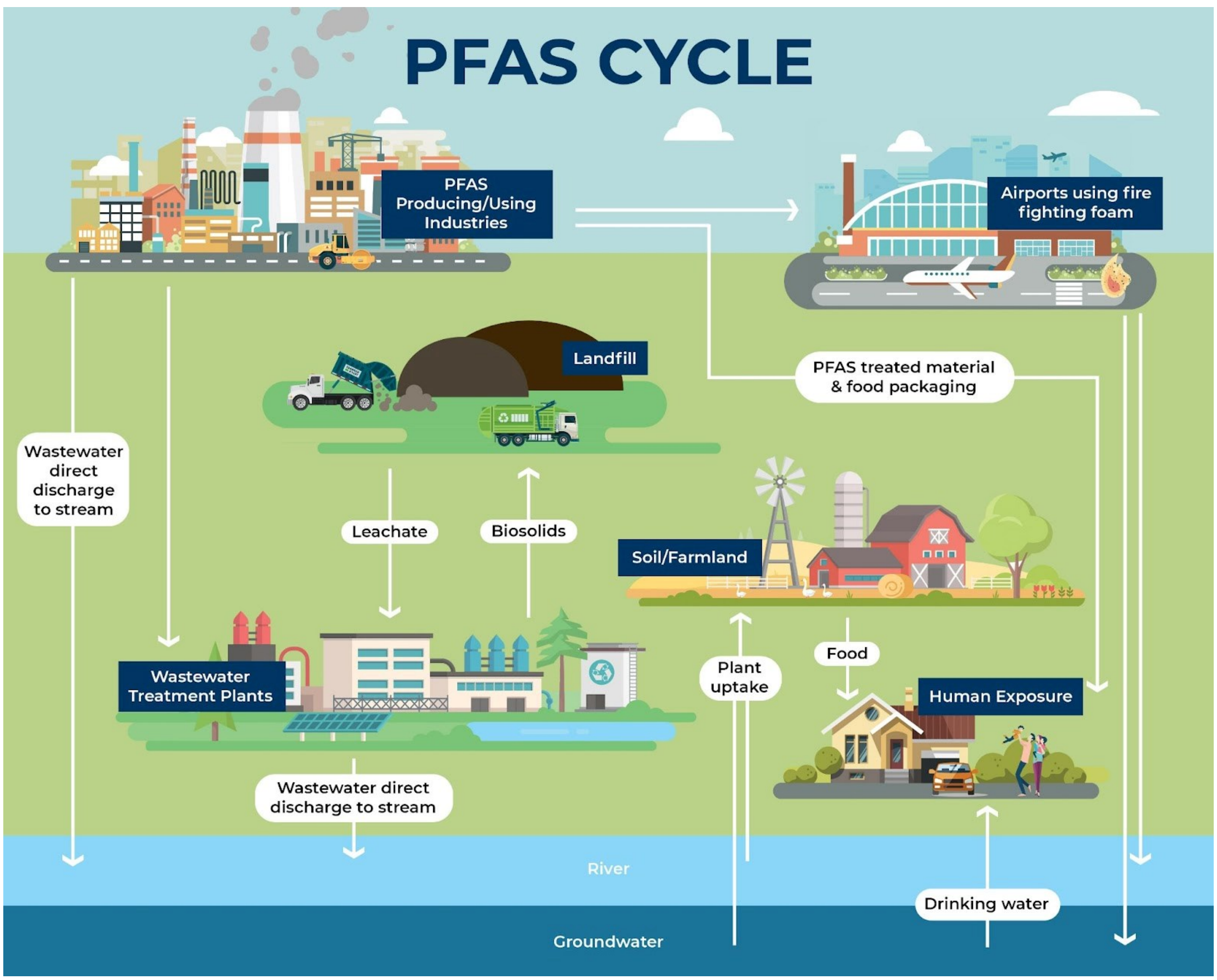
Certain PFAS used as replacements for PFOA, such as GenX, have been found to be environmentally persistent and associated with similar adverse health effects.[17] As of 2020, chemical manufacturing companies revealed that they still used other PFAS that can break down into PFOS and PFOA later in their life cycle.[18]

EXPOSURE PATHWAYS

EPA's definition of an exposure pathway is how a "stressor" comes into contact with a "receptor." Such stressors include chemicals that may have an adverse effect on receptors, i.e., humans and the environment. Within this framework, exposure pathways can have the following components:

1. Source: the space and time at which the stressor enters the environment.
2. Media: the method by which the stressor travels from the source into the environment.
3. Exposure: where the receptor and media meet.
4. Exposure route: how stressors enter the bodies of receptors.
5. Receptors: any part of the ecosystem that is exposed to the stressor.

Figure 1. Some pathways for environmental PFAS contamination and human exposure to PFAS



Source: [*Walnut Valley Water District*]

Stressors and Sources

PFAS are commonly used as processing aids, mist suppressants, surface active agents, solvents for cleaning and degreasing, adhesive and sealant chemicals, and finishing agents in a wide range of sectors.[19] These sectors include electronics manufacturing, paint and coating manufacturing, metal plating, oil and gas drilling, and fluoropolymer production. The application of PFAS in manufacturing can introduce PFAS into the environment through landfill disposal, wastewater treatment plant (WWTP) effluent, and septic systems, among other pathways, which can contaminate drinking water, groundwater, and surface water. See Appendix E for examples of stressors. See Appendix F for a list of "industry branches and other use categories where PFAS were or are employed" developed by Glüge et al.

Widespread use of PFAS in consumer products, such as food packaging, household materials, personal care products, non-stick cookware, and water-resistant clothing, can result in human exposure to PFAS through ingestion, dermal absorption, and inhalation. PFAS that are used as water-resistant and oil-resistant coatings on cookware and food packaging can migrate into butter, oils, vinegar, and drinking water. PFAS have been detected in indoor dust and may come from household materials, such as carpet, furnishings, upholstery, paints, polishes, and other building materials.[20] Cosmetic products, including lip products, mascara, and foundation, can contain PFAS that are ingested or absorbed through the skin.[21]

Emergency use products, such as aqueous film-forming foam (AFFF), can generate a stream of water-based and air-based media that disperses sulfonated and fluorotelomeric PFAS into air-based and water-based exposure pathways. AFFF is a water-based fire suppressant used to extinguish class B hydrocarbon fuel fires. AFFF is most commonly used in sites with significant flammable liquid hazards, such as military facilities, airports or airfields, chemical plants and storage facilities, and oil refineries. Municipal fire departments use AFFF for emergency responses and have trained with the material. PFOS and PFOA can be found in legacy PFOS AFFF and legacy fluorotelomer AFFF, which were phased out in the United States in 2002 and 2016, respectively. As an alternative to legacy AFFF, manufacturers have been producing short-chain (C6) fluorosurfactants, which do not break down to PFOS or PFOA but may break down to other short-chain PFAS.[22]

Media

Media by which PFAS enter and spread through the environment include groundwater, surface water, wastewater, soil, and air. PFAS contamination in groundwater can lead to elevated levels of PFAS in drinking water supplies. Due to the persistence of PFAS in aquatic environments, the ocean has been suggested as the final environmental sink for many PFAS.[23] PFAS contamination in wastewater can come from domestic wastewater when residents use and wash products containing PFAS and from industrial wastewater generated by facilities that manufacture or use PFAS. Biosolids, a product of the wastewater treatment process, are often used as fertilizer and can contribute to the spread of PFAS in the environment if the wastewater from which it was produced contained PFAS. In the atmosphere, PFAS can travel as vapors or adsorbed substances on airborne particles that later deposit onto surfaces or waterways. Airborne PFAS sources include emissions from industrial facilities and PFAS incineration sites.[24] These sources may deposit PFAS in soil, groundwater, and surface water in surrounding areas. Studies show that indoor dust levels, which may contain PFAS precursors, positively correlate with PFAS concentrations in human blood.[25]

Disposal of materials containing PFAS leads to a cyclical problem of releasing PFAS into solid waste, atmospheric, and aqueous pathways, which can result in continued human exposure to PFAS. Landfilling of these materials can contribute to PFAS in leachate, sludge, and wastewater. PFAS in wastewater can spread into the environment through effluent and residuals, such as biosolids, if PFAS are not fully removed. Wastewater treatment options for removing PFAS are limited and not readily available. Incineration of materials containing PFAS can lead to the incomplete breakdown and spread of PFAS, as well as the release of pollutants such as greenhouse gases.

Human Exposure

PFAS ingestion is considered the predominant pathway for human bioaccumulation of PFAS.[26] PFAS can be ingested through primary pathways, such as drinking water and PFAS-contaminated food, or secondary pathways, such as food packaging. Studies conducted by the New Jersey Department of Environmental Protection indicate that drinking water is the main source of PFAS exposure for people whose drinking water supplies are contaminated with PFAS.[27,28] For people whose drinking water does not contain PFAS, the majority of PFAS exposure can be attributed to other sources, such as ingestion of food and other materials contaminated with PFAS.[29]

PFAS contamination in food can occur as a result of environmental contamination or migration from food packaging that contains PFAS. Surface water contaminated with PFAS can lead to higher levels of PFAS in fish, shellfish, and other animals. Subsistence fishers, such as residents of Environmental Justice communities or tribal communities, may experience higher risk of exposure to PFAS if the waterbodies they fish in are contaminated with PFAS. In November 2021, Maine Department of Inland Fisheries and Wildlife issued a “Do Not Eat” advisory for deer in areas with high levels of PFOS in soil and surface water.[30] The U.S. Food & Drug Administration (FDA) has developed validated methods to test for 20 PFAS in a diverse sample of foods. Additionally, the FDA conducts PFAS testing for food produced in areas with known PFAS contamination, such as industrial facilities where PFAS are produced or applied and areas where AFFF has been released.[31] The application of biosolids that contain PFAS on farms can lead to contamination of crops and livestock. In 2016, Maine Department of Agriculture, Conservation & Forestry detected high levels of PFOS in milk produced on certain dairy farms. In 2021, Maine Department of Environmental Protection began investigating PFAS contamination in communities as a result of land application of biosolids.

While ingestion is considered the primary pathway for PFAS exposure among the general population, other potential routes of exposure include inhalation and dermal contact. The relative weight of exposure pathways may vary by population and occupation. For instance, workers at facilities that produce or use PFAS may experience elevated exposure to PFAS through inhalation and dermal contact.[32] Firefighters may be exposed to PFAS through their turnout gear, which can contain PFAS in the outer shell and moisture barrier.

REMEDIATION

Due to the stability of PFAS, remediation strategies for PFAS are unlike those for other chemical pollutants. Bioremediation cannot occur because bacteria do not naturally break the C-F bonds. PFAS oxidation can break down some of the chemicals but does not completely destroy them.

There are two traditional strategies for large-scale PFAS remediation in aqueous exposure pathways, particularly those located in the subsurface environment. One strategy is “dig and haul,” which consists of off-site disposal of soil contaminated with PFAS. Determining the extent of PFAS contamination in soil requires extensive soil testing, which can be disruptive and expensive. There are concerns about spreading PFAS into the environment through soil disposal. Soil burial in landfills may lead to the contamination of surface water and groundwater from landfill leachate containing PFAS if the leachate is not collected and treated. Incineration may spread PFAS through airborne distribution and deposition.

Another strategy is groundwater extraction and treatment, colloquially known as “pump and treat” methods. The most common treatment uses granular activated carbon (GAC) for drinking water. PFAS molecules adsorb or attach to GAC, enabling the removal of PFAS in drinking water. Variations exist between the kinds of GAC, sources, and efficacy.[33,34] Research suggests that activated carbon, both granular and powdered, can be sourced from various agricultural wastes, such as husks, bark, and shells, in addition to the more conventional coal-based sources.[35] The carbon filtration matrices used in GAC treatment require periodic flushing or cleaning, which results in the collection of waste products that must be managed and disposed of to reduce further release of PFAS to the environment.

Adsorption and retention on ion exchange resin is another method of remediating PFAS in drinking water. Resin beads are adsorbents with a neutral carbon backbone that concludes a charged functional group. In aqueous environments, many PFAS contain a charged functional group, which enables their bonding to oppositely charged functional groups on resin beads. Beads that have accumulated PFAS can then be filtered and removed. The efficacy of ion exchange resins is determined by factors like a resin's affinity for other charged particles in water and the electric charge of particular PFAS.[36,37] Treatment using ion exchange resins requires recharging the matrix and managing the resulting wastes.

GAC and ion exchange resins are effective at treating PFAS in drinking water to levels below EPA's health advisory of 70 parts per trillion (ppt) and the Massachusetts PFAS6 Maximum Contaminant Level (MCL) of 20 ppt.[38] Other strategies for PFAS remediation include high pressure membrane filtration, advanced oxidation, direct photolysis, oxidation/ reduction, photocatalysis, and electrochemical reaction.[39]

HEALTH & ENVIRONMENTAL IMPACTS

Growing concerns over widespread PFAS exposure have spurred research on the potential health and environmental impacts of PFAS. Both experimental and observational studies have indicated associations between PFAS exposure and several adverse health effects. There is emerging evidence that short-chain PFAS are also associated with similar health impacts. Environmental Justice communities may be disproportionately impacted by PFAS contamination.

HUMAN HEALTH

Due to the ubiquity and persistence of PFAS in the environment and their associated health impacts, PFAS are considered a risk to human health, especially among highly exposed populations. Researchers have detected elevated serum levels of certain PFAS among workers in facilities that produce or use PFAS, residents living near these facilities, and firefighters.[40,41] Other highly exposed populations include residents near military bases, fire training sites, and airfields. PFAS have also been detected at lower levels in the general population as a result of widespread exposure to PFAS and the long elimination half-lives of the chemicals. A 2016 study found that the concentration of PFOS and PFOA in large public water systems that serve a combined six million U.S. residents exceeded EPA's lifetime health advisory of 70 ppt.[42] Other studies estimate that tap water for 18-80 million U.S. residents contains PFOS and PFOA at a concentration of 10 ppt or greater.[43] The Centers for Disease Control and Prevention (CDC) estimates most U.S. residents have PFOS and PFOA in their blood.[44]

In recent decades, researchers have produced a growing body of evidence for health hazards associated with exposure to a variety of PFAS.[45] Much of the current knowledge of associated health effects are derived from toxicological and epidemiological studies of four PFAS: PFOS, PFOA, PFHxS, and PFNA.[46] The C8 Health Project is regarded as the largest study on the health effects of exposure to perfluorocarbon compounds and, in particular, PFOA. As part of a settlement agreement for a class action lawsuit, DuPont provided funding to monitor over 69,000 residents in six water districts near the DuPont Washington Works facility in West Virginia.[47] The study identified six diseases associated with PFOA exposure: kidney and testicular cancer, ulcerative colitis, thyroid disease, high cholesterol, and pregnancy -induced hypertension.[48]

In addition to the health effects identified in the C8 Health Project, PFOA is associated with suppressed immune responses to vaccines and lower birth weight.[49] A recent study of COVID-19 disease severity found a correlation between higher serum levels of PFBA in patients and more severe COVID-19 disease incidence.[50] PFOS, PFOA, and PFHxS may lead to decreased immune response from vaccines in children, particularly for tetanus and diphtheria.[51] In 2017, the International Agency for Research on Cancer classified PFOA as a possible human carcinogen. Other PFAS, including PFOS, PFNA, and PFHxS, are associated with changes to the liver, endocrine disruption, and developmental effects.[52] Additional research is needed to understand the cumulative effects of exposure to multiple PFAS.

Throughout the 2000s, major U.S. manufacturers of PFAS voluntarily phased out production of PFOS and PFOA. By 2014, CDC detected lower serum levels of PFOS and PFOA in the general population compared to serum levels in 1999.[53] However, many industries have replaced long-chain PFAS with short-chain PFAS. While short-chain PFAS are not as commonly detected in the blood, researchers have detected the chemicals in human organs and breast milk.[54] Certain short-chain PFAS, such as PFHxA, PFBS, and PFBA, are associated with adverse health impacts on the liver, endocrine system, development, and reproduction.[55] Compared to long-chain PFAS, short-chain PFAS may have a greater ability to bind to biomolecules and may exhibit greater persistence in living organisms.[56,57] Conventional methods of removing long-chain PFAS from drinking water are less effective at removing short-chain PFAS, which have been detected in public drinking water supplies.[58]

GLOBAL ENVIRONMENT

In 2001, PFAS garnered international attention when researchers documented the presence of PFOS in wildlife around the world.[59] Since then, researchers have detected bioaccumulation of PFAS in a range of biota, including aquatic organisms, birds, and plants. Out of all the PFAS currently being studied, PFOS is found in the highest concentration in biota.[60] Researchers have detected PFAS in whole fish and fish liver at varying concentrations and bioaccumulation of short-chain PFAS in plants.[61,62,63]

PFAS are released into aquatic environments via point sources, such as sewage treatment plants, manufacturing plants, and landfills, as well as nonpoint sources, such as atmospheric deposition, septic systems, and groundwater that discharges to surface water. Continuous exposure to PFAS in rivers and oceans, especially near contaminated sites, may cause adverse effects in aquatic organisms.[64] In certain families of fish, studies suggest an association between PFAS exposure and changes in growth, development, and reproduction.[65] Researchers have observed adverse effects on embryonic survival and reproduction among birds exposed to PFAS.[66] Field and laboratory studies of mammals, while limited, have detected changes in liver function and immunologic function associated with PFAS exposure above certain concentrations.

Disposal of PFAS-containing waste via incineration may release toxic air pollutants and greenhouse gases.[67] Due to the stability of the carbon-fluorine bond, destruction of these bonds requires thermal treatment at very high temperatures. While thermal destruction of PFOS and PFOA generally requires temperatures of 1000°C or higher, the efficacy of thermal incineration may vary for different PFAS. There are concerns that treatment temperatures that are too low can lead to the release of PFAS into the atmosphere. It can also lead to the emission of fluorinated greenhouse gases, such as 1H-pentafluoroethane, whose ability to raise global temperatures is 3,500 times more potent than that of carbon dioxide.[68] Additional research and monitoring of PFAS air emissions and commercially run incinerators is needed to ensure complete destruction of PFAS, particularly in light of the severe impacts of climate change.

FLUOROPOLYMERS

A polymer is a chemical molecule made almost entirely of many similar or the same repeating monomer subunit chemically bonded together. Polymers are often large compounds consisting of hundreds of monomer subunits. Fluorinated polymers are molecules composed of monomers that contain one or more fluorine atoms in their chemical structure.

Fluoropolymers are a subset of fluorinated polymers. Following the industry-derived definition in Buck et al. 2011, a fluoropolymer refers to a long, high-molecular weight fluorinated polymer that forms through chemical bonds between similar carbon-fluorine monomers.[69] Before these monomers bond to form a long polymer chain, these monomers each contain a carbon-carbon double bond in their chemical structure.[70] Fluoropolymers differ from side-chain fluorinated polymers, which break down into non-polymeric PFAS in the environment.[71]

Properties of fluoropolymers include common characteristics of PFAS, such as environmental persistence, water-resistance, and oil-resistance. Fluoropolymers are solid plastics with properties that make them important components of industrial processes and consumer products.[72] Widely used fluoropolymers include Teflon's primary component fluoropolymer, polytetrafluoroethylene (PTFE), which is present in Teflon-coated cookware, medical devices, and other water-resistant and highly durable plastic-coated products.[73] Firefighter turnout gear commonly includes PTFE and other fluoropolymers in the moisture barrier and outer shell. When fluoropolymers degrade over time, they can migrate to the thermal layer and they can be released as dust.[74] Skin contact or inhalation of dust with polymer byproducts are additional sources of human exposure to fluoropolymers.[75,76]

Human and environmental exposure to fluoropolymers largely occurs through the production, use, and disposal of products containing fluoropolymers. The production of materials that contain fluoropolymers often involves using other PFAS as processing aids, additives, or chemical intermediate.[77] Historically, PFOA and PFNA have been used as emulsifiers in the industrial polymerization process. PFOA and PFNA have been released into the environment through industrial effluent. Although use of PFOA has been phased out in the United States, replacements such as GenX and other short-chain PFAS have demonstrated properties similar to that of PFOA, such as environmental persistence, stability in water, bioaccumulation in humans and animals, and potential for long-range transport.[78]

Fluoropolymer disposal can result in airborne or waterborne release of breakdown products into the environment. Landfilled fluoropolymers can release PFAS into soil and water leachates, as well as contribute to environmental microplastic concentrations.[79] Animals, particularly marine animals, ingest microplastic. These plastics then absorb and concentrate other contaminants, including PFAS, and pose a growing risk to marine ecosystem diversity.[80,81] Incinerating fluoropolymers at insufficiently high temperatures can release dust or gases that are associated with adverse health effects.[82,83]

ENVIRONMENTAL JUSTICE

The environmental justice movement seeks to provide equitable environmental protection to all communities and to engage all people in the development and implementation of environmental laws and regulations. Environmental Justice (EJ) communities, or "overburdened communities, are defined by EPA as "minority, low-income, tribal or indigenous populations or geographic locations in the United States that potentially experience disproportionate environmental harms and risks."[84] Communities located near polluting industries are at risk for increased cumulative exposure to a range of toxic chemicals through contaminated land, water, and air.[85] The health impacts associated with environmental hazards can add to the existing burden of chronic diseases in these communities.

EJ communities may be disproportionately impacted by PFAS contamination for a number of reasons. Residents of EJ communities may be more likely to consume recreationally caught fish, which would increase their exposure to PFAS if the fish they consume live in contaminated waterbodies and have elevated levels of PFAS. Low-income communities are less likely to have the resources for PFAS detection and remediation in drinking water and other environmental media, which can lead to prolonged exposure to PFAS. Outreach regarding PFAS that is conducted only in English may miss residents who experience literacy challenges or for whom English is not their first language. To achieve an equitable distribution of environmental risks and benefits, it is critical to engage in meaningful partnerships with EJ communities, accurately assess the impact of PFAS contamination on these communities, and provide financial support and technical assistance.

PFAS IN MASSACHUSETTS

Massachusetts is one of 16 states that have established an enforceable standard for certain PFAS in drinking water. MassDEP has been testing public water systems (PWSs) and private wells to assess PFAS contamination. MassDEP is also identifying sites with known or potential releases of PFAS, including military installations, airports, firefighting training sites, and manufacturing facilities. Given the financial burden on many impacted communities to address PFAS contamination, the state has appropriated funding for a variety of PFAS-related activities, including testing and remediation projects. The case studies in this section explore how municipalities have responded to PFAS contamination in their communities, lessons they have learned, and the challenges they continue to face. Municipal officials have identified a need for more state guidance and assistance. In the 192nd Massachusetts General Court, legislators have filed bills to protect residents from PFAS contamination.

REGULATION

Drinking Water

In 2016, EPA issued a lifetime health advisory for PFOS and PFOA of 70 ppt in drinking water but stopped short of establishing an enforceable federal MCL. In the absence of a federal MCL, MassDEP established an enforceable state MCL in October 2020 that limits the sum of six specific PFAS – PFOS, PFOA, PFHxS, PFNA, PFHpA, and PFDA, known as “PFAS6” – to 20 ppt. The MCL, which will be reassessed every three years to reflect new scientific findings, requires community water systems and non-transient non-community water systems to test for PFAS. MassDEP requires PWSs to test drinking water for PFAS using either EPA Method 537 or 537.1 and to report all results to the department.[86]

Groundwater and Soil

Under Chapter 21E of the Massachusetts General Laws, the Massachusetts Oil and Hazardous Material Release Prevention and Response Act, MassDEP is tasked with ensuring the cleanup of oil and hazardous material contamination. MassDEP regulates the assessment, notification, and remediation of contaminated sites through the Massachusetts Contingency Plan (MCP).[87] In December 2019, MassDEP released final PFAS-related revisions to the MCP that established reportable concentrations and cleanup standards for PFAS in groundwater and soil. The new rule set a limit of 20 ppt for the sum of PFAS6 in groundwater and 0.3 to 2 parts per billion in soil. Massachusetts is one of only a handful of states with cleanup standards for PFAS contamination in groundwater and soil.

Wastewater and Residuals

EPA and MassDEP implement parallel surface water discharge permitting programs. In October 2021, EPA announced a new analytical method that can detect 40 PFAS in eight environmental matrices, including wastewater and biosolids.[88] Method 1633 is not required for compliance with the Clean Water Act until it has been promulgated through rulemaking. However, EPA has recommended its use for PFAS requirements in National Pollutant Discharge Elimination System (NPDES) permits. Both NPDES and MassDEP surface water discharge permits include conditions for quarterly PFAS monitoring of influent, effluent, and sludge for municipal permits and annual PFAS monitoring of effluent for specific industrial sectors. These conditions will go into effect six months after Method 1633 is available to the public.

MassDEP includes additional PFAS requirements in its discharge permits. For municipal permits, all significant industrial users will be required to conduct annual monitoring of effluent. All industrial permittees will be required to evaluate whether the facility uses products containing PFAS and how they can be reduced or eliminated. For most facilities, these requirements will go into effect six months after Method 1633 is available to the public or two years from the effective date of the permit, whichever is earlier. PFAS monitoring requirements go into effect 180 days from the effective date of the permit for facilities that discharge upstream of drinking water intakes.

As part of the wastewater treatment process, WWTPs must manage the disposal of sludge and biosolids, which are collectively referred to as residuals. Biosolids must meet federal and state standards to be land applied. In Massachusetts, 38% of residuals are reused as fertilizer or soil amendment, which are subject to MassDEP's Land Application regulations.[89] Through the MassDEP Residuals Program, land applied biosolids must receive an Approval of Suitability and are subject to quarterly PFAS monitoring requirements for 16 PFAS. In 2019, the Maine Department of Environmental Protection announced new testing requirements for land application of biosolids for three PFAS: PFOS, PFOA, and PFBS. MassDEP is consulting with stakeholders and conducting technical work to establish interim screening levels for PFAS in residuals but has not yet established standards for land application of biosolids. This work includes consideration of Maine's testing results and other state actions. Recently, Maine has started reassessing the impacts of residuals reuse, as well as its reuse regulations and screening standards.

Consumer Products

Under Chapter 94 of the Massachusetts General Laws, the Massachusetts Department of Public Health (DPH) permits and regulates the sale of many consumer products, such as bedding, upholstered furniture, and stuffed toys. As a part of 105 CMR 500.93, DPH regulates bottled water sold in Massachusetts and requires licensed bottlers to meet testing requirements that show their bottled water complies with state and federal drinking water standards, including PFAS6. Chapter 94B and supporting regulations 105 CMR 650.00 grants authority to the DPH Commissioner to ban hazardous substances in consumer products. Bans and regulations of hazardous substances in consumer products have historically been carried out by DPH's Bureau of Environmental Health.

Toxics Use Reduction Act

Under the Massachusetts Toxics Use Reduction Act (TURA), businesses with more than 10 employees and which use chemicals on the TURA List of Toxic or Hazardous Substances in quantities exceeding TURA thresholds must comply with the following program requirements: report their use of chemicals on the TURA List, create a Toxics Use Reduction Plan every two years, and pay an annual fee to the state. The program is implemented by MassDEP, the Massachusetts Office of Technical Assistance (OTA), and the Toxics Use Reduction Institute (TURI) at the University of Massachusetts Lowell.

The TURA Science Advisory Board conducted a three-year scientific review process for PFAS. In June 2020, the Science Advisory Board recommended adding PFAS Not Otherwise Listed (NOL) as a category to the TURA List. After the TURA Administrative Council voted in August 2021 to add PFAS NOL to the TURA List and to add a definition of the term "substance" to 301 CMR 41.02, the Executive Office of Energy and Environmental Affairs released draft regulations and held a public comment period and a public hearing. On December 7, 2021, the Administrative Council unanimously voted on final regulations to add Certain PFAS NOL as a category to the TURA List in 301 CMR 41.03 and to clarify the definition of "substance" in 301 CMR 41.02. Certain PFAS NOL is defined as "those PFAS that contain a perfluoroalkyl moiety with three or more carbons (e.g., –CnF2n–, n ≥ 3; or CF3–CnF2n– , n≥2) or a perfluoroalkylether moiety with two or more carbons (e.g., –CnF2nOCmF2m− or –CnF2nOCmFm–, n and m ≥ 1), wherein for the example structures shown, the dash (–) is not a bond to a hydrogen and may represent a straight or branched structure, that are not otherwise listed."

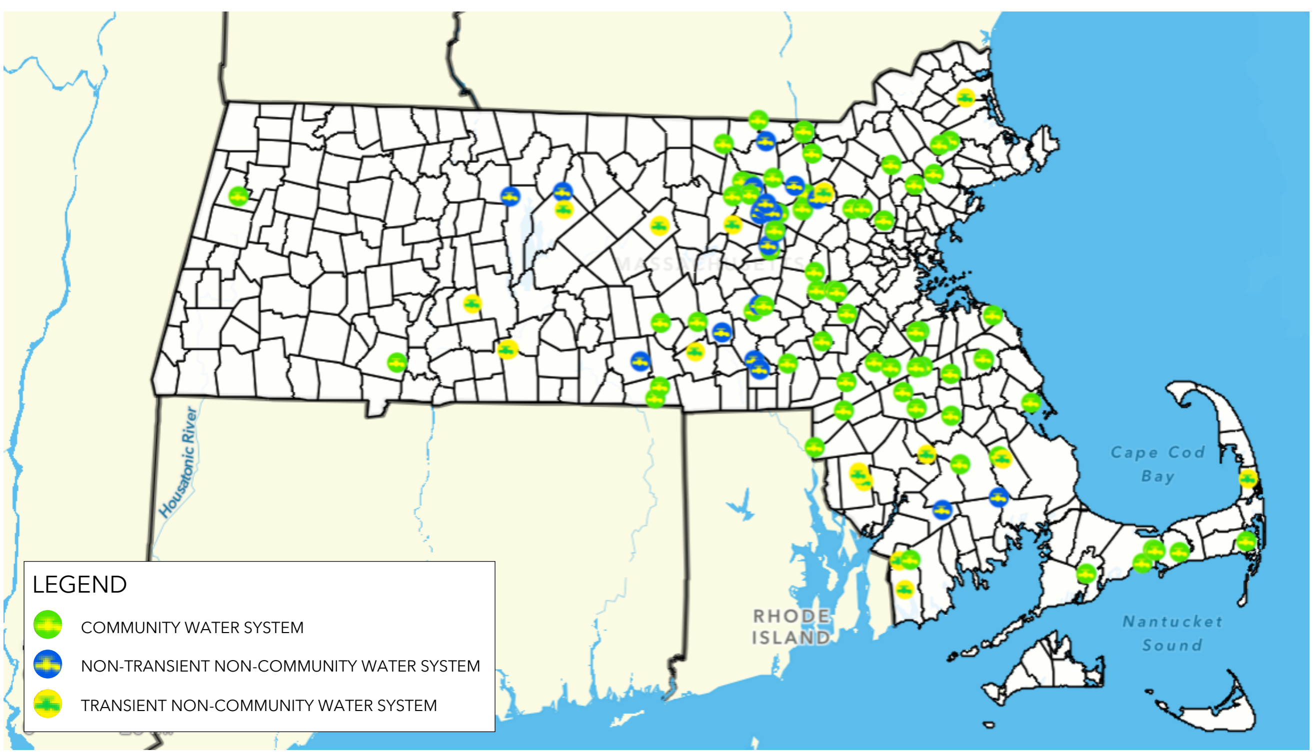
Under these final regulations, facilities subject to TURA that manufacture or process at least 25,000 lb/year or use at least 10,000 lb/year of Certain PFAS NOL will be required to track their use beginning in 2022 and report their use by July 1, 2023.

DETECTION

Public Water Systems

In January 2021, large PWSs serving 50,000 residents or more were required to begin testing for PFAS and smaller PWSs began testing later in the year. MassDEP has sampled over 1,000 PWSs, including the 25 largest PWSs in the state. While most PWSs did not report levels of PFAS6 greater than 20 ppt, 127 PWSs detected levels of PFAS6 exceeding the MCL as of April 5, 2022.[90] Seventy-seven of these PWSs are community water systems, 29 are non-transient, non-community water systems, and 21 are transient, non-community water systems. The MCL only applies to community water systems and non-transient, non-community water systems. Transient, non-community water systems are required to collect, analyze, and report the results of one PFAS sample from each sampling point by September 30, 2022 and an individual health risk assessment may be performed. Community water systems are defined as PWSs that "serve at least 15 service connections used by year-round residents or regularly serve at least 25 year-round residents." Non-transient, non-community water systems include workplaces, schools, and hospitals. Transient, non-community water systems include restaurants, parks, and motels. MassDEP is currently working with over 20 community and municipal water systems to bring them into compliance with the MCL.

Figure 2. Massachusetts PWSs that detected PFAS6 over the MCL in their finished water



Source: MassDEP. Accessed April 5, 2022.

Private Wells

More than 500,000 Massachusetts residents rely on private wells for drinking water.[91] Private wells typically serve a single residence and are regulated by local boards of health rather than MassDEP. Private wells located near sites that potentially release PFAS into groundwater, such as waste disposal and firefighting training sites, are at risk for PFAS contamination. In partnership with municipal officials, local boards of health, and the University of Massachusetts Amherst, MassDEP launched the Private Wells PFAS Sampling Program in November 2020. The program offers free PFAS sampling and analysis for 85 towns where 60% or more of residents rely on private wells. MassDEP selected approximately 40 private wells in each town for sampling and analysis, and private well owners could choose to participate in the program.

As of April 2022, the majority of the 1,194 well owners in 68 communities who have sampled and received results from the program had PFAS6 levels below 20 ppt. The following 21 communities had PFAS6 results over the MCL: Boxborough, Carlisle, Carver, Granby, Harvard, Holland, Lakeville, Leverett, Nantucket, Newbury, Pelham, Rehoboth, Rochester, Sherborn, Shutesbury, Stow, Tyngsborough, Wellfleet, West Tisbury, Westhampton, and Westport. For private wells with PFAS6 results from 20 ppt to 90 ppt, MassDEP and UMass Amherst will provide technical assistance to the private well owner and inform the local board of health and MassDEP Bureau of Waste Site Cleanup of the results. PFAS6 results over 90 ppt will prompt follow-up from MassDEP Bureau of Waste Site Cleanup.[92] Properties that are not the source of contamination are granted Downgradient Property Status and owners will not be held liable by MassDEP. Under Chapter 21E and the MCP, if private property is found to be the source of contamination, owners may be responsible for the cost of sampling and installation of treatment systems in impacted homes.[93] However, MassDEP considers this to be an unusual circumstance.

DPH responds to individual and community-level concerns about health risks from PFAS exposure through private well water. DPH also develops PFAS educational materials for primary care providers responding to PFAS concerns from their patients.[94]

Surface Water

In 2020, MassDEP partnered with the United States Geological Survey (USGS) to assess PFAS in 27 Massachusetts rivers. Samples were taken from 64 sites that were located upstream or downstream of WWTPs, downstream of possible nonpoint and industrial sources, and at locations with no known PFAS sources. USGS detected PFAS in all the rivers that were sampled, with the highest concentrations found in sites downstream of WWTPs. Of the 24 individual PFAS tested, including PFAS6, an average of 10 PFAS were detected in the samples. Forty-one sites had concentrations greater than 50 ppt for the sum of all 24 PFAS tested and 43 sites had PFAS6 concentrations greater than 20 ppt. All seven communities that rely on the rivers for public drinking water are in compliance with MassDEP's MCL of 20 ppt for PFAS6.

Recreational Waterbodies and Recreationally Caught Fish

In 2021, DPH conducted pilot testing for PFAS in surface water in 16 waterbodies and for PFAS in fish in five waterbodies on Cape Cod. These waterbodies were selected for pilot testing due to their proximity to Joint Base Cape Cod, where PFAS have been detected in groundwater and surface water as a result of historical releases of PFAS, and for their levels of recreational activities, such as swimming and fishing.

DPH did not detect PFAS at levels that are currently considered unsafe for swimming or recreational activities in the 16 waterbodies that were tested.[95] DPH detected elevated levels of PFAS in fish that were sampled from Johns Pond in Mashpee, Flax Pond (Picture Lake) in Bourne, Jenkins and Grews Ponds in Falmouth, and Mashpee-Wakeby Pond in Mashpee and Sandwich. Following the detection of elevated PFAS in fish, DPH provided outreach to the affected Cape communities, which included coordinating with local health departments, the Mashpee Wampanoag tribe, and local advocacy groups. Through pilot testing, DPH derived screening values for PFAS fish consumption advisories and for evaluating health risks from recreational activities. DPH also coordinated with the Department of Marine Fisheries on an approach to sample shellfish for site-related contamination in Bourne.[96]

Exposure Assessment in Hampden County, Massachusetts

In 2019, CDC and the Agency for Toxic Substances and Disease Registry (ATSDR) began conducting exposure assessments in communities that have detected PFAS in their drinking water and are located near current or former military bases. ATSDR selected Hampden County as a site for assessment due to the use of AFFF at the Barnes Air National Guard Base and the detection of PFAS in drinking water in Westfield as early as 2013. Even though the drinking water in Westfield has met EPA's health advisory and MassDEP's MCL since 2018, the purpose of the exposure assessment is to measure PFAS in the bodies of individuals who have been exposed to PFAS. Using blood samples from a random selection of households that have been exposed to PFAS in drinking water, ATSDR compared serum levels for seven PFAS among residents of Hampden County to the U.S. population. ATSDR found that 92% of participants in the exposure assessment had blood levels of PFHxS higher than the national average, 67% had PFOA levels above the national average, and 61% had PFOS levels above the national average.[97]

DPH responded to individual and community-level concerns about health risks from previous exposures to water contaminated with PFAS. DPH also reviewed, analyzed, and reported health outcome data, including cancer incidence data, and developed PFAS educational materials to train primary care providers responding to patient concerns about PFAS.[98]

Mosquito Pesticide and Pesticide Containers

In December 2020, Public Employees for Environmental Responsibility (PEER), a non-profit organization dedicated to environmental protection, detected PFAS in the pesticide Anvil 10+10, which is used for mosquito control in Massachusetts.[99] EPA and MassDEP detected PFAS in the fluorinated HDPE containers used to store and transport the mosquito pesticide product and determined that these containers are a source of PFAS in certain mosquito pesticide products.[100] In response to these findings, the manufacturer of Anvil 10+10 recalled products stored and transported in fluorinated containers and switched to non-fluorinated containers, which MassDEP determined do not contain detectable levels of PFAS. State agencies determined that application of the pesticides with detectable levels of PFAS prior to recall did not present a significant risk to water supplies and public health in Massachusetts.[101] Since Spring 2021, MassDEP has been working with the Massachusetts Department of Agricultural Resources to test additional pesticide products.

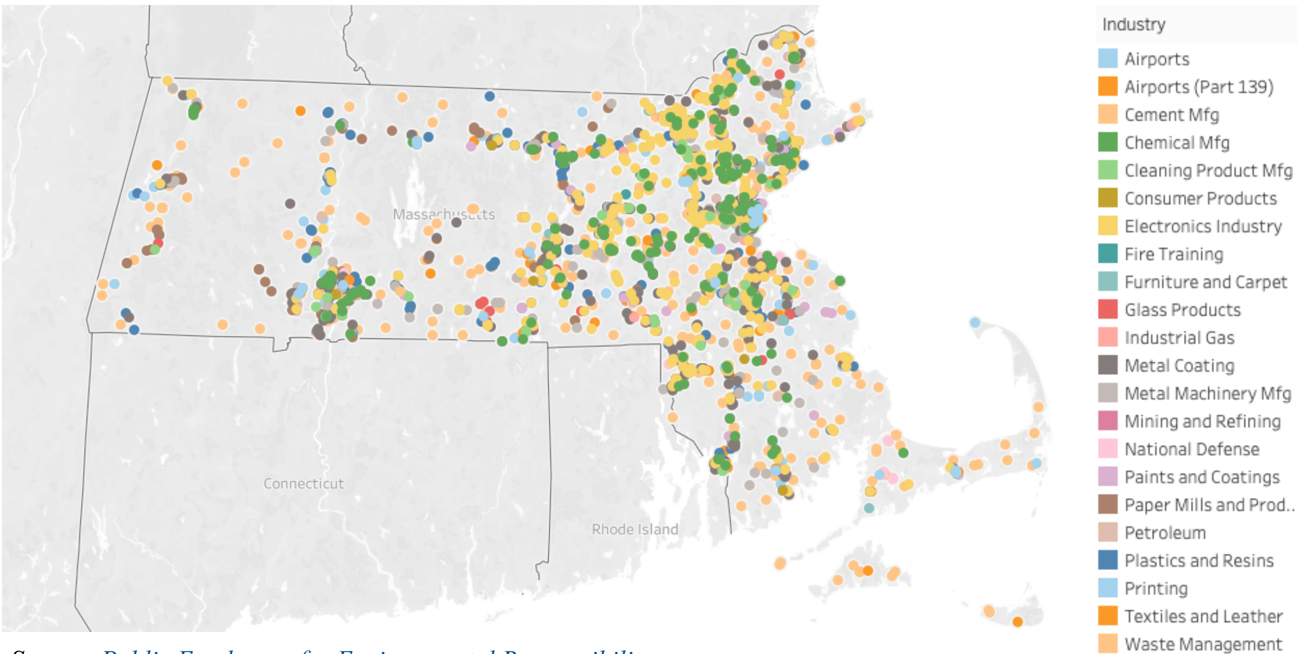
On July 20, 2020, Governor Baker signed An Act to Mitigate Arbovirus in the Commonwealth, which created the Mosquito Control for the Twenty-First Century Task Force (MCTF). MCTF was charged with studying mosquito control processes established under Chapter 252 of the Massachusetts General Laws, including the use of pesticides containing PFAS, and recommending reforms to the state's mosquito control system. On April 1, 2022, MCTF submitted recommendations to the Legislature. Recommendation PS-7 focuses on avoiding the use of pesticides that contain PFAS and other emerging contaminants by directing the Massachusetts Pesticide Board Subcommittee, or the appropriate entity that reviews and registers mosquito pesticides for use in the state, to use available analytical methods to ensure pesticides registered in Massachusetts are not contaminated with PFAS or emerging contaminants of concern. MCTF also recommends preventing the sale or use of mosquito pesticides contaminated with PFAS or emerging contaminants of concern.[102]

SOURCES OF CONTAMINATION

MassDEP has identified numerous sites with known or potential releases of PFAS across the state, including military installations, airports, fire training academies, and commercial properties. See Appendix G for a list of sites with reportable releases of PFAS. Use of AFFF for training, maintenance exercises, and emergency responses is currently considered the primary source of contamination at military installations, airports, and fire training academies. In instances where these sites have been identified as the sources of PFAS contamination in nearby water supplies, groundwater, and soil that exceed standards set by the state, these sites have been held financially responsible for PFAS remediation. There are many water supplies with PFAS levels exceeding the MCL for which sources of contamination have not been identified.

Manufacturers can release PFAS into the environment through the use and disposal of PFAS in the production process. In 2021, PEER sued EPA for access to the agency's list of known or potential sources of PFAS contamination.[103] According to data obtained from EPA, Massachusetts has over 2,000 manufacturing facilities that are known or potential sources of PFAS.[104] The inclusion of military installations, airports, waste management facilities, and fire training academies brings the total number of facilities to over 2,600. Approximately 400 facilities are located within a three-mile radius of areas where minority residents comprise 40% of the population, which meets the Massachusetts criteria for an Environmental Justice population. The industries with the greatest number of facilities on this list are electronics, waste management, metal coating, metal machinery manufacturing, plastics and resins, printing, and chemical manufacturing.

Figure 3. Facilities that "may be handling PFAS" in Massachusetts



Source: Public Employees for Environmental Responsibility

FUNDING

In response to the detection of PFAS in drinking water, Massachusetts appropriated $8.4 million in funding for the testing and treatment of PFAS contamination in drinking water systems through supplemental budgets in the Acts of 2019 and Acts of 2020. MassDEP has administered two rounds of grant funding to support the design of drinking water treatment systems in communities impacted by PFAS. $5 million has been awarded to 27 PWSs. Funding also supports private well PFAS sampling and analysis, which was offered by MassDEP at no cost for communities where 60% or more of residents rely on private wells. The Baker-Polito Administration allocated an additional $2.3 million in grant funding to impacted PWSs. MassDEP will administer this grant funding through the Interim PFAS6 Response Grant Program. Communities impacted by PFAS are eligible to receive reimbursement for costs already incurred for ongoing PFAS remediation.

In addition to the $8.4 million appropriated for PFAS testing and treatment, $20 million was appropriated to the Massachusetts Clean Water Trust (the Trust) to address PFAS contamination. The Trust collaborates with MassDEP to provide low-interest loans to municipalities and other eligible entities for water quality improvement projects through the Massachusetts State Revolving Funds (SRF). In 2020, the Board of Trustees approved a pilot program that provides 0% interest loans through the Drinking Water State Revolving Fund (DWSRF) for PWSs conducting PFAS remediation projects. The Board approved expansion of the program to Clean Water State Revolving Fund projects in 2021. In coordination with MassDEP, the Trust intends to apply approximately $21.3 million in American Rescue Plan Act (ARPA) funds, made available to the Trust by Chapter 102 of the Acts of 2021, to 10 PFAS remediation projects in the 2021 DWSRF Intended Use Plan. These funds will be provided as loan forgiveness, i.e. grants, and are on top of the principal forgiveness that is awarded by the DWSRF to Disadvantaged Communities.

The Trust established a formal DWSRF Disadvantaged Communities program to provide additional subsidies to communities most in need of financial assistance based on an Adjusted Per Capita Income (APCI) metric.[105] The Trust and MassDEP use per capita income, employment rate, and population change to calculate affordability tiers annually.

Communities with APCI less than 100% of the State APCI are considered “Disadvantaged Communities” and are assigned to one of the following three affordability tiers: Tier 3 communities with APCI less than 60% of the State APCI receive the highest level of subsidy; Tier 2 communities with APCI between 60% and 80% of the State APCI receive the second level of subsidy; and Tier 1 communities with APCI between 80% and 100% of the State APCI receive the third level of subsidy.[106]

In 2018, MassDEP administered the AFFF Take-Back Program in partnership with the Department of Fire Services (DFS) to assist local fire departments in identifying and disposing of firefighting foam containing PFAS. Through the first round of the program, MassDEP worked with 105 fire departments to identify, collect, and dispose of 221,172 pounds of firefighting foam containing PFAS. This effort cost approximately $213,000 and was supported by Massachusetts Chapter 21E/ Bureau of Waste Site Cleanup capital funding.

Beginning in Fiscal Year 2021, Massachusetts appropriates $1.2 million annually to DPH’s Bureau of Environmental Health budget for health-related work on PFAS and other emerging contaminants. This funding provides capacity for sampling and testing of PFAS in surface water and fish, planning for testing in bottled water, and planning for an electronic data management system for emerging contaminants.

CASE STUDIES

Hudson, Massachusetts

The Town of Hudson is served by a combination of surface water drawn from a local reservoir and groundwater that is pumped from four different wells and treated for iron and manganese. During peak water usage in the summers, the Department of Public Works (DPW) distributes 3.2 million gallons of water daily. In January 2019, PFAS testing in Hudson's public water supply returned results over 70 ppt, exceeding EPA's health advisory. The Town worked closely with MassDEP to trace the water with elevated PFAS levels to Cranberry Well, Hudson's largest contributing well, which was immediately shut down. MassDEP notified two responsible parties for the contamination: Precision Coating, a medical coating applicator company, and Boyd Coating, which occupied the building before it was acquired by Precision Coating in 2016. PFAS were introduced into groundwater through the company's septic system and into the air through the heating, ventilating, and air conditioning system. The Town negotiated a settlement with the responsible parties, which included funding from Precision Coating to distribute bottled water to Hudson residents and to construct a temporary PFAS filtration system at the Cranberry Well.

The PFAS filtration system funded by Precision Coating at the Cranberry Well site features four vessels to filter the water before it enters the town's treatment system. The system uses carbon-based filters to separate PFAS from the water and was one of the first of its kind in Massachusetts. Hudson also worked with engineering consultants to design and build a temporary PFAS filtration system at its main water filtration system on Chestnut Street. The temporary PFAS filtration system is similar to the system at Cranberry Well but with resin filters, which cost the town between $320,000 and $360,000 to replace each year. Hudson currently spends $68,000 to send the used resin filters to Ohio for disposal.

The Town had to overcome several steep funding and permitting challenges in order to quickly implement the temporary resin-based filtration system, and was fortunate to have support from MassDEP. The Select Board agreed to fund the temporary filtration system and spend $991,000 to design a new treatment plant. One of the biggest hurdles that the Town faced was working within Massachusetts procurement guidelines set by the Division of Capital Asset Management and Maintenance (DCAMM). With assistance from MassDEP, the Town was able to secure an emergency procurement waiver from DCAMM, which allowed the town to bypass DCAMM guidelines for soliciting contractors and other construction necessities and lowered the total cost for the Cranberry Well filtration system by $800,000. DPW was also able to secure a lease on a filtration system from Evoqua, for which MassDEP granted critical temporary approval.

The new water filtration system at Chestnut Street Water Filtration Plant in Hudson

Source: Hudson Department of Public Works

The filtration systems were installed by July 2019, and no PFAS have been detected in the treated water since. Hudson is now preparing to upgrade the temporary filtration system at Chestnut Street to a permanent PFAS treatment system similar to the system at Cranberry Well. The Town has faced challenges finding qualified contractors, securing waivers for PFAS procurement that are typically for emergency use only, and securing funds for carbon change-outs. Although Hudson has received assistance through SRF loans and other grants, efforts to address PFAS contamination have impacted ratepayers. Water rates have increased by 21% for each of the past two years and will increase again by 16% next year. As more towns begin to address PFAS contamination and the demand for testing and remediation increases, town officials anticipate issues with procurement, lab access, and increased expenses for testing. Town officials are also concerned that state and federal regulations will change, rendering current systems out-of-date.

Easton, Massachusetts

The majority of residents in the Town of Easton receive their drinking water from a PWS that is sourced from seven groundwater wells. In 2014, Easton tested its drinking water under EPA's Third Unregulated Contaminant Monitoring Rule and registered "non-detect" for PFAS using an approved analytical method that was less sensitive than those currently required. This result was expected due to the absence of known releases of PFAS in or near the Town. During a well replacement in 2019, MassDEP required Easton to test for PFAS using the current, more sensitive analytical methods. The test returned results of 15.6 ppt at the replacement well and further testing detected PFAS in other wells throughout the Town.

Since PFAS testing in Easton occurred before MassDEP established the MCL of 20 ppt for PFAS6, there was no regulatory framework for public notice requirements that the Town could use as guidance. To notify residents, town officials published a notice of the test results on the Town's website and worked with MassDEP to run a broader public education campaign. At

Easton Water Commissioners Meeting on November 18, 2019

Source: Town of Easton

the first public meeting in November 2019, the Town launched an in-home PFAS filter rebate program run through the water department. It was challenging for town officials to communicate with the public on a contaminant that was not regulated at the time and for which they had limited knowledge, but the Town persisted in keeping the public informed and moving forward with mitigation.

These early efforts to address PFAS contamination resulted in a PFAS response strategy that the Town continues to use today. Easton's PFAS response strategy is focused on the following three pillars:

1. Communicating what is known and unknown about PFAS to the public.
2. Educating the community on short-term and long-term options to address PFAS contamination.
3. Designing and funding PFAS mitigation.

Easton has faced several challenges in implementing interim measures to address PFAS contamination. Given the location of the wells and the demand they meet, the Town did not have the option to shut off the wells. While the in-home filter rebate program was considered innovative in 2019, the filters were tested to demonstrate that they meet EPA's health advisory of 70 ppt. Once MassDEP issued its MCL of 20 ppt, it was not clear if the in-home filters could meet the new standard. In response to the new MCL, Easton installed Blue Water Drop Filter Sites that provided free water to residents. The Town also established a 24/7 hotline and email for residents impacted by PFAS contamination. Given the limited bandwidth of the Easton Water Division, with just nine staff serving 25,000 residents, the Town had to contract with a third party to provide 24/7 support. The annual cost to run the Blue Water Drop Filter Sites and the 24/7 hotline is approximately $86,000.

Easton developed long-term solutions to PFAS contamination in tandem with the implementation of short-term measures. MassDEP grant funding has provided $200,000 to Easton to advance these efforts. To meet the design and construction costs associated with treatment, Town Meeting in 2021 approved $9.2 million of local funding to construct up to three GAC treatment plants for three wells, which town officials anticipate will be constructed by June 2023. The Town also received a $2 million earmark from the state's ARPA distribution. The Town is constructing a green sand plant for three other wells that currently do not have PFAS levels exceeding the MCL. The plant will be designed to be "PFAS ready" with sufficient space for a GAC treatment plant should PFAS levels rise or regulatory thresholds change.

Easton is funding the bonds for these treatment plants with water user fees, which town officials expect to increase by 10% each year for the next three to five years. Over the course of five years, the average household can expect their annual water costs to increase by a total of $250. Following local funding approval, the Town joined multi-district litigation suing chemical manufacturers for the costs to mitigate PFAS contamination.[107]

Barnstable, Massachusetts

Barnstable is the largest town on Cape Cod with a year-round population of approximately 49,000 residents. Like other towns on Cape Cod, Barnstable draws its drinking water from a sole-source aquifer through private and public wells. Due to this unique geology, the aquifer is especially vulnerable to PFAS contamination from sources such as the Cape Cod Gateway Airport and a regional Fire Training Academy. Both of these sites have used AFFF and are located near 11 public water supply wells.

Secondary pathways for PFAS to accumulate and contaminate groundwater and drinking water supplies include septic systems, which most residential properties in Barnstable utilize, and the town sewer system, both of which received PFAS-contaminated water in the past. Wastewater from the town sewer system is sent to Barnstable Water Pollution Control Facility, which does not treat wastewater for PFAS due to lack of existing remediation technology for wastewater.

Barnstable Fire Training Academy

Source: [CapeCodFD.com]()

PFAS have been detected in 18 public supply wells in Barnstable at levels exceeding MassDEP's MCL of 20 ppt and in nine supply wells above EPA's health advisory of 70 ppt. The Hyannis Water System and Centerville-Osterville-Marston Mills (COMM) Water District, two of the five public water supply districts in Barnstable, are treating its drinking water for PFAS6. The treated water now registers non-detect levels for all tested PFAS. The Hyannis Water System installed activated carbon treatment systems at 11 wells, which incurred capital costs of $22 million and annual operating costs of approximately $800,000. This has resulted in significant rate increases for users of the PWS, which include EJ communities. Barnstable also established a permanent interconnection with the Town of Yarmouth and COMM Water District to use as interim sources until treatment could be installed. To address potential additional PFAS contamination in the future, Barnstable has begun including language in all municipal purchasing documents requesting PFAS-free products.

Barnstable has been investigating additional sources of groundwater supply. Of the three most promising new sources under consideration, the source that would yield the most water would require treatment for PFAS. Contamination is so widespread that the town is considering the development of a contaminated source and factoring in the cost of PFAS treatment to make a final decision on a new source of groundwater supply.

LEGISLATION

The following PFAS-related bills have been filed in the 192nd General Court of the Commonwealth of Massachusetts:

H.2350 S.1387	An Act restricting toxic PFAS chemicals in consumer products to protect our health	Rep. Jack Lewis Sen. Jo Comerford
H.985 S.624	An Act studying the effect of per- and polyfluoroalkyl substances in commercial products	Rep. Kelly Pease Sen. John Velis
H.2475 S.1576	An Act relative to the reduction of certain toxic chemicals in firefighter personal protective equipment	Rep. James Hawkins Sen. Diana DiZoglio
H.937 S.556	An Act providing for the public health by establishing an ecologically based mosquito management program in the Commonwealth	Rep. Tami Gouveia Sen. Adam Hinds
H.878 S.517 S.610	An Act to save recycling costs in the commonwealth	Rep. Michael Day Sen. Sal DiDomenico Sen. Michael Rush
H.2348	An Act to ban the use of PFAS in food packaging	Rep. Jack Lewis
H.960	An Act relative to proper disposal of products containing PFAS	Rep. James Kelcourse Rep. Lenny Mirra
H.3836	An Act prohibiting disposal by incineration of certain aqueous film-forming foam	Rep. Thomas Golden
S.1494	An Act relative to chemicals in food packaging	Sen. Michael O. Moore
S.593	An Act to protect the Commonwealth from toxic chemicals	Sen. Susan Moran
S.207	An Act relative to toxic-free kids	Sen. Cindy Friedman
S.2655	An Act establishing a moratorium on the procurement of structures or activities generating PFAS emissions	Sen. Marc Pacheco

LEGISLATIVE & REGULATORY LANDSCAPE

In recent years, states have led the way in addressing PFAS contamination. Many states have proposed and passed legislation to regulate PFAS in drinking water, fund PFAS testing and remediation, and limit the use of PFAS in consumer products and firefighting foam. States are beginning to hold PFAS manufacturers financially accountable for the impact of PFAS on public health and the environment. The federal government is addressing PFAS contamination by funding research, adding certain PFAS to the Toxics Release Inventory, and drafting regulations, among other actions. Around the world, governments are beginning to regulate certain PFAS and a handful of countries are planning to propose the regulation of PFAS as a class.

STATE ACTION

Drinking Water

Since EPA has not issued a federal drinking water standard for PFAS, 16 states, including Massachusetts, have taken steps to regulate PFAS in drinking water. These states have established enforceable drinking water standards that require PWSs to treat drinking water if PFAS levels exceed the MCL. Generally, states have established MCLs that are stricter than EPA's lifetime health advisory of 70 ppt for PFOS and PFOA. State MCLs vary as to the concentration of PFAS in drinking water, the specific PFAS included in the MCLs, and whether the MCLs apply to individual PFAS or a sum of multiple PFAS. New Hampshire, which was among the first states to regulate PFAS in drinking water, set MCLs of 15 ppt for PFOS, 12 ppt for PFOA, 11 ppt for PFNA, and 18 ppt for PFHxS. Vermont, on the other hand, established its MCL of 20 ppt for the sum of five PFAS: PFOS, PFOA, PFNA, PFHxS, and PFHpA. Other states that have established MCLs for PFAS include Maine, New York, New Jersey, and Michigan.

Some states without MCLs have issued guidance and notification levels for PFAS. Minnesota, Ohio, and North Carolina have established recommendations for PFAS concentration limits in drinking water. However, these states do not require action to be taken if the recommended limit is exceeded. California and Connecticut are among the states that require notification to state officials that PFAS concentrations in drinking water sources exceed state-issued limits. Virginia, which does not have PFAS guidance or notification levels, passed a bill in 2020 that directs the State Board of Health to review MCLs in other states and to adopt regulations establishing MCLs no higher than EPA's health advisory for PFAS in public drinking water systems.

Consumer Products

PFAS are used in a wide range of consumer products due to the chemical properties that make them resistant to water, oil, grease, and heat. Products that frequently contain PFAS include non-stick cookware, food packaging, stain-resistant coating on carpets and other fabrics, and water-resistant clothing. Several states, including New York, Washington, and Maine, have enacted laws to protect consumers by prohibiting the use of PFAS in food packaging, and many more states have proposed similar bills. Some bans are contingent on the availability of a safer alternative to PFAS while others are not. New York requires manufacturers of children's products to notify sellers if the products contain certain chemicals, including PFOS and PFOA. Maryland and California have enacted laws to prohibit the manufacturing and sale of cosmetic products that contain certain chemicals, including PFOS, PFOA, and PFNA.

In July 2021, Maine passed a law to prohibit the sale of any products that contain intentionally added PFAS by 2030. The law sets an earlier deadline of 2023 for banning the sale of fabric treatments, carpets, and rugs that contain intentionally added PFAS. Products can be exempted from the ban if the Maine Department of Environmental Protection has determined by rule that use of PFAS in the product is unavoidable. The law also requires manufacturers of products for sale that contain intentionally added PFAS to submit written notification to the Maine Department of Environmental Protection beginning in 2023.

In March 2022, Washington passed a law that directs the Washington Department of Ecology to determine regulatory action and adopt rules to address PFAS in priority consumer products, as identified in the PFAS chemical action plan, by December 1, 2025. Priority consumer products include firefighting personal protective equipment and apparel.

Regulating PFAS as a Class

Maine and California are currently the only two states that regulate PFAS as a class in consumer products. In Maine's law to prohibit the sale of any products that contain intentionally added PFAS by 2030, PFAS is defined as "any member of the class of fluorinated organic chemicals containing at least one fully fluorinated carbon atom." California recently passed four laws regulating PFAS in children's products, food packaging, and recycling, which use the same definition of PFAS as a class as Maine. Both states have carved out exemptions for specific essential uses of PFAS, such as medical devices, as determined by their respective regulatory bodies.

Firefighting Foam and Turnout Gear

Many states have passed laws to minimize the release of AFFF into the environment. Washington, Maryland, Michigan, and New Hampshire have enacted laws that prohibit the use of firefighting foam containing PFAS for testing and training purposes. Michigan requires fire departments to report the use of firefighting foam containing PFAS to the state's pollution emergency alert system. State lawmakers are also addressing disposal of AFFF. Michigan requires the Department of Environment, Great Lakes, and Energy to establish a collection program for firefighting foam containing PFAS. The program must accept and properly dispose of firefighting foam containing PFAS free of charge. New York passed a law in 2020 to suspend incineration of firefighting foam containing PFAS in the City of Cohoes, where DOD contracted with a local facility to incinerate AFFF.

California and Washington require sellers of personal protective equipment to provide written notice to purchasers if the equipment contains intentionally added PFAS. In 2022, Washington designated firefighting personal protective equipment as a priority consumer product for the purposes of regulation under the Safer Products for Washington program. A group of Massachusetts firefighters recently filed suit in the United States District Court for the District of Massachusetts seeking relief as a result of PFAS exposures from AFFF and their turnout gear.[108]

Landfills, Wastewater, and Biosolids

The disposal of products containing PFAS and PFAS precursors in landfills serves as a potential pathway for PFAS to enter waste streams, drinking water supplies, and the environment. PFAS have been detected in wastewater influent and effluent. To address this issue, Rhode Island proposed legislation to direct the Department of Environmental Management to adopt standards for monitoring PFAS in groundwater and leachate around landfills. Minnesota appropriated $500,000 in fiscal year 2022 to implement an initiative to identify and reduce sources of PFAS that enter municipal WWTPs.

In 2019, Maine Department of Environmental Protection announced new testing requirements for land application of biosolids for three PFAS: PFOS, PFOA, and PFBS. Maine passed a law in 2021 that requires PFAS testing for soil and groundwater where sewer sludge has been used as fertilizer. On January 1, 2022, Maine established a "Land Contamination Monitoring Fund" that includes an annual $10 per ton handling fee for all biosolids land applied in the state. Other states are also establishing PFAS thresholds for biosolids.

Remediation

PFAS remediation activities, such as sampling, testing, treatment, and disposal, can be very costly for individuals and communities impacted by PFAS contamination. States have started appropriating funds to provide low-interest loans and grants for PFAS remediation projects. New Hampshire established the PFAS Remediation Loan Fund to provide up to $50 million in low-interest loans for PWSs and WWTPs to ensure compliance with the state's MCL. Disadvantaged communities in New Hampshire may be eligible for 10% loan forgiveness and 30-year loan terms. Connecticut and Florida have passed laws that appropriate funds for PFAS remediation at contaminated sites, and other states have introduced similar bills. Colorado created the PFAS cash fund, which supports the state's PFAS grant program and PFAS Takeback Program. Some funds are specific to sites impacted by certain categories of PFAS contamination, such as Maine's Land Application Contaminant Monitoring Fund.

Accountability

As individuals, communities, and states continue to pay for PFAS detection and remediation, some states are taking steps to hold manufacturers financially responsible for their role in PFAS contamination. New Jersey was the first state to issue a directive that requires five chemical companies — Solvay, DuPont, Dow DuPont, Chemours, and 3M – to assess the extent of damage from PFAS contamination and to establish a fund for PFAS remediation efforts. New Hampshire recently introduced a bill to require Saint Gobain Performance Plastics to pay for ongoing remediation of water in certain wells that the company had contaminated with PFAS, as determined by the New Hampshire Department of Environmental Services. Maine is the first state to establish a statute of limitations specific to PFAS personal injury and property damage claims. The law clarifies that plaintiffs can file claims within six years of discovering PFAS harm or injury. Other states are considering similar bills.

States are pursuing legal action against manufacturers and other parties responsible for PFAS contamination in drinking water and the environment. New York and Vermont have filed lawsuits against chemical manufacturers for their role in PFAS production. In 2018, Minnesota settled its lawsuit against 3M for $850 million and plans to spend $700 million on 14 communities impacted by PFAS pollution from 3M. The settlement is used to fund projects such as creating new drinking water treatment plants and public wells, treating private wells, and connecting homes to municipal water supplies. In 2021, Delaware reached a settlement agreement with DuPont, Chemours, and Cortova. The chemical manufacturers will pay a total of $50 million to the state. The funds will be administered by the Delaware Department of Natural Resources and Environmental Control for a range of PFAS remediation projects.

FEDERAL ACTION

U.S. Environmental Protection Agency

As the agency tasked with protecting the American people from environmental pollution, EPA has taken steps to understand and reduce exposure to PFAS. In 2016, EPA established a lifetime health advisory of 70 ppt for PFOS and PFOA in drinking water. EPA currently requires certain facilities covered under the Toxics Release Inventory (TRI) program to report data on how they are managing chemical waste. Over 170 PFAS have been added to TRI through the National Defense Authorization Act since 2020. Under the Toxic Substances Control Act (TSCA) New Chemicals Program, EPA evaluates toxicity and bioaccumulation of new substances and substitutes for long-chain PFAS.

In 2019, EPA released the PFAS Action Plan, which outlines short-term and long-term action items that the agency is taking to address PFAS. The Action Plan includes steps to collect new data on PFAS, institute reporting requirements for manufacturers and importers of PFAS and products containing PFAS, issue guidance for disposal of PFAS and non-consumer products with PFAS, establish limits on PFAS in wastewater discharge, and authorize the agency to require responsible parties to clean up PFAS or pay for PFAS remediation.

In October 2021, EPA released its PFAS Strategic Roadmap to build on the work laid out in the PFAS Action Plan from 2019. The Safe Drinking Water Act authorizes EPA to establish enforceable National Primary Drinking Water Regulations (NPDWR) for contaminants in public drinking water systems. The agency is developing NPDWR for PFOS and PFOA, and anticipates issuing proposed regulations in Fall 2022. Since there is limited toxicity data for most PFAS, EPA is developing a national PFAS testing strategy using categories of PFAS. Under TSCA, EPA is authorized to require PFAS manufacturers to conduct and fund the studies. In addition to collecting toxicity data, EPA plans to enhance industry reporting on PFAS collected through TRI by proposing rulemaking to categorize existing PFAS on the TRI list as "Chemicals of Special Concern" and to add more PFAS to TRI. Other steps the agency has taken to address PFAS since 2019 include the implementation of a rigorous review process for new PFAS and the development of a new validated method to measure up to 40 PFAS in eight environmental media. EPA toxicologists have developed health risk-based screening levels and/or reference doses for particular PFAS compounds, including PFBS, GenX, and PFBA.

The Safe Drinking Water Act requires EPA to issue, every five years, a list of unregulated contaminants that must be monitored by PWSs that serve over 10,000 people and a subset of PWSs that serve fewer than 10,000 people. In December 2021, EPA published its Unregulated Contaminant Monitoring Rule 5 (UCMR 5), which requires PWSs to collect samples for 29 PFAS between January 2023 and December 2025 using EPA Method 537 or 537.1.[109] The purpose of UCMR 5 is to collect data on the presence and concentration of these 29 PFAS in drinking water across the country and to support science-based decision-making. In July 2021, EPA published the Draft Fifth Drinking Water Contaminant Candidate List and proposed listing PFAS as a chemical group rather than as individual chemicals.

Agency for Toxic Substances and Disease Registry

ATSDR is a federal public health agency under the U.S. Department of Health and Human Services that has been investigating PFAS exposure since 2010. The agency currently has 28 active PFAS projects to identify sites where people have been exposed to PFAS, study the extent of and health impacts of PFAS exposure, and develop strategies to prevent or reduce exposure. In 2018, ATSDR was tasked with conducting exposure assessments in communities near current or former military sites with high levels of PFAS in drinking water, including Hampden County, Massachusetts, where the Barnes Air National Guard Base is located. Preliminary results show that residents of Hampden County have higher blood serum levels of PFOS, PFOA, and PFHxS compared to the national average.[110] ATSDR is currently conducting a multi-site study in collaboration with seven research partners to examine the relationship between PFAS exposure and health outcomes in differing populations and at differing levels of exposure. One of the research partners is Silent Spring Institute, a non-profit scientific research organization based in Massachusetts. The organization will study PFAS exposure in Hyannis and Ayer, Massachusetts.

In 2018, ATSDR developed minimal risk levels (MRLs) for certain PFAS. As a screening tool, MRLs are set below exposure levels that may cause adverse health effects in vulnerable populations. The MRL for oral exposure over an intermediate duration (15 to 364 days) for PFOS is 2×10^{-6} mg/kg/day, 3×10^{-6} mg/kg/day for PFOA and PFNA, and 2×10^{-5} mg/kg/day for PFHxS.[111] There is currently insufficient data to derive MRLs for other PFAS and different routes of exposure.

U.S. Department of Defense

Since the 1960s, the military has used AFFF containing PFAS for fuel fires and spills, training exercises, hangar system operations and testing, and emergency response actions. The release of PFAS into the environment has increased the risk of PFAS exposure through drinking water for communities near military sites, as well as service members and their families. In response to EPA's lifetime health advisory for PFOS and PFOA, DOD started limiting the use of AFFF to emergency responses and no longer allows the use of AFFF for testing and training.[112] DOD is actively seeking fluorine free foam alternatives to AFFF.

In 1986, DOD established the Defense Environmental Restoration Program to investigate known or suspected PFAS releases at military installations, take short-term removal actions in instances where there is an immediate need to address PFAS contamination, and initiate long-term remedial actions for PFAS cleanup. DOD has identified nearly 700 installations with known or suspected PFAS releases.[113] In Fiscal Year 2020, DOD obligated $242.5 million to investigate PFAS releases and $28.3 million to clean up PFAS. DOD has initiated response actions at installations with PFAS levels at or above EPA's 70 ppt health advisory. These actions include providing alternative sources of water, installing treatment systems, and connecting homes with private wells to public drinking water systems. In December 2021, DOD issued guidance that recognized the role of state-promulgated drinking water standards, cited as "Applicable or Relevant and Appropriate Requirements," in facility cleanups. This includes DOD-funded removal actions where there is an immediate need to address a substantial threat to public health.[114]

Congress and the Biden Administration

Lawmakers have introduced over 30 PFAS-related bills in the 117th Congress. Among these bills are the PFAS Action Act of 2021, which the House passed in July 2021 with support from Congresswoman Lori Trahan (MA-03), and the PFAS Accountability Act. The PFAS Action Act of 2021 would expedite EPA regulatory action on PFAS. These regulatory actions include designating PFOS and PFOA as "hazardous substances" under the Comprehensive Environmental Response, Compensation, and Liability Act and as "hazardous air pollutants" under the Clean Air Act, conducting toxicity testing for PFAS under TSCA, and setting drinking water standards for PFOS and PFOA. The bill would also enact labeling requirements for products that are not PFAS-free and establish wastewater effluent regulations under the federal Clean Water Act. The PFAS Accountability Act would establish a federal cause of action for individuals with significant PFAS exposure to bring claims against PFAS manufacturers. The bill would allow courts to order medical monitoring if an individual or class has an increased risk of disease as a result of significant exposure to PFAS.

The American Rescue Plan Act of 2021 was passed by Congress and signed into law by President Biden on March 11, 2021. The $1.9 trillion stimulus package provides $350 billion to states, tribes, and local governments. The U.S. Department of the Treasury issued guidance that recipients of Coronavirus State and Local Fiscal Recovery Funds can use the funds for necessary investments in drinking water and wastewater infrastructure.[115] Eligible projects include building, maintaining, and upgrading drinking water systems and WWTPs. Recipients have the flexibility to determine high priority projects that are most relevant for their communities.

On November 15, 2021, President Biden signed the $1 trillion infrastructure bill into law. The Infrastructure Investment and Jobs Act provides $55 billion in grants and low-interest loans to states, tribes, territories, and disadvantaged communities for drinking water, wastewater, and stormwater infrastructure.[116] The law sets aside $10 billion for states to address PFAS in drinking water with a focus on underserved communities. Massachusetts is expected to receive a total of $13.5 billion from this law, of which $1 billion will be dedicated to water infrastructure projects.[117]

GLOBAL CONTEXT

International organizations, such as the United Nations, and governments around the world are beginning to regulate PFAS. The United Nations Conference of Parties has added PFOS and PFOA to the list of chemicals under the Stockholm Convention on Persistent Organic Pollutants. Signatories of the treaty are required to take action to eliminate the production and use of PFOA and to restrict the production and use of PFOS, with specific exemptions. Approved acceptable use exemptions for PFOA include invasive and implantable medical devices and firefighting foam in installed systems for class B fires. PFHxS is under consideration for listing.

The European Union regulates chemicals through Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), one of the strictest laws regulating chemical substances, and the European Chemicals Agency, which was established by REACH. REACH restricts the production and use of PFAS in the European Union for certain PFAS, including short-chain PFAS. The Council of the European Union has asked the European Commission to consider the development of an action plan to phase out non-essential uses of PFAS under an “essential use” framework. Leading PFAS researchers have published multiple statements recommending the regulation of PFAS as a group rather than as individual chemicals. Denmark, Germany, the Netherlands, Sweden, and Norway plan to propose a ban on PFAS as one class under REACH.[118]

CHALLENGES

Massachusetts faces many challenges that arise from the prevalence and complexity of PFAS contamination. These challenges include the high cost of PFAS testing and remediation, the presence of PFAS in wastewater and residuals, the lack of access to information on sources of contamination and industrial uses of PFAS, and the risk of regrettable substitutions for PFAS. Given the breadth of these challenges, there is a clear need for Massachusetts to develop a comprehensive, coordinated strategy that addresses PFAS along their entire lifecycle.

COSTS

Drinking Water

The cost of PFAS testing and remediation can be prohibitively expensive for many communities, PWSs, homeowners with private wells, fire departments, and other entities facing PFAS contamination. For EPA Method 537.1, each sample can cost over $200 to analyze, which does not include the cost of hiring a third party to develop a sampling plan and to collect the samples. Many sampling locations require the analysis of a sample and a field blank, which would double the cost of sampling. While MassDEP, DPH, and larger organizations have the ability to negotiate the cost of analyses with private labs, PWSs and individuals generally do not have the same negotiating power and end up paying higher prices for analysis. Many homeowners have expressed reluctance to test their private wells for PFAS due to concerns about the potential liability for contamination, the cost of remediation, and reduced property value.

On the municipal scale, the capital costs for a water treatment facility that processes 0.5 million gallons per day (MGD) is estimated to range from $2 million to $7 million with annual operation and maintenance costs of $40,000 to $150,000.[119] For a facility that processes 3 to 4 MGD, capital costs can range from $6 million to $14 million with annual operation and maintenance costs of $100,000 to $400,000. Short-term responses to PFAS contamination in drinking water are also costly. The provision of alternative drinking water, such as bottled water, can cost tens of thousands of dollars per week, depending on the size of the community.[120] Although Massachusetts offers low-interest loans to towns and cities through the SRF, municipalities must raise funds to pay these loans back to the state. Water rates in some impacted towns have increased by 10% to 20%, which disproportionately impacts low-income households.[121] Additionally, these SRF loans and other funding assistance do not cover annual operation and maintenance costs. Water systems, especially those with small rate bases, face significant challenges in funding treatment necessary to provide safe drinking water.

Wastewater and Biosolids

WWTPs are tasked with the disposal of treated effluent and byproducts of the treatment process. Options for removing PFAS from wastewater effluent are limited and not readily available. Currently, WWTPs can recoup some operating costs by selling and distributing biosolids as land applied fertilizer. Due to the presence of PFAS in wastewater, PFAS have been detected in biosolids. Maine has established limits for three PFAS in the land application of biosolids and Massachusetts requires WWTPs to screen for 16 PFAS. If the land application of biosolids is no longer an option due to federal or state regulations, WWTPs must find other methods to dispose of biosolids, such as landfilling or incineration. These alternatives are limited in their availability, are more expensive, and can contribute to the spread of PFAS.

AFFF

Due to current and historical use of AFFF, airports, fire departments, and fire training academies have been impacted by the cost of PFAS testing and remediation. In 2019, MassDEP sent requests to select airports in Massachusetts to investigate historical releases of AFFF. Beverly Airport spent approximately 30% of its total annual operating budget to comply with MassDEP's request and did not detect PFAS contamination exceeding the MCL. Nantucket Memorial Airport detected PFAS at levels exceeding MassDEP's MCL in water samples from the airport and in downgradient private wells. In addition to the cost of testing, Nantucket Memorial Airport is paying for the provision of bottled water to affected individuals and for the installation of 18 point-of-entry treatment systems in impacted wells. The airport has spent $5.2 million in PFAS-related costs, representing approximately one-third of its annual operating revenue.[122] In August 2021, Nantucket Memorial Airport filed a lawsuit against manufacturers of AFFF for monetary damages.

Through the AFFF Take-Back Program initiated in 2018, MassDEP has worked with 105 fire departments to identify, collect, and dispose of more than 200,000 pounds of firefighting foam containing PFAS. MassDEP paid for the collection and disposal of the foam while fire departments paid for replacement fluorine free foam. While MassDEP continues to provide this service to individual fire departments that request AFFF pick-up, there is limited funding to conduct another state-wide outreach campaign to search out remaining stocks of AFFF. MassDEP continues to work with DFS to reduce the use of AFFF for emergency response activities and to support methods to minimize potential environmental impacts when such use is unavoidable. Fire departments face cost barriers to decontaminating facilities and equipment exposed to AFFF and to purchasing fluorine free foam.

Industrial Use

As policymakers look upstream to reduce the production of PFAS and prevent PFAS contamination, businesses are beginning to investigate the removal of PFAS from their supply chain and manufacturing processes. In 2016, IKEA reported that the company had successfully phased out PFAS in all of its textile products. Other companies, including Levi Strauss & Co. and Crate & Barrel, have followed suit to phase out all PFAS.[123] While larger companies may have the resources to reduce their use of PFAS, smaller companies face more barriers in doing so. In Massachusetts, TURI and OTA provide resources and tools, such as training, industry grants to offset project costs, and research grants to find safer alternatives, to businesses to reduce their use of regulated toxic chemicals.

Externalities

PFAS manufacturers have largely eluded financial responsibility for the impacts of PFAS contamination. Instead, the burden of paying for PFAS detection and remediation has fallen on private citizens, PWSs, state and local governments, airports, and other entities that do not produce PFAS. The public continues to fund research to assess the risk of novel PFAS to human health and the environment, study the extent of PFAS contamination, and develop remediation technology.[124]

In addition to the direct costs of addressing PFAS contamination, there are indirect costs of health and environmental impacts. A study released by the Nordic Council estimates the annual direct health care costs of PFAS exposure at €52 billion to €84 billion for European Economic Area countries. Adjusting for population size and exchange rate, researchers estimate the equivalent cost in the U.S. at $37 billion to $59 billion annually.[125] These estimates do not fully capture the loss in quality of life associated with illness.

A report by Toxic-Free Future has linked the production of PFAS for use in food packaging with the release of chlorodifluoromethane (HCFC-22), a greenhouse gas and ozone-depleting substance.[126] Although HCFC-22 can no longer be produced, imported, or used in the U.S. in accordance with the Montreal Protocol, the production of HCFC-22 as an intermediary in the manufacture of PFAS is not subject to these prohibitions. As a result, HCFC-22 continues to be released into the atmosphere. Toxic-Free Future considers the manufacture of PFAS for food packaging as a significant contributor to climate change and its associated costs.

REGULATION

Regrettable Substitutions

A key concern of regulating PFAS on a chemical-by-chemical or small group basis is that thousands of unregulated PFAS may have similar adverse health effects to those associated with PFAS that are currently regulated.[127] The practice of replacing regulated PFAS with other structurally similar PFAS continues to expose people to potentially hazardous substances. GenX, which has been manufactured as a replacement for PFOA, has been detected all around the world and has been associated with certain negative health effects in animal studies.[128] A regulatory approach that requires evaluating PFAS on an individual basis may delay efforts to protect public health and the environment.

Firefighter Turnout Gear

Firefighters can be exposed to PFAS through their personal protective equipment, also known as turnout gear.[129] The National Fire Protection Association (NFPA) requires the moisture barrier of turnout gear to withstand 40 consecutive hours of UV light, a standard that currently only textiles containing PFAS can meet. There are firefighters, activists, and scientists who oppose this standard because the moisture barrier is the middle layer of turnout gear and is not exposed to UV light in practice. Removing this standard would allow manufacturers to produce turnout gear that does not contain PFAS, which could reduce occupational health risks to firefighters, who experience higher cancer rates than the general population.[130] However, an NFPA committee announced in September 2021 that it would continue to require turnout gear to pass the 40-hour UV light test. This decision prevents fire departments from switching to completely PFAS-free turnout gear.[131] Some manufacturers have developed turnout gear that does not contain PFAS in the outer shell, which is considered low-PFAS gear. Nantucket Fire Department is among the first in the nation to purchase low-PFAS gear for its firefighters.

Municipal and Homeowner Liability

Under Chapter 21E and the MCP, MassDEP regulates the unpermitted release and cleanup of oil and hazardous material contamination. Homeowners are required to notify MassDEP if PFAS6 is detected in groundwater on their property at concentrations equal to or greater than 20 ppt. Financial and legal obligations for PFAS assessment and cleanup are dependent upon whether PFAS was released on the property or if PFAS migrated to the property from elsewhere. If MassDEP determines PFAS was released on the property, homeowners may be responsible for addressing contamination on their property and other impacted properties. If PFAS migrated to the property from elsewhere, homeowners are eligible for Downgradient Property Status, with limited obligations under Chapter 21E and the MCP.

Although MassDEP has discretionary authority with respect to the issuance of Notices of Responsibility, homeowners and municipalities can still be considered "responsible parties" for PFAS contamination under Chapter 21E and the MCP. In the case where a municipal fire department releases AFFF on a private property during an emergency response and that property is determined to be the source of PFAS contamination, homeowners could be responsible for the cleanup and any costs incurred, and could file suit against the municipality for releasing AFFF on their property.

COORDINATION

Due to the scope and complexity of PFAS contamination, it has been challenging to create and execute a coordinated response among local communities, state and federal agencies, PWSs, businesses, advocacy organizations, and experts in the field. Municipalities and PWSs have expressed a need for clear and consistent guidance from the state regarding standards and regulations for PFAS in drinking water, groundwater, soil, wastewater, and other media. Many municipalities and PWSs are grappling with PFAS contamination for the first time due to new state standards for PFAS introduced in the past three years. Some towns have sought guidance from other towns on short-term and long-term PFAS remediation strategies and best practices.

ACCESS TO INFORMATION

Sources of Contamination

A major barrier to prohibiting and restricting the production and use of PFAS in Massachusetts is the lack of access to information on who is using PFAS and in what quantities. Efforts to detect PFAS in Massachusetts have generally focused on exposure pathways in environmental media, such as drinking water, groundwater, surface water, fish, wastewater, biosolids, and soil. EPA has been compiling a list of known or potential sources of PFAS contamination, but this information was not released publicly until PEER sued EPA for access to the agency's list of facilities.[132]

Consumer Products

Although organizations such as the Green Science Policy Institute have compiled lists of PFAS-free consumer products, the lack of labeling on products containing PFAS creates a challenge for consumers to make informed purchasing decisions.[133] Some retailers, including Panera, Whole Foods, and various outerwear companies, have publicized their efforts to remove PFAS from their supply chain. However, the onus is primarily on consumers to find information on PFAS in the products they are purchasing. Most manufacturers do not release industry information on the use cases for different PFAS in the manufacturing process since much of this is considered confidential business information. Even if this information were made available to the public, most consumers would likely find it challenging to understand the scientific and technical language at a level to which they could make informed purchasing decisions.

Public Education

Gaps in public awareness of PFAS exposure pathways and the impacts of PFAS on human health can serve as barriers to individual-level behavior changes and broader societal action to address PFAS contamination. There is a growing movement in fields such as architecture and interior design to use PFAS-free building materials, carpets, and upholstery. During a workshop hosted by Built Environment Plus in July 2021, several architects and interior designers cited the lack of client knowledge of the health effects of PFAS as a barrier to using PFAS-free materials. Health care providers have been seeking guidance on how to discuss PFAS exposure and health risks with patients.

RECOMMENDATIONS

Throughout 2021, the PFAS Interagency Task Force held nine public hearings and heard testimony from researchers, advocacy groups, community members, municipal officials, state agencies, public water systems, legislators, and other stakeholders on the issues surrounding PFAS. After careful consideration of the extent of PFAS contamination in the state, evidence of the health and environmental impacts associated with PFAS exposure, and the distinct challenges of addressing PFAS, the PFAS Interagency Task Force proposes the following set of recommendations for the Commonwealth of Massachusetts to protect residents and the environment from PFAS contamination.

FUND PFAS DETECTION AND REMEDIATION

1. Fund MassDEP and DPH to conduct PFAS testing in drinking water, groundwater, surface water, wastewater, residuals, soil, air, fish tissue, and additional environmental media that may be exposure pathways for PFAS.
2. Fund MassDEP to conduct PFAS testing and investigations in locations with known or suspected PFAS releases to identify sources of contamination.
3. Fund MassDEP and DPH to provide PFAS-related technical assistance to municipalities and public water systems.
4. Appropriate additional funding to the Clean Water Trust for PFAS remediation projects.
5. Establish a PFAS Remediation Fund that provides grants to municipalities, public water systems, and homeowners for capital and ongoing costs for PFAS remediation.

SUPPORT ENVIRONMENTAL JUSTICE COMMUNITIES

6. Appropriate funding to the Clean Water Trust to increase the loan forgiveness percentage for PFAS remediation projects that are eligible for the Disadvantaged Communities program.
7. Direct DPH to conduct outreach with community stakeholders to ensure affected residents have information in accessible language regarding their exposure to PFAS through drinking water, fish, and other sources.

PHASE OUT PFAS IN CONSUMER PRODUCTS

8. Prohibit the sale of consumer products with intentionally added PFAS by 2030. Identify priority consumer products with intentionally added PFAS for an earlier phase-out, including textiles, food packaging, and children's products. Allow DPH to grant temporary exemptions to consumer products for which PFAS alternatives do not currently exist and that DPH and MassDEP have determined to be environmentally preferable products or essential to the health and safety of the Commonwealth.
9. Require manufacturers of consumer products containing intentionally added PFAS for sale in Massachusetts to notify the state using the Interstate Chemicals Clearinghouse beginning in 2025.
10. Require manufacturers of consumer products containing intentionally added PFAS for sale in Massachusetts to add labels indicating these products contain PFAS.
11. Fund TURI to provide research grants to identify and develop safer alternatives to PFAS in consumer products that receive exemptions from DPH and in firefighter turnout gear.

EXPAND PFAS REGULATION

12. Define PFAS as "fluorinated organic chemicals containing at least one fully fluorinated carbon atom" for the regulation of PFAS in consumer products.
13. Encourage MassDEP to establish standards for PFAS in drinking water and groundwater beyond PFAS6 as part of its upcoming review cycle.
14. Direct MassDEP to evaluate the appropriateness of incorporating PFAS conditions in groundwater discharge permits for industrial wastewater.
15. Direct MassDEP to evaluate the appropriateness of establishing pre-treatment requirements and limits for PFAS in effluent for industrial surface water discharge permits.

ENCOURAGE PRIVATE WELL PFAS TESTING AND REMEDIATION

16. Create a funding program for communities to receive and distribute loans for private well PFAS remediation.
17. Identify strategies to lower the cost of PFAS testing for private well owners.
18. Encourage municipalities to require PFAS testing during transfer of property with private wells and with new well permits.

SUPPORT FIREFIGHTERS AND LOCAL FIRE DEPARTMENTS

19. Fund a second round of the AFFF Take-Back Program to collect and dispose of AFFF, clean up and decontaminate storage facilities and equipment exposed to AFFF, and purchase fluorine free foam for fire departments.
20. Prohibit the use of AFFF for firefighting training and maintenance.
21. Support efforts to reduce the use of AFFF in emergency responses and require fire departments to notify MassDEP of releases of AFFF. Explore alternative practices to minimize potential environmental impacts where such use is federally required.
22. Require manufacturers of firefighter turnout gear to provide written notice of the inclusion of PFAS in turnout gear to the purchaser at time of sale.
23. Review standards for turnout gear, support efforts to identify and develop turnout gear that is completely free from PFAS, and ban the sale of turnout gear with PFAS once there are viable alternatives in the marketplace.
24. Increase funding for DFS and MFA to conduct cancer awareness trainings and refer firefighters to screenings for cancers associated with PFAS exposure.
25. Direct the Massachusetts Cancer Registry to retroactively standardize "firefighter" as an occupation and to collect information on occupational exposure to PFAS.

ADDRESS PFAS CONTAMINATION ACCOUNTABILITY

26. Identify a path for adopting reasonable limitations for liability claims against homeowners and municipalities for PFAS contamination.
27. Continue evaluating potential claims against PFAS manufacturers to seek remediation costs and other damages for PFAS contamination.
28. Direct MassDEP to work with DOD to implement their 2021 guidance to sample public and private drinking water wells and to initiate removal actions to address exceedances of the state MCL.

ENHANCE PUBLIC AWARENESS OF PFAS

29. Direct MassDEP and DPH to build upon existing efforts to jointly conduct public education and awareness campaigns around PFAS contamination, health impacts, and state efforts to address PFAS.
30. Direct DPH to build upon existing efforts to provide guidance to health care providers and local governments on how to communicate the health impacts of PFAS, exposure pathways, and safe drinking water levels to patients and the public.

ACKNOWLEDGEMENTS

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APPENDIX A: TASK FORCE PUBLIC HEARINGS

Jun. 1, 2021	Introductions and Presentation from MassDEP Martin Suuberg, MassDEP
Jun. 15, 2021	What are PFAS chemicals, where are they found, and what are their impacts on human health? Robert Simon, American Chemistry Council Alicia Timme-Laragy, University of Massachusetts Amherst School of Public Health & Health Sciences Elsie Sunderland, Harvard T.H. Chan School of Public Health & Harvard John A. Paulson School of Engineering and Applied Sciences
Jul. 6, 2021	How do PFAS chemicals impact public health and the environment? Phil Brown, Northeastern University Laurel Schaider, Silent Spring Institute Rainer Lohmann, University of Rhode Island Marc Nascarella, Massachusetts Department of Public Health
Jul. 20, 2021	How are communities in Massachusetts impacted by and responding to PFAS? Mark Ells, Town of Barnstable Denise Dembkoski, Town of Stow Mark Wetzel, Town of Ayer Matthew Mostoller, Acton Water District Thomas Holder, Wayland Department of Public Works Connor Read, Town of Easton Joseph Favaloro, Massachusetts Water Resources Authority Advisory Board Jennifer Pederson, Massachusetts Water Works Association

Aug. 3, 2021	What action is being taken at the federal level and in other states to address PFAS? Congresswoman Lori Trahan, U.S. House of Representatives (MA-03) Pat Breysse, National Center for Environmental Health/Agency for Toxic Substances and Disease Registry Kristen Hildreth, National Conference of State Legislatures Shelly Oren, National Conference of State Legislatures
Sep. 7, 2021	What are the sources of PFAS in Massachusetts and who is responsible for addressing PFAS contamination? Gloria Bouillon, Beverly Regional Airport Christopher Faux, Massachusetts National Guard Peter Ostroskey, Massachusetts Department of Fire Services Peter Burke, Hyannis Fire Department John Deerborn, Longmeadow Fire Department Michael Belliveau, Defend Our Health Robert Bilott, Taft Law
Sep. 21, 2021	How can Massachusetts address PFAS contamination and what are the costs? Bethany Card, Executive Office of Energy and Environmental Affairs Jeffrey Arps, Tighe & Bond Andrew Goldberg, Attorney General's Office

Oct. 5, 2021	Honorable Members of the Massachusetts Legislature Rep. Jack Lewis, 7th Middlesex Rep. Kelly Pease, 4th Hampden Sen. Susan Moran, Plymouth & Barnstable Sen. Marc Pacheco, 1st Plymouth and Bristol Sen. Joanne Comerford, Hampshire, Franklin & Worcester Sen. Michael O. Moore, 2nd Worcester Rep. James Hawkins, 2nd Bristol
Oct. 19, 2021	State and Regional Advocacy Groups Deirdre Cummings, MASSPIRG Kyla Bennett, Public Employees for Environmental Responsibility Sarah Woodbury, Defend Our Health Erica Kyzmir-McKeon, Conservation Law Foundation Nate Barber, Nantucket Fire Department Sean Mitchell, Nantucket Fire Department Jason Burns, Fall River Fire Department Andrew Rainer, Brody Hardoon Perkins & Kesten, LLP Matt Pawa, Seeger Weiss LLP Alison Field-Juma, OARS Kristen Mello, Westfield Residents Advocating For Themselves Tania Taranovski, Farm to Institution New England Sue Phelan, GreenCAPE Jaime Honkawa, Nantucket PFAS Action Group Ayesha Khan, Nantucket PFAS Action Group

APPENDIX B: TASK FORCE MEMBER VOTE RECORD

On April 20, 2022, the Task Force held its final public meeting and voted unanimously to approve *PFAS in the Commonwealth: Final Report of the PFAS Interagency Task Force.*

Approve
Rep. Kate Hogan, Co-Chair of the PFAS Interagency Task Force, 3rd Middlesex District **Sen. Julian Cyr**, Co-Chair of the PFAS Interagency Task Force, Cape and Islands District **Rep. Sally Kerans**, 13th Middlesex District **Rep. Kelly Pease**, 4th Hampden District **Martin Suuberg**, Massachusetts Department of Environmental Protection **Bethany Card**, Executive Office of Energy and Environmental Affairs **Peter Ostroskey**, Massachusetts Department of Fire Services **Robert Oliver** (stand-in for Alicia Fraser), Massachusetts Department of Public Health **Jeanne Benincasa Thorpe**, Executive Office of Public Safety and Security **Dawn Brantley** (stand-in for Patrick Carnevale), Massachusetts Emergency Management Agency **Suzanne Condon**, Formerly Massachusetts Department of Public Health **Andrew Goldberg**, Attorney General's Office **Rebecca Weidman**, Massachusetts Water Resources Authority **John Lebeaux**, Massachusetts Department of Agricultural Resources **Connor Read**, Massachusetts Municipal Association **Jennifer Pederson**, Massachusetts Water Works Association **Jeffrey Arps**, Tighe & Bond **David Reckhow**, University of Massachusetts Amherst **Blair Wylie**, Beth Israel Deaconess Medical Center

APPENDIX C: GROUPING METHODS

Essential and Non-Essential Use Framework

The Montreal Protocol, which was designed to phase out non-essential use of chlorofluorocarbons, outlines two criteria for a chemical to be considered essential. First, its use must be necessary for social priorities or functions, such as protecting health and safety. Second, there must be no alternative chemicals that may feasibly be produced as a replacement. In an essential use framework, chemicals that are not considered critical to societal functions, or for which there exists a viable alternative, are considered "non-essential" and can be phased out by some deadline or sunset clause. The essential use framework could be applied to the regulation of PFAS by phasing out all PFAS considered non-essential to various human activity.[134]

Maine has applied an "essential use" framework in its regulation of PFAS in consumer products by phasing out the use of all PFAS in consumer products by 2030 except those with uses deemed unavoidable by the Maine Department of Environmental Protection.[135] While the European Union has proposed restricting all non-essential uses of PFAS, the definition of "essential" has yet to be determined and may vary from the Montreal Protocol.

Intrinsic Properties Grouping Strategies

Based on chemical structure, PFAS can be grouped into categories defined by specific structural features that have particular, intrinsic properties like persistence, bioaccumulation, and toxicity. Cousins et al. defines four grouping approaches that are based on such properties. Some of these categories have been applied in PFAS production, remediation, and regulation.

Grouping Based on Persistence: A "P-Sufficient" Approach

This grouping strategy consists of PFAS and precursors with perfluoroalkyl and perfluoroether structural features. Such features have the property of persistence without degradation in the environment. Because all PFAS either are chemicals with such structural features or environmentally break down into them, this class encompasses all PFAS. An advantage of this strategy is that it requires no additional research since all PFAS have structural features that lead to persistence.[136] While this specific methodology has not been applied in PFAS regulation, Maine is using a class-based approach to regulate all PFAS in consumer products.

Grouping Based on Bioaccumulation: Long Chain, Short Chain, and Further Strategies
This grouping strategy differentiates between PFAS that exhibit bioaccumulative properties and those that do not exhibit such properties. The chemical manufacturing industry categorizes perfluorocarboxylic acids and perfluoroalkane sulfonic acids as bioaccumlative PFAS, which are primarily PFAS with six or more carbons. This group includes PFOS and PFOA. Phase-out of legacy, long-chain PFAS has resulted in the introduction of short-chain PFAS, which were originally thought to exhibit lower bioaccumulation in human and animal tissue.[137] However, recent studies have detected bioaccumulation of PFAS plants and other organisms.

Risk Assessment-Based Grouping Strategies
This approach evaluates PFAS based on the risk of human exposure to PFAS and their health impacts. Several forms of grouping strategies are available under this approach.

Arrowhead Approach
A representative PFAS chemical, or "arrowhead molecule," stands in for all the parent, precursor, and byproduct chemicals. This approach assumes that selecting this representative arrowhead molecule will capture and regulate related molecules upstream and downstream of it.[138] Chemical manufacturers have used this approach to phase out PFOS, PFOA, and their precursors, parents, and byproducts.[139] The total oxidizable precursor (TOP) assay measures these precursors. Both REACH and the Stockholm Convention use a similar approach to group precursors to long-chain per- and polyfluoroalkyl acids.

This approach assesses large groups of chemicals at the same time, thereby eliminating the need for case-by-case regulation of individual PFAS. However, large groups of chemicals may not be clearly defined and once defined, may be difficult to measure. This method requires thorough knowledge of possible precursors, and there is debate over what constitutes a parent or precursor to a chosen representative PFAS. Measuring precursors may be a challenge since the TOP assay is one of the few methods available and is not standardized. Additionally, some arrowhead approaches may not capture all relevant precursors.[140]

Total and Extractable/Adsorbable Organofluorine Approaches
This strategy depends on measuring the total or extractable/adsorbable number of carbon-fluorine ("organofluorine") bonds within a group, which are mainly found in synthetic chemicals like PFAS, within a tested product above a certain regulatorily defined limit. Under this strategy, media containing total organofluorine (TOF) or extractable organofluorine (EOF) over a certain regulatorily defined limit would qualify as the PFAS "grouping" to be governed.

Particle-induced gamma-ray spectroscopy, X-ray photoelectron spectroscopy, and combustion ion chromatography measure the total organofluorine, while organic solvents or sorbents can extract or adsorb organofluorine. Testing for organic fluorine differs from testing for fluorides, which are the negatively charged, non-carbon-bonded, single-atom form of a fluorine atom. As part of CDC's community water fluoridation program to reduce cavities, fluorides have been voluntarily added to municipal drinking water since 1945.[141]

Advantages of this approach include the speed and simplicity of testing and the range of PFAS that can be captured. Total fluorine bypasses the challenge of testing for individual PFAS, including those that do not have chemical structures available. A disadvantage of this approach is that it captures a broad range of all organic fluorine chemicals, including chemicals that may not be PFAS. Testing for extractable organofluorine or adsorbable organofluorine may more accurately reflect the amount of PFAS in the tested medium, though it may still remain broad and require additional screening for specific chemicals. As a risk-assessment informing strategy, this screen can provide insight into whether possible PFAS, as signaled by TOF or EOF, exist at or above an unacceptable level of risk to human health.

APPENDIX D: PRECURSORS

PFAS precursors are compounds that can degrade into PFAS chemicals through biological processes within organisms or abiotic processes in the environment. Similar to PFAS, these precursors are anthropogenic chemicals synthesized by the fluoropolymer, surfactant, and chlorofluorocarbon industries. These precursors may be found in solid, liquid, or gaseous form.[142] Volatile liquid precursors can travel as atmospheric gases before undergoing an oxidation process that deposits them long distances from their source. When ingested, PFAS precursor compounds often biochemically transform into perfluoroalkyl acids.[143] They are generally measured using the TOP assay. The full range of PFAS precursors for every known PFAS is often poorly characterized or not well understood.

APPENDIX E: STRESSORS

Below are two examples of industrial point sources and nonpoint sources that can release PFAS into the environment.

PFAS in Biotechnology

In the biotechnology industry, the combination of water resistance and gaseous solvation make PFAS useful materials for biochemical research processes. For example, certain PFAS have been used in dissolving gases to make cell cultures and in other processes.[144]

PFAS in Building Materials

As long-lasting, water-resistant chemicals, PFAS are widely used in building and construction in materials such as carpet, roofing, paint and caulking, adhesives, electrical piping, and sealants to reduce friction, water damage, corrosion, and more.[145] Fluoropolymers can be used in building materials such as tape, insulation, coating, and more.[146] For many of these materials, there are high performance alternatives that do not contain PFAS. Professional fields are beginning to store and track information on alternatives to materials containing PFAS.[147,148] For some materials, such as Teflon-based electrical tape, alternatives remain elusive.

Building materials can introduce PFAS into the environment through industrial effluent released into wastewater systems and through waste material disposal in landfills. Consumers can be exposed to PFAS in building materials through direct contact or inhalation. Consumer demand for PFAS-free products, such as stain-resistant carpets, has contributed to policy efforts to phase out PFAS in water-resistant coating.[149]

APPENDIX F: PFAS USE CATEGORIES

The following list of PFAS use categories was developed by Glüge et al.[150]

Industry Branches

Aerospace
Biotechnology
Building and construction
Chemical industry
Electroless plating
Electroplating
Electronic industry
Energy sector
Food production industry
Machinery and equipment
Manufacture of metal products
Mining
Nuclear industry
Oil and gas industry
Pharmaceutical industry
Photographic industry
Production of plastic and rubber
Semiconductor industry
Textile production
Watchmaking industry
Wood industry

Other Use Categories

Aerosol propellants
Air conditioning
Antifoaming agent
Ammunition
Apparel
Automotive
Cleaning compositions
Coatings, paints and varnishes
Conservation of books and manuscripts
Cookware
Dispersions
Electronic devices
Fingerprint development
Firefighting foam
Flame retardants
Floor covering including carpets and floor polish
Glass
Household applications
Laboratory supplies, equipment and instrumentation
Leather
Lubricants and greases
Medical utensils
Metallic and ceramic surfaces
Music instruments
Optical devices
Paper and packaging
Particle physics
Pesticides
Pharmaceuticals
Pipes, pumps, fittings and liners
Plastic, rubber and resins
Printing
Refrigerant systems
Sealants and adhesives
Soldering
Soil remediation
Sport articles
Stone, concrete and tile
Textile and upholstery
Tracing and tagging
Water and effluent treatment
Wire and cable insulation, gaskets and hoses

APPENDIX G: SITES WITH REPORTABLE RELEASES OF PFAS IN MA

The following list of sites with reportable releases of PFAS in Massachusetts was compiled by MassDEP on April 8, 2022. Additional information can be found on Cleanup of Sites & Spills and Waste Site & Reportable Releases Data Portal.

Town	Site Name	Release Tracking
Acton	Conant 1 and 2, Acton	2-0021558
Ayer	Former Fort Devens	2-0000662
Ayer	Spectacle Pond PWS - Ayer and Littleton	2-0020964
Ayer	Routhier Tire Facility	2-0017975
Ayer	Aggregate Industries Quarry, Littleton	2-0021349
Ayer	Littleton Landfill	2-0021373
Ayer	Tire Recycling Facility	2-0017951
Ayer	L3 Essco	2-0021573
Barnstable	Barnstable Fire Training Academy	4-0026179
Barnstable	Cape Cod Gateway Airport (Barnstable)	4-0026347
Barnstable	Group 1 Automotive	4-0028855
Barnstable	Group 1 Automotive	4-0028856
Bedford	Hanscom AFB	3-0000223
Bedford	Hanscom AFB	3-0032206
Bedford	Hanscom Civil Air Terminal - East Ramp	3-0037062
Boxborough	Boxborough Town Center	2-0021557
Boxborough	Swanson Road and Beaver Brook Rd Area	2-0021768
Boxborough	Boxborough Town Hall	2-0021549

Cambridge	Tobin School	3-0001658
Canton	Neponset Valley Industrial Park, Canton	4-0027908
Carlisle	Residential Property	3-0037077
Carlisle	Residential Property	3-0037255
Carver	Route 44 Development/Park Avenue	4-0028330
Carver	North Carver Landfill	4-0000268
Chelmsford	Chelmsford Dept of Public Works Property	3-0036649
Clinton	Clinton Fire Department	2-0021022
Cohasset	Residential Property	4-0028618
Dudley	Schofield Avenue Well 3, Dudley	2-0021551
Dudley	Dudley Municipal Landfill	2-0021744
East Bridgewater	100 Industrial Drive	4-0028937
Edgartown	Martha’s Vineyard Airport	4-0027571
Grafton	Solar Farm Construction Site, Grafton	2-0019764
Hingham	Hingham DPW Stockyard	4-3025357
Holden	HHC Realty, Gas Station	2-0021383
Hopedale	Former Draper Landfill	2-0000765
Hudson	Chestnut Street PFAS	2-0020923
Hudson	Former Boyd Coatings Research Co.	2-0020439
Hudson	Kane - Chestnut PWS, Hudson	2-0020907
Littleton	Aggregate Industries	2-0021349
Littleton	Littleton Landfill	2-0021373

Littleton	Littleton Middle School	2-0021798
Littleton	Concord Lumber Company	2-0021885
Lunenburg	PFAS SRM at Residential Properties	2-0021819
Mansfield	Mansfield Airport	4-0027689
Mashpee	Joint Base Cape Cod	4-0000037
Mendon	Commercial Property at 28 Hastings Street	2-0021840
Middleton	Muzzy Wasil Realty Trust	3-0031498
Middleton	Muzichuk Garage Inc.	3-0031499
Middleton	Residential Property, 272 North Main Street	3-0031505
Middleton	67 North Main Street	3-0034062
Middleton	Polarized New England	3-0037006
Millbury	Oak Pond PWS, Millbury	2-0021550
Millis	PWS Wells 1&2, Millis	2-0021224
Millis	Former Stride Rite, Millis	2-0021523
Millis	GAF Corporation	2-0021455
Nantucket	Nantucket Airport	4-0028219
Natick	Army Research Center	3-0002473
Northfield	Four Star Farm, Northfield	1-0021289
Pepperell	Nashua Road, Pepperell	2-0021571
Plymouth	Pilgrim Nuclear Power Station	4-0028765
Princeton	Princeton Town Campus	2-0021072
Princeton	30 Mountain Road Residence	2-0021721

Princeton	54 Mountain Road Residence	2-0021796
Princeton	22 Mountain Road Residence	2-0021797
Rehoboth	Former L&R Truck Repair Property	4-0028503, 4-0016945
Rehoboth	Rehoboth Town Hall	4-0029201
Seekonk	Seekonk Manufacturing	4-0029113
Sharon	Metal Bellows, Route 1 Sharon	4-0000261
Shrewsbury	Sewall Street PWS #4 & Home Farm PWS	2-0020057
Shrewsbury	Former Allegro Microsystem, Worcester	2-0021682
Stow	Bose Corporation, Stow	2-0019626
Stow	Former Fire Station, Stow	2-0021075
Stow	Gleasondale Mill	2-0021116
Stow	Mass Firefighter Academy	2-0021045
Stow	Taylor Rd and Garner Rd Area	2-0021812
Townsend	Harbor Trace Well, Townsend	2-0021592
Tyngsboro	Residential Property	3-0037366
Wayland	Planned Rivers Edge Development	3-0036013
Westfield	Barnes Air National Guard Base	1-0000288
Westminster	Bean Porridge Hill Area	2-0021866
Weymouth	Naval Air Station	4-3002621
Worcester	Former Allegro Microsystems	2-0021682
Wrentham	Commercial Property 1130 South Street	4-0028947

REFERENCES

1 U.S. Environmental Protection Agency. “National PFAS Datasets.” Enforcement and Compliance History Online, https://echo.epa.gov/tools/data-downloads/national-pfas-datasets. Accessed April 6, 2022.

2 Buck et al. “Perfluoroalkyl and Polyfluoroalkyl Substances in the Environment: Terminology, Classification, and Origins.” *Integrated Environmental Assessment and Management* 7, no. 4 (2011): 513–41. https://doi.org/10.1002/ieam.258.

3 U.S. Environmental Protection Agency. “PFAS Explained.” PFOA, PFOS and Other PFAS, https://www.epa.gov/pfas/pfas-explained. Accessed April 6, 2022.

4 Sunderland et al. “A Review of the Pathways of Human Exposure to Poly- and Perfluoroalkyl Substances (PFASs) and Present Understanding of Health Effects.” Journal of Exposure Science & Environmental Epidemiology 29, no. 2 (March 2019): 131–47. https://doi.org/10.1038/s41370-018-0094-1.

5 Ibid.

6 Toxics Use Reduction Institute. “Per- and Poly-Fluoroalkyl Substances (PFAS).” https://www.turi.org/Our_Work/Toxic_Chemicals/Chemical_Information/Per-_and_poly-fluoroalkyl_substances_PFAS. Accessed April 6, 2022.

7 Glüge et al. “An Overview of the Uses of Per- and Polyfluoroalkyl Substances (PFAS).” *Environmental Science: Processes & Impacts* 22, no. 12 (2020): 2345–73. https://doi.org/10.1039/D0EM00291G.

8 Brendel et al. “Short-Chain Perfluoroalkyl Acids: Environmental Concerns and a Regulatory Strategy under REACH.” *Environmental Sciences Europe* 30, no. 1 (February 27, 2018): 9. https://doi.org/10.1186/s12302-018-0134-4.

9 Cousins et al. “Strategies for Grouping Per- and Polyfluoroalkyl Substances (PFAS) to Protect Human and Environmental Health.” *Environmental Science: Processes & Impacts* 22, no. 7 (2020): 1444–60. https://doi.org/10.1039/D0EM00147C.

10 Brendel et al. “Short-Chain Perfluoroalkyl Acids: Environmental Concerns and a Regulatory Strategy under REACH.”

11 Li et al. “Short-Chain per- and Polyfluoroalkyl Substances in Aquatic Systems: Occurrence, Impacts and Treatment.” *Chemical Engineering Journal* 380 (January 15, 2020): 122506.

12 Cousins et al. “Strategies for Grouping Per- and Polyfluoroalkyl Substances (PFAS) to Protect Human and Environmental Health.”

13 Sunderland et al. “A Review of the Pathways of Human Exposure to Poly- and Perfluoroalkyl Substances (PFASs) and Present Understanding of Health Effects.”

14 Bilott, Robert. Exposure: Poisoned Water, Corporate Greed, and One Lawyer's Twenty-year Battle Against DuPont. Atria Books, 2020.

15 Cousins et al. “Strategies for Grouping Per- and Polyfluoroalkyl Substances (PFAS) to Protect Human and Environmental Health.”

16 U.S. Environmental Protection Agency. “Fact Sheet: 2010/2015 PFOA Stewardship Program.” Assessing and Managing Chemicals Under TSCA, https://www.epa.gov/assessing-and-managing-chemicals-under-tsca/fact-sheet-20102015-pfoa-stewardship-program. Accessed April 6, 2022.

17 U.S. Environmental Protection Agency. “Technical Fact Sheet: Human Health Toxicity Assessment for GenX Chemicals.” Human Health Toxicity Assessment for GenX Chemicals, https://www.epa.gov/system/files/documents/2021-10/genx-final-tox-assess-tech-factsheet-2021.pdf. Accessed April 6, 2022.

18 Rizutto, Pat. “Older PFAS That EPA Thought Obsolete Still Used, Agency Told (3).” Bloomberg Law, https://news.bloomberglaw.com/environment-and-energy/older-pfas-that-epa-thought-obsolete-still-used-agency-told. Accessed April 6, 2022.

19 Glüge et al. “An Overview of the Uses of Per- and Polyfluoroalkyl Substances (PFAS).”

20 Sunderland et al. “A Review of the Pathways of Human Exposure to Poly- and Perfluoroalkyl Substances (PFASs) and Present Understanding of Health Effects.”

21 Whitehead et al. “Fluorinated Compounds in North American Cosmetics.” *Environmental Science & Technology Letters* 8, no. 7 (July 13, 2021): 538–44. https://doi.org/10.1021/acs.estlett.1c00240.

22 Interstate Regulatory Technology Council. “3 Firefighting Foams.” Per- and Polyfluoroalkyl Substances, https://pfas-1.itrcweb.org/3-firefighting-foams/. Accessed April 6, 2022.

23 Yamashita et al. "Perfluorinated acids as novel chemical tracers of global circulation of ocean waters." *Chemosphere* 70, no. 7 (2008): 1247-1255. https://doi.org/10.1016/j.chemosphere.2007.07.079.

24 Beahm, Cathy. “PFAS Air Emissions: New Hampshire’s Experience.” Fifth Meeting of the Massachusetts PFAS Interagency Task Force, Boston, MA, August 3, 2021.

25 Makey et al. “Airborne Precursors Predict Maternal Serum Perfluoroalkyl Acid Concentrations.” *Environmental Science & Technology* 51, no. 13 (July 5, 2017): 7667–75. https://doi.org/10.1021/acs.est.7b00615.

26 Hill, Nicholas I., Jitka Becanova, and Rainer Lohmann. “A sensitive method for the detection of legacy and emerging per-and polyfluorinated alkyl substances (PFAS) in dairy milk,” Analytical and Bioanalytical Chemistry (2021): 1-9.

27 New Jersey Department of Environmental Protection Division of Water Supply & Geoscience. “Occurrence of Perfluorinated Chemicals in Untreated New Jersey Drinking Water Source: Final Report.” (Government Report, Trenton, NJ, 2014). https://www.nj.gov/dep/watersupply/pdf/pfc-study.pdf.

28 Andrews, David Q. and Olga V. Naidenko. “Population-Wide Exposure to Per-and Polyfluoroalkyl Substances from Drinking Water in the United States.” *Environmental Science & Technology Letters* 7, no. 12 (2020): 931-936.

29 Hu et al. “Detection of Poly- and Perfluoroalkyl Substances (PFASs) in U.S. Drinking Water Linked to Industrial Sites, Military Fire Training Areas, and Wastewater Treatment Plants.” *Environmental Science & Technology Letters* 3, no. 10 (October 11, 2016): 344–50. https://doi.org/10.1021/acs.estlett.6b00260.

30 Maine Department of Inland Fisheries & Wildlife. “Deer Consumption Advisory.” https://www.maine.gov/ifw/hunting-trapping/hunting-resources/deer/index.html. Accessed April 6, 2022.

31 U.S. Food and Drug Administration. “Testing Food for PFAS and Assessing Dietary Exposure.” https://www.fda.gov/food/chemical-contaminants-food/testing-food-pfas-and-assessing-dietary-exposure. Accessed April 6, 2022.

32 Agency for Toxic Substances and Disease Registry. “PFAS Chemical Exposure.” Centers for Disease Control and Prevention, https://www.atsdr.cdc.gov/pfas/health-effects/exposure.html. Accessed April 6, 2022.

33 Du et al. “Removal of Perfluorinated Carboxylates from Washing Wastewater of Perfluorooctanesulfonyl Fluoride Using Activated Carbons and Resins.” *Journal of Hazardous Materials* 286 (April 9, 2015): 136–43. https://doi.org/10.1016/j.jhazmat.2014.12.037.

34 Dixit et al. “PFAS Removal by Ion Exchange Resins: A Review.” *Chemosphere* 272 (June 1, 2021): 129777. https://doi.org/10.1016/j.chemosphere.2021.129777.

35 Wanninayake, Dushanthi M. “Comparison of Currently Available PFAS Remediation Technologies in Water: A Review.” *Journal of Environmental Management* 283 (April 1, 2021): 111977. https://doi.org/10.1016/j.jenvman.2021.111977.

36 Woodard, Steve, John Berry, and Brandon Newman. “Ion Exchange Resin for PFAS Removal and Pilot Test Comparison to GAC.” *Remediation Journal* 27, no. 3 (2017): 19–27. https://doi.org/10.1002/rem.21515.

37 Arps, Jeffrey and James Collins. “PFAS Solutions and Costs.” Seventh Meeting of the Massachusetts PFAS Interagency Task Force, Boston, MA, September 21, 2021.

38 Woodard, Steve, John Berry, and Brandon Newman. “Ion Exchange Resin for PFAS Removal and Pilot Test Comparison to GAC.”

39 Li et al. “Short-Chain per- and Polyfluoroalkyl Substances in Aquatic Systems: Occurrence, Impacts and Treatment.” *Chemical Engineering Journal* 380 (January 15, 2020): 122506. https://doi.org/10.1016/j.cej.2019.122506.

40 Agency for Toxic Substances and Disease Registry. “How can I be exposed?” Per- and Polyfluoroalkyl Substances (PFAS) and Your Health, https://www.atsdr.cdc.gov/pfas/health-effects/exposure.html. Accessed April 6, 2022.

41 Graber et al. “Prevalence and Predictors of Per- and Polyfluoroalkyl Substances (PFAS) Serum Levels among Members of a Suburban US Volunteer Fire Department.” *International Journal of Environmental Research and Public Health* 18, no. 7 (April 2, 2021): 3730. https://doi.org/10.3390/ijerph18073730.

42 Hu et al. “Detection of Poly- and Perfluoroalkyl Substances (PFASs) in U.S. Drinking Water Linked to Industrial Sites, Military Fire Training Areas, and Wastewater Treatment Plants.”

43 Andrews, David Q., and Olga V. Naidenko. “Population-Wide Exposure to Per- and Polyfluoroalkyl Substances from Drinking Water in the United States.” *Environmental Science & Technology Letters* 7, no. 12 (December 8, 2020): 931–36. https://doi.org/10.1021/acs.estlett.0c00713.

44 Agency for Toxic Substances and Disease Registry. “ Perfluoroalkyl and Polyfluoroalkyl Substances (PFAS) in the U.S. Population.” August 21, 2017, https://www.atsdr.cdc.gov/pfas/docs/PFAS_in_People.pdf.

45 Sunderland et al. “A Review of the Pathways of Human Exposure to Poly- and Perfluoroalkyl Substances (PFASs) and Present Understanding of Health Effects.”

46 Cousins et al. “Strategies for Grouping Per- and Polyfluoroalkyl Substances (PFAS) to Protect Human and Environmental Health.”

47 Frisbee et al. “The C8 Health Project: Design, Methods, and Participants.” *Environmental Health Perspectives* 117, no. 12 (December 1, 2009): 1873–82. https://doi.org/10.1289/ehp.0800379.

48 Ibid.

49 Buser, Melanie et al. "Toxicological Profile for Perfluoroalkyls." Agency for Toxic Substances and Disease Registry, Toxicological Report, Atlanta, 2021, https://www.atsdr.cdc.gov/toxprofiles/tp200.pdf.

50 Grandjean et al. "Severity of COVID-19 at Elevated Exposure to Perfluorinated Alkylates." *PLOS ONE* 15, no. 12 (December 31, 2020): e0244815. https://doi.org/10.1371/journal.pone.0244815.

51 Ibid.

52 Toxics Use Reduction Institute. "Per- and Poly-fluoroalkyl Substances (PFAS): Policy Analysis." May, 2021, https://www.mass.gov/doc/turi-pfas-policy-analysis-may-2021/download.

53 Agency for Toxic Substances and Disease Registry. " Perfluoroalkyl and Polyfluoroalkyl Substances (PFAS) in the U.S. Population."

54 Temkin, Alexis, "The New Generation of 'Forever Chemicals' – Toxicity, Exposure, Contamination and Regulation." *Environmental Working Group*, May 27, 2021, https://www.ewg.org/news-insights/news/new-generation-forever-chemicals-toxicity-exposure-contamination-and-regulation. Accessed April 6, 2022.

55 Rice et al. "Comparative Analysis of the Toxicological Databases for 6:2 Fluorotelomer Alcohol (6:2 FTOH) and Perfluorohexanoic Acid (PFHxA)." *Food and Chemical Toxicology* 138 (April 1, 2020): 111210, https://doi.org/10.1016/j.fct.2020.111210.

56 Ritter, Stephen K. "Fluorochemicals go short." *Chemical & engineering news* 88, no. 5 (2010): 12-17.

57 Butt et al. "Biotransformation Pathways of Fluorotelomer-Based Polyfluoroalkyl Substances: A Review." *Environmental Toxicology and Chemistry* 33, no. 2 (2014): 243–67. https://doi.org/10.1002/etc.2407.

58 Li et al. "Short-Chain per- and Polyfluoroalkyl Substances in Aquatic Systems: Occurrence, Impacts and Treatment."

59 Giesy, John P. and Kurunthachalam Kannan. "Global Distribution of Perfluorooctane Sulfonate in Wildlife." *Environmental Science & Technology* 35, no. 7 (April 1, 2001): 1339–42. https://doi.org/10.1021/es001834k.

60 Fair et al. "Perfluoroalkyl Substances (PFASs) in Edible Fish Species from Charleston Harbor and Tributaries, South Carolina, United States: Exposure and Risk Assessment." *Environmental Research* 171 (April 1, 2019): 266–77. https://doi.org/10.1016/j.envres.2019.01.021.

61 Ng, Carla A. and Konrad Hungerbühler. "Bioaccumulation of Perfluorinated Alkyl Acids: Observations and Models." *Environmental Science & Technology* 48, no. 9 (May 6, 2014): 4637–48. https://doi.org/10.1021/es404008g.

62 Toxics Use Reduction Institute. "Per- and Poly-fluoroalkyl Substances (PFAS): Policy Analysis."

63 Ghisi et al. "Accumulation of Perfluorinated Alkyl Substances (PFAS) in Agricultural Plants: A Review." *Environmental Research* 169 (February 1, 2019): 326–41, https://doi.org/10.1016/j.envres.2018.10.023.

64 Ahrens, Lutz and Mirco Bundschuh. "Fate and Effects of Poly- and Perfluoroalkyl Substances in the Aquatic Environment: A Review." *Environmental Toxicology and Chemistry* 33, no. 9 (2014): 1921–29. https://doi.org/10.1002/etc.2663.

65 Ankley et al. "Assessing the Ecological Risks of Per- and Polyfluoroalkyl Substances: Current State-of-the Science and a Proposed Path Forward." *Environmental Toxicology and Chemistry* 40, no. 3 (2021): 564–605. https://doi.org/10.1002/etc.4869.

66 Nordén, Marcus, Urs Berger, and Magnus Engwall. "Developmental Toxicity of PFOS and PFOA in Great Cormorant (Phalacrocorax Carbo Sinensis), Herring Gull (Larus Argentatus) and Chicken (Gallus Gallus Domesticus)." *Environmental Science and Pollution Research* 23, no. 11 (June 1, 2016): 10855–62. https://doi.org/10.1007/s11356-016-6285-1.

67 Stoiber, Tasha, Sydney Evans, and Olga V. Naidenko. "Disposal of Products and Materials Containing Per- and Polyfluoroalkyl Substances (PFAS): A Cyclical Problem." *Chemosphere* 260 (December 1, 2020): 127659. https://doi.org/10.1016/j.chemosphere.2020.127659.

68 Glüge et al. "An Overview of the Uses of Per- and Polyfluoroalkyl Substances (PFAS)."

69 Buck et al. "Perfluoroalkyl and Polyfluoroalkyl Substances in the Environment: Terminology, Classification, and Origins."

70 Ibid.

71 Lohmann et al. "Are Fluoropolymers Really of Low Concern for Human and Environmental Health and Separate from Other PFAS?" *Environmental Science & Technology* 54, no. 20 (October 20, 2020): 12820–28. https://doi.org/10.1021/acs.est.0c03244.

72 Henry et al. "A Critical Review of the Application of Polymer of Low Concern and Regulatory Criteria to Fluoropolymers." *Integrated Environmental Assessment and Management* 14, no. 3 (2018): 316–34. https://doi.org/10.1002/ieam.4035.

73 Lohmann et al. "Are Fluoropolymers Really of Low Concern for Human and Environmental Health and Separate from Other PFAS?"

74 Peaslee et al. “Another Pathway for Firefighter Exposure to Per- and Polyfluoroalkyl Substances: Firefighter Textiles.” *Environmental Science & Technology Letters* 7, no. 8 (August 11, 2020): 594–99. https://doi.org/10.1021/acs.estlett.0c00410.

75 Ibid.

76 Lohmann et al. “Are Fluoropolymers Really of Low Concern for Human and Environmental Health and Separate from Other PFAS?”

77 Kwiatkowski et al. “Scientific Basis for Managing PFAS as a Chemical Class.” *Environmental Science & Technology Letters* 7, no. 8 (August 11, 2020): 532–43. https://doi.org/10.1021/acs.estlett.0c00255.

78 Lohmann et al. “Are Fluoropolymers Really of Low Concern for Human and Environmental Health and Separate from Other PFAS?”

79 Ibid.

80 Guzzetti, Eleonora, Antoni Sureda, Silvia Tejada, and Caterina Faggio. “Microplastic in Marine Organism: Environmental and Toxicological Effects.” *Environmental Toxicology and Pharmacology* 64 (December 1, 2018): 164–71. https://doi.org/10.1016/j.etap.2018.10.009.

81 De Silva et al. “PFAS Exposure Pathways for Humans and Wildlife: A Synthesis of Current Knowledge and Key Gaps in Understanding.” *Environmental Toxicology and Chemistry* 40, no. 3 (2021): 631–57. https://doi.org/10.1002/etc.4935.

82 Kwiatkowski et al. “Scientific Basis for Managing PFAS as a Chemical Class.”

83 Shusterman, DJ. “Polymer Fume Fever and Other Fluorocarbon Pyrolysis-Related Syndromes. *Occupational Medicine* 8, no. 3 (July 1, 1993): 519-31. https://europepmc.org/article/med/8272977.

84 U.S. Environmental Protection Agency. “EJ 2020 Glossary.” Environmental Justice, https://www.epa.gov/environmentaljustice/ej-2020-glossary. Accessed April 6, 2022.

85 Johnston, Jill, and Lara Cushing. “Chemical Exposures, Health and Environmental Justice in Communities Living on the Fenceline of Industry.” *Current Environmental Health Reports* 7, no. 1 (March 2020): 48–57. https://doi.org/10.1007/s40572-020-00263-8.

86 The Massachusetts Drinking Water Regulations, 310 CMR 22.00 (2020).

87 Massachusetts Contingency Plan, 310 CMR 40.00 (2019).

88 U.S. Environmental Protection Agency. “CWA Analytical Methods for Per- and Polyfluorinated Alkyl Substances *PFAS).” Clean Water Act Analytical Methods, https://www.epa.gov/cwa-methods/cwa-analytical-methods-and-polyfluorinated-alkyl-substances-pfas. Accessed April 6, 2022.

89 Suuberg, Martin. “PFAS Interagency Task Force.” First Meeting of the Massachusetts PFAS Interagency Task Force, Boston, MA, June 1, 2021.

90 Massachusetts Department of Environmental Protection. “MassDEP addressing PFAS contamination.” https://mass-eoeea.maps.arcgis.com/apps/MapSeries/index.html?appid=aaf23d08bb834ffaa0625328f6734eae#. Accessed April 6, 2022.

91 Massachusetts Department of Environmental Protection. “Private Well Guidelines.” https://www.mass.gov/service-details/private-well-guidelines. Accessed April 6, 2022.

92 Massachusetts Department of Environmental Protection. “Frequently Asked Questions about the MassDEP Private Wells PFAS Sampling Program.” Fact Sheet, Massachusetts Department of Environmental Protection, Boston, MA, updated March 31, 2022, https://www.mass.gov/doc/frequently-asked-questions-about-the-massdep-private-wells-pfas-sampling-program/download.

93 Massachusetts Department of Environmental Protection. “MassDEP Private Wells PFAS Sampling Program.” Fact Sheet, Massachusetts Department of Environmental Protection, Boston, MA, https://www.mass.gov/doc/private-wells-pfas-sampling-program-21e-questions-and-answers/download. Accessed April 6, 2022.

94 Nascarella, Marc. “Human Health Risks of Exposure to PFAS.” Second Meeting of the Massachusetts PFAS Interagency Task Force, Boston, MA, July 6, 2021.

95 Massachusetts Department of Public Health. “PFAS (Per- and Polyfluoroalkyl Substances) in Recreationally Caught Fish.” https://www.mass.gov/info-details/pfas-per-and-polyfluoroalkyl-substances-in-recreationally-caught-fish. Accessed April 6, 2022.

96 Nascarella, Marc, “Human Health Risks of Exposure to PFAS” Second Meeting of the Massachusetts PFAS Interagency Task Force, Boston, MA, July 6, 2021

97 Agency for Toxic Substances and Disease Registry. “CDC/ATSDR PFAS Exposure Assessment Community Level Results: Hampden County (MA) near Barnes Air National Guard Base.” Per- and Polyfluoroalkyl Substances (PFAS) and Your Health, https://www.atsdr.cdc.gov/pfas/communities/factsheet/Community-Level-Results-Factsheet.html. Accessed April 6, 2022.

98 Nascarella, Marc. “Human Health Risks of Exposure to PFAS.”

99 Public Employees for Environmental Responsibility. “Aerially Sprayed Pesticide Contains PFAS.” December 1, 2020, https://peer.org/aerially-sprayed-pesticide-contains-pfas/.

100 Fox, Jeremy C. "EPA finds toxic compounds in mosquito spray used in Mass.; maker will change packaging." Boston Globe, January 14, 2021, https://www.bostonglobe.com/2021/01/15/metro/epa-finds-toxic-compounds-mosquito-spray-used-mass-maker-will-change-packaging/.

101 Eastern Research Group, Inc. "Report 4: Chemical Composition and Toxicity of Pesticides Used in Ground and Aerial Spraying in Massachusetts." Executive Office of Energy and Environmental Affairs, Mosquito Control for the Twenty-First Century Task Force, August, 2021, https://www.mass.gov/doc/mosquito-control-task-force-report-august-2021/download.

102 Mosquito Control for the Twenty-First Century Task Force. "Recommendations of the Mosquito Control for the Twenty-First Century Task Force." March 31, 2022, https://www.mass.gov/doc/recommendations-of-the-mosquito-control-for-the-twenty-first-century-task-force/download.

103 Gillam, Carey and Alvin Chang. "Revealed: More than 120,000 US Sites Feared to Handle Harmful PFAS 'Forever' Chemicals." *The Guardian*, October 17, 2021, https://www.theguardian.com/environment/2021/oct/17/us-epa-pfas-forever-chemicals-sites-data.

104 Public Employees for Environmental Responsibility. "PFAS Map | Over 120,000 Facilities "May be Handing [sic] PFAS." https://www.peer.org/areas-of-work/public-health/pfas/pfas-map/. Accessed April 6, 2022.

105 The Massachusetts Clean Water Trust. "Drinking Water State Revolving Fund - Disadvantaged Communities Program." https://www.mass.gov/info-details/drinking-water-state-revolving-fund-disadvantaged-communities-program#the-drinking-water-state-revolving-fund-and-disadvantaged-communities-. Accessed April 6, 2022.

106 The Massachusetts Clean Water Trust. "The Affordability Calculation." https://www.mass.gov/service-details/the-affordability-calculation. Accessed April 6, 2022.

107 Seltz, Johanna. "Easton sues chemical companies over PFAS in water." *Boston Globe*, September 21, 2021, https://www.bostonglobe.com/2021/09/21/metro/easton-sues-chemical-companies-over-pfas-water/.

108 Marchetti, et al. v. 3M Company, et al., 22-cv-10251 (D. Mass.; filed Feb. 15, 2022).

109 U.S. Environmental Protection Agency. "Fifth Unregulated Contaminant Monitoring Rule." Monitoring Unregulated Drinking Water Contaminants, https://www.epa.gov/dwucmr/fifth-unregulated-contaminant-monitoring-rule. Accessed April 6, 2022.

110 Agency for Toxic Substances and Disease Registry. "CDC/ATSDR PFAS Exposure Assessment Community Level Results: Hampden County (MA) near Barnes Air National Guard Base."

111 Buser et al. "Toxicological Profile for Perfluoroalkyls."

112 Vergun, David. "DOD Officials Discuss Fire-Fighting Foam Replacement, Remediation Efforts." Department of Defense News, September 16, 2021, https://www.defense.gov/News/News-Stories/Article/Article/2349028/dod-officials-discuss-fire-fighting-foam-replacement-remediation-efforts/.

113 U.S. Government Accountability Office. "Firefighting Foam Chemicals: DOD Is Investigating PFAS and Responding to Contamination, but Should Report More Cost Information." June 22, 2021, https://www.gao.gov/products/gao-21-421.

114 Office of the Assistant Secretary of Defense. "Memorandum for Assistance Secretary of the Army (Installations, Energy and Environment), Assistant Secretary of the Navy (Energy, Installations and Environment), Assistant Secretary of the Air Force (Installations, Environment and Energy), Director, National Guard Bureau (Joint Staff, J8), Director, Defense Logistics Agency (Installation Management). December 22, 2021, https://media.defense.gov/2022/Jan/04/2002917022/-1/-1/0/STATE-STANDARDS-FOR-PFAS-IN-CERCLA-REMOVAL-ACTIONS.PDF.

115 U.S. Department of the Treasury. "FACT SHEET: The Coronavirus State and Local Fiscal Recovery Funds Will Deliver $350 Billion for State, Local, Territorial, and Tribal Governments to Respond to the COVID-19 Emergency and Bring Back Jobs." May 10, 2021, https://home.treasury.gov/system/files/136/SLFRP-Fact-Sheet-FINAL1-508A.pdf.

116 The White House. "Fact Sheet: The Bipartisan Infrastructure Deal." Briefing Room, November 6, 2021, https://www.whitehouse.gov/briefing-room/statements-releases/2021/11/06/fact-sheet-the-bipartisan-infrastructure-deal/.

117 Massachusetts Water Resources Authority. "Assistant Speaker Katherine Clark promotes the clean water infrastructure provisions in the recently signed Infrastructure Investment and Jobs Act." December 7, 2021, https://www.youtube.com/watch?v=ILaVcfQdXZE&t=27s.

118 European Commission. "Poly- and perfluoroalkyl substances (PFAS)." October 14, 2020, https://ec.europa.eu/environment/pdf/chemicals/2020/10/SWD_PFAS.pdf.

119 Arps, Jeffrey and James Collins. "PFAS Solutions and Costs." Seventh Meeting of the Massachusetts PFAS Interagency Task Force, Boston, MA, September 21, 2021.

120 Holder, Thomas. "PFAS Solutions and Costs." Fourth Meeting of the Massachusetts PFAS Interagency Task Force, Boston, MA, July 20, 2021.

121 Read, Connor. “PFAS Response on a Local Level.” Fourth Meeting of the Massachusetts PFAS Interagency Task Force, Boston, MA, July 20, 2021.

122 Hinkle, Jeanette. “Nantucket Airport Lawsuit Blames Manufacturers for PFAS Contamination.” Cape Cod Times, September 16, 2021, https://www.capecodtimes.com/story/news/2021/09/16/nantucket-airport-lawsuit-blames-manufacturers-pfas-contamination-3-m-dupont-cape-cod-chemical/8337479002/.

123 Kwiatkowski et al., “Scientific Basis for Managing PFAS as a Chemical Class.”

124 Cousins et al. “Strategies for Grouping Per- and Polyfluoroalkyl Substances (PFAS) to Protect Human and Environmental Health.”

125 Cordner et al. “The True Cost of PFAS and the Benefits of Acting Now.” *Environmental Science & Technology*, July 7, 2021. https://doi.org/10.1021/acs.est.1c03565.

126 Shreder, Erika and Beth Kemler. “Path of Toxic Pollution: How making ‘forever chemicals’ for food packaging threatens people and the climate.” Toxic-Free Future, Safer Chemicals Healthy Families, and Mind the Store, September, 2021, https://48h57c2l31ua3c3fmq1ne58b-wpengine.netdna-ssl.com/wp-content/uploads/2021/09/Report-Daikin-Path-of-Toxic-Pollution.pdf.

127 Kwiatkowski et al. “Scientific Basis for Managing PFAS as a Chemical Class.”

128 North Carolina Department of Health and Human Services Division of Public Health. “GenX in the Lower Cape Fear River Basin.” Epidemiology: Occupational and Environmental. Last modified March 7, 2022, https://epi.dph.ncdhhs.gov/oee/a_z/genx.html.

129 Peaslee et al. “Another Pathway for Firefighter Exposure to Per- and Polyfluoroalkyl Substances: Firefighter Textiles.”

130 Daniels, Robert D. “Firefighter Cancer Rates: The Facts from NIOSH Research.” Centers for Disease Control and Prevention, May 20, 2019, https://blogs.cdc.gov/niosh-science-blog/2017/05/10/ff-cancer-facts/.

131 Zuckoff, Eve. “Firefighters Blast Decision To Allow Toxic PFAS Chemicals To Stay In Their Gear.” NPR Boston (WGBH), September 15, 2021, https://www.wgbh.org/news/local-news/2021/09/15/firefighters-blast-decision-to-allow-toxic-pfas-chemicals-to-stay-in-their-gear.

132 Gillam, Carey and Alvin Graham. “Revealed: More than 120,000 US Sites Feared to Handle Harmful PFAS ‘Forever’ Chemicals.” The Guardian, October 17, 2021, https://www.theguardian.com/environment/2021/oct/17/us-epa-pfas-forever-chemicals-sites-data.

133 Green Science Policy. “PFAS-Free Products.” PFAS Central, https://pfascentral.org/pfas-free-products/. Accessed April 6, 2022.

134 Glüge et al. “An Overview of the Uses of Per- and Polyfluoroalkyl Substances (PFAS).”

135 An Act To Stop Perfluoroalkyl and Polyfluoroalkyl Substances Pollution. Public Law, Chapter 447 (LD 1503, 2021).

136 Cousins et al. “Strategies for Grouping Per- and Polyfluoroalkyl Substances (PFAS) to Protect Human and Environmental Health.”

137 Brendel et al. “Short-Chain Perfluoroalkyl Acids: Environmental Concerns and a Regulatory Strategy under REACH.”

138 Balan, Simona Andreea, and Qingyu Meng. "PFASs in Consumer Products." *Forever Chemicals: Environmental, Economic, and Social Equity Concerns with PFAS in the Environment* (2021): 51.

139 Cousins et al. “Strategies for Grouping Per- and Polyfluoroalkyl Substances (PFAS) to Protect Human and Environmental Health.”

140 Ibid.

141 Centers for Disease Control. “Over 75 Years of Community Water Fluoridation.” https://www.cdc.gov/fluoridation/basics/anniversary.htm. Accessed April 6, 2022.

142 Young, Cora J. and Scott A. Mabury. “Atmospheric Perfluorinated Acid Precursors: Chemistry, Occurrence, and Impacts.” *Reviews of Environmental Contamination and Toxicology Volume 208: Perfluorinated Alkylated Substances*, edited by Pim De Voogt, 1–109. Reviews of Environmental Contamination and Toxicology. New York, NY: Springer, 2010. https://doi.org/10.1007/978-1-4419-6880-7_1.

143 Sunderland et al. “A Review of the Pathways of Human Exposure to Poly- and Perfluoroalkyl Substances (PFASs) and Present Understanding of Health Effects.”

144 Glüge et al. “An Overview of the Uses of Per- and Polyfluoroalkyl Substances (PFAS).”

145 Fernández, Set Rojello, Carol Kwiatkowski, and Tom Bruton. “Building a Better World: Eliminating Unnecessary PFAS in Building Materials.” Green Science Policy Institute, 2021, https://greensciencepolicy.org/docs/pfas-building-materials-2021.pdf.

146 Janousek et al. “Previously unidentified sources of perfluoroalkyl and polyfluoroalkyl substances from building materials and industrial fabrics.” *Environmental Science: Processes & Impacts* 21, no. 11 (2019): 1936-1945. https://doi.org/10.1039/c9em00091g.

147 Zhang et al. “Novel and legacy poly-and perfluoroalkyl substances (PFASs) in indoor dust from urban, industrial, and e-waste dismantling areas: The emergence of PFAS alternatives in China.” *Environmental Pollution* 263 (2020): 114461. https://doi.org/10.1016/j.envpol.2020.114461.

148 Health Product Declaration Collaborative. “The HPD Public Repository.” https://www.hpd-collaborative.org/hpd-public-repository/.

149 Fernández, Set Rojello, Carol Kwiatkowski, and Tom Bruton. “Building a Better World: Eliminating Unnecessary PFAS in Building Materials.”

150 Glüge et al. “An Overview of the Uses of Per- and Polyfluoroalkyl Substances (PFAS).”