Per- and Poly-fluorinated Alkyl Substances (PFAS):
Policy Analysis
DRAFT
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Overview

The per- and poly-fluorinated alkyl substances (PFAS) constitute a large category of chemicals. PFAS chemicals have unique properties such as water and stain resistance, that can make them useful in a variety of settings. They all share certain characteristics, such as persistence and breakdown products of concern. The SAB has reviewed the science on PFAS of several chain lengths. This document provides a brief overview of PFAS, including information on the scientific information reviewed by the SAB to date. This document is an overview, and is not exhaustive.

PFAS have been studied in detail by a number of authoritative bodies. For example, the Organisation for Economic Co-operation and Development (OECD) has done the most comprehensive work on PFAS as a class; the US EPA has done extensive research on two PFAS compounds; and certain states have researched individual PFAS chemicals in depth. Therefore, the TURA program will make use of existing documentation on the topic wherever possible.

Several efforts are under way to address limited aspects of PFAS contamination in Massachusetts, including an effort to set MCLs for a limited number of these chemicals. While these activities are on-going, PFAS continue to be used in industry and products, and released into the environment. Addressing PFAS under the TURA program would help manufacturers to understand how PFAS are being used and identify ways to reduce their use.

This draft policy analysis includes information on PFAS categorization, health and environmental effects, uses, and regulatory context. Additional information will be added after the Advisory Committee and Administrative Council have provided their input on this draft.

Category description

The following is a description of the broad chemical category of PFAS. This is an approach to organizing chemicals that have similar chemical characteristics, not a description of a proposed regulatory category.

An OECD study identified over 4,700 PFAS-related CAS numbers. In its 2018 document, *Toward a New Comprehensive Global Database of Per- and Polyfluoroalkyl Substances (PFASs): Summary Report on Updating the OECD 2007 List of Per- and Polyfluoroalkyl Substances (PFASs),* OECD broadly divided PFAS into "commonly recognized per- and polyfluoroalkyl substances" and "other highly fluorinated substances that match the definition of PFASs, but have not yet been commonly regarded as PFASs." Within the first category of "commonly recognized" PFAS, OECD divides the substances into perfluoroalkyl/per- and polyfluoroalkylether acids (PFAAs), PFAA precursors, and other PFASs. For convenience and clarity within the present document, TURI uses the following broad terms for subcategories of

PFAAs: "carboxylic and sulfonic acids," "phosphonic and phosphinic acids," and "ethers" (see Figure 1).

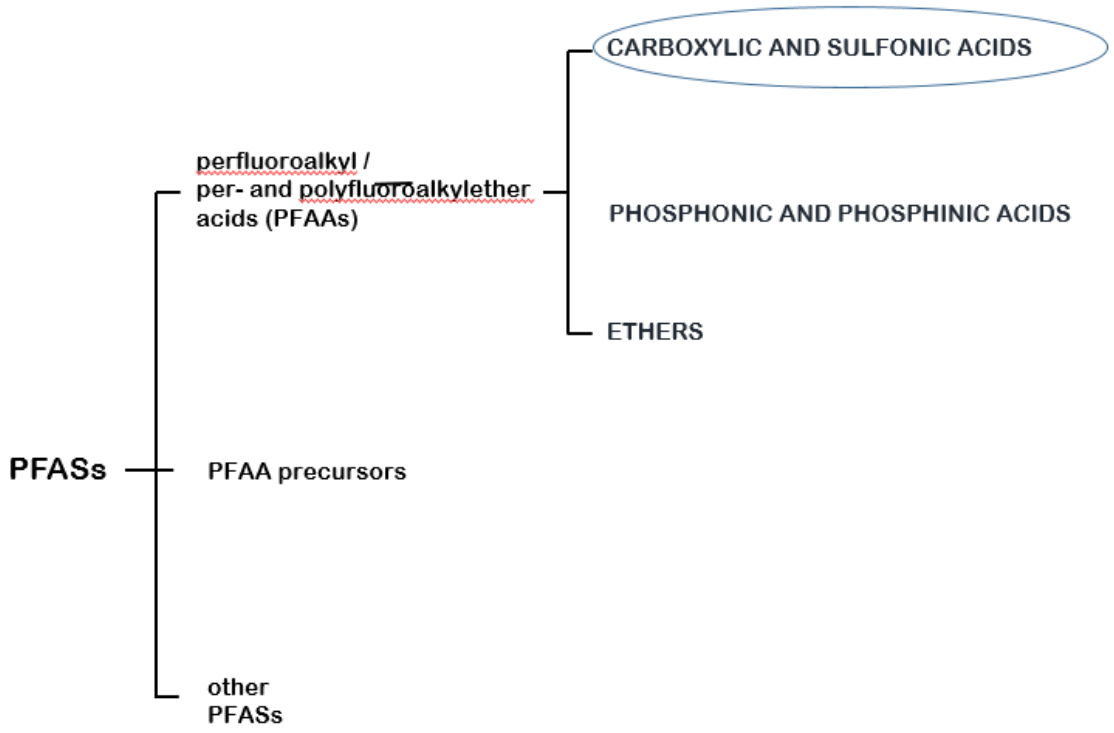


Figure 1: Overview of PFAS

Note: The SAB's work to date has focused on the carboxylic and sulfonic acids, circled in this diagram.

- **PFAAs.** The PFAAs are further separated into sub-groups: the carboxylic and sulfonic acids (perfluoroalkyl carboxylic acids [PFCAs], perfluoroalkane sulfonic acids [PFSAs] – circled in Figure 1) the phosphonic and phosphinic acids (perfluoroalkyl phosphonic acids [PFPAs], perfluoroalkyl phosphinic acids [PFPiAs]), and the ethers (per- and polyfluoroether carboxylic and sulfonic acids [PFECAs and PFESAs]). This grouping is shown below in simplified form in Figure 1, and with additional detail in Appendix A.
- **PFAA Precursors.** The PFAA precursors are chemicals that break down into the PFAAs.
- **Other PFAS.** The category of "other PFASs" includes fluoropolymers and other compounds (see Appendix for more details). Note that the polymers may be solid resins or lower molecular weight polymer dispersons.

Note: PFCAs, PFSAs, and their precursors are often identified by the length of the fluorinated carbon chain. For example, C8 refers to an 8-carbon alkyl chain. OECD and EPA have also developed an approach to categorizing PFAS into "long chain" and "short chain."[1]

[1] OECD 2018 notes that "Based on the commonly accepted OECD definition, long-chain PFAAs refer to perfluoroalkyl carboxylic acids (PFCAs) with ≥ 7 perfluorinated carbons and perfluoroalkane sulfonic acids (PFSAs) with ≥ 6 perfluorinated carbons." OECD. 2018. *TOWARD A NEW COMPREHENSIVE GLOBAL DATABASE OF PER- AND POLYFLUOROALKYL SUBSTANCES (PFASs): SUMMARY REPORT ON UPDATING*

The SAB's work to date has focused on the PFAAs. Within this category, the science described in this document refers to the carboxylic and sulfonic acids, which have been widely identified as contaminants in the environment, GenX and ADONA (as examples of PFECAs) and the phosphonic/phosphinic acids.

Summary of Scientific Information: PFAAs

The present summary focuses only on the PFAAs as this has been the SAB's focus to date.

Summary. In general, the chemicals that the SAB has reviewed are characterized by very high persistence in the environment; they do not break down under normal environmental conditions. In addition, all of these chemicals pose some degree of bioaccumulation concern, especially in air breathing organisms. The longer-chain chemicals are the most bioaccumulative, but the shorter-chain chemicals also bioaccumulate, at least in plants. Key health endpoints of concern include effects on the endocrine system, including liver and thyroid, as well as metabolic effects, developmental effects, neurotoxicity, and immunotoxicity. Some of these health endpoints have been documented for multiple chemicals that the SAB reviewed. Other health effects have been documented for only one or two chemicals, but are highlighted here because they have been found in a large number of studies.

SAB approach. In order to understand the characteristics of a range of PFAAs, the SAB examined eight substances of varying chain lengths: PFNA (C9); PFOS and PFOA (C8); PFHpA (C7); PFHxA and PFHxSs (C6)[2]; and PFBA and PFBS (C4). Two ethers, GenX and ADONA, were then reviewed. Currently, the SAB is reviewing the phosphonic and phosphinic acids (PFPA and PFPiAs).

For PFOS and PFOA, the SAB recommended listing based on PBT data from authoritative sources.

For the other chemicals, the SAB reviewed the literature on health effects as well.

THE OECD 2007 LIST OF PER- AND POLYFLUOROALKYL SUBSTANCES (PFASs). ENV/JM/MONO(2018)7. Series on Risk Management No. 39. Viewed at http://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=ENV-JM-MONO(2018)7&doclanguage=en, February 2019. For a helpful discussion of naming conventions, see ITRC. "Naming Conventions and Physical and Chemical Properties of Per- and Polyfluoroalkyl Substances (PFAS), available at https://pfas-1.itrcweb.org/wp-content/uploads/2018/03/pfas_fact_sheet_naming_conventions__3_16_18.pdf. As explained by ITRC, "Note that for carboxylates, the total number of carbons used for naming the compound includes the carbon in the carboxylic acid functional group (COOH), and so although PFOA has seven carbons in its fluoroalkyl tail, all eight of the carbons in the molecule are used to name it, hence perfluorooctanoate. However, in terms of chemical behavior, PFOA would be more analogous to seven-carbon perfluoroheptane sulfonate, PFHpS, than to eight-carbon perfluorooctane sulfonate, PFOS."

[2] Note regarding the C6 molecules: EPA classifies PFHxS along with PFOS and PFOA as a long-chain PFAS, while PFHxA is classified with the shorter-chain PFAS.

The literature on health effects of PFOS and PFOA was also used for context in evaluating the other PFAS substances. This included examining the health and environmental effects of PFOS and PFOA, then examining the literature to determine whether information is available on these effects for the other chemicals in question.

In addition to considering primary research publications, the SAB was able to draw upon analyses conducted by many other government agencies, including other states such as Minnesota and New Jersey.

PFAAs are highly persistent and do not break down under environmentally relevant conditions. Longer-chain substances (in particular the C8 substances, PFOS and PFOA) have been studied in greater depth than shorter-chain substances. The in-depth information on longer-chain substances includes epidemiological data on more than 70,000 individuals resulting from widespread human exposure to C8 compounds in drinking water in Parkersburg, West Virginia.

PFOS and PFOA. In its examination of the C8 substances, the SAB found evidence of persistence, bioaccumulation, and acute toxicity. These findings were sufficient for the SAB to recommend listing these substances. In addition, the SAB was able to review the results of the C8 Health Project.[1] This project resulted from a settlement agreement related to PFOA contamination in two states. It documented a wide range of chronic human health endpoints associated with exposure to PFOA. Hazards that were documented within the C8 Health Project include carcinogenicity (probable links to kidney and testicular cancer), pregnancy-induced hypertension (PIH), ulcerative colitis, thyroid disease, and hematological effects including effects on blood cholesterol levels, among others. In addition, a report by the National Toxicology Program (NTP) notes that PFOS and PFOA are "presumed to be an immune hazard to humans." [2] This information added important additional context for understanding the range of health impacts of PFAS of other lengths as well. The SAB was able to use this information to identify health endpoints for literature review.

C7 and lower. For the PFAS substances with fewer than eight carbons, less information was available. They are all highly persistent in the environment and have a range of half-lives[3] in the human body (days to years). These substances also show some evidence of bioaccumulation and they are very mobile, creating the potential for global transport. They have been found in serum and breastmilk, and their presence in the environment creates the potential for on-going exposures. They are less acutely toxic than the C8 substances. However, the SAB's literature review found evidence of a range of chronic health effects, including immunotoxicity, thyroid, liver/metabolic effects, endocrine effects, hematological effects, neurodevelopmental effects, reproductive effects, asthma, and neurotoxicity. These substances are strong acids and are very corrosive in their concentrated form.

It is also worth noting that while the shorter-chain substances are not as bioaccumulative in air-breathing organisms as the longer-chain substances, they show greater bioaccumulation in plants.[4][5]

C9. The New Jersey Drinking Water Institute had recently published its Health-Based Maximum Contaminant Level Support Document for the C9 substance, perfluorononan-1-oic acid

(PFNA).[6] PFNA also is highly persistent in the environment and has a half-life of greater than 1.7 years.[7] PFNA shows bioaccumulation concern and mobility in the environment. The SAB's literature review also found evidence of developmental/reproductive effects, immunotoxicity, effects on the liver, neurotoxicity and corrosivity.

GenX and ADONA. The EPA Draft Toxicity Assessment for GenX was published shortly before the SAB review. The SAB noted persistence, mobility, corrosivity, and liver toxicity as the primary concerns for GenX. For ADONA the SAB noted that it followed the patterns of the other PFAS that the SAB has reviewed, such as liver effects, persistence, differences in effects based on gender, corrosivity, and maternal toxicity. However, available data were not sufficient for a listing recommendation. An overall lack of publicly available studies, especially cancer, immunotoxicity, neurotoxicity, thyroid and complete reproductive details was noted.

PFPA and PFPiA. The SAB is currently reviewing the phosphonic and phosphinic acids.

Bioaccumulation – additional information. It is also helpful to understand that while bioaccumulation is often assessed through studies of fish, in the case of PFAS, this approach is less relevant. PFAS bind to proteins rather than to lipids,[8] so it is important to consider levels in blood serum, rather than in fatty tissue. In addition, gill-breathing organisms are more able to eliminate certain PFAS due to their water solubility, while air-breathing organisms are more vulnerable to bioaccumulation.[9] Although bioaccumulation in fish may be lower than in air-breathing organisms, bioaccumulation of certain PFAS is being detected in fish (for example, in fish livers).[10]

Table 1 shows the information reviewed by the SAB regarding chronic health effects. An "X" indicates that there was evidence for that effect in the literature. For additional information, see Appendix B.

Table 1: Chronic health effects

	PFNA	PFOA	PFOS	PFHpA	PFHxA	PFHxS	PFBA	PFBS	Gen X	ADONA	PFPA/ PFPiA *
Cancer		Kidney, testicular							X		
Immunotoxicity	X	Ulcerative colitis	X					X	X		
Thyroid		X			X	X	X	X		X	
Endocrine (other than thyroid)					X	X	X	X			
Hematological		Cholesterol				X	X	X			
Liver/metabolic	X			X	X	X	X	X	X	X	
Reproductive	X	PIH**							X	X	
Developmental	X			X	X		X	X	X		
Neurodevelopmental						X					
Neurotoxicity	X				X	X		X			
Asthma						X		X			
Other	Mutagenicity				Kidney			Kidney	Kidney		

Note: The SAB did not conduct a literature review for PFOS and PFOA due to the volume of information available through authoritative bodies and large scale epidemiological studies. Therefore, the endpoints shown for PFOA are not identical to those shown for the other chemicals. For PFOS, the SAB was able to use information from NTP so a literature review of additional studies was not necessary.
* SAB examination of data still in process.
** Pregnancy Induced Hypertension

Table 2 shows the information reviewed by the SAB regarding the presence of PFAS in the environment, including presence in groundwater and surface water, as well as their potential for persistence and bioaccumulation.

Table 2: Persistence, presence in the environment, and bioaccumulation

	PFNA	PFOA	PFOS	PFHpA	PFHxA	PFHxS	PFBA	PFBS	GenX	ADONA	PFPA/ PFPiA*
Persistence	X	X	X	X	X	X	X	X	X	X	X
Bioaccumulation	X	X	X	X	X	X	X	X	X		
Presence in the environment	X	X	X	X	X	X	X	X	X		
Presence in biota, including humans	X	X	X	X	X	X	X	X	X		

Information on these chemical properties is drawn from peer reviewed studies and from US or EU government documents. PFOS and its salts and perfluorooctanyl sulfonyl fluoride are designated as Persistent Organic Pollutants under the Stockholm Convention; PFOA, its salts, and PFOA-related compounds as well as PFHxS, its salts and PFXxS-related compounds are currently under review for possible addition to the Convention as well. PFHxS and its salts are listed as vPvB, and PFNA and its salts, APFO, and PFOA are listed as PBT by the European Chemicals Agency (ECHA, Candidate List of Substances of Very High Concern for Authorization, https://echa.europa.eu/candidate-list-table).
* SAB work still in progress.

Use information

Non-polymeric per- and polyfluoroalkyl substances may be as used as surfactants, wetting agents, emulsifiers and polymerization processing aids, mist suppressants, pesticide active ingredients, and film formers.[11] Polymeric per- and polyfluoroalkyl substances may be used as lubricants, insulators, protective coatings, and raw materials for textiles, semiconductors, and automotive components.[12] Some per- or polyfluoroalkyl substances may be coincidentally manufactured and released to the environment as a result of the use or manufacture of other PFAS chemicals. For example, it has been documented that PFHxA can be a byproduct of per- and polyfluoroalkyl substance manufacturing.[13]

Many of the chemicals in this category may be used for multiple purposes. For example, perfluorobutane sulfonic acid (PFBS) is used as a surfactant, flame retardant, and in metal plating.[14]

To determine how many facilities may be using PFAS in MA, TURA program staff analyzed EPCRA Tier II data and also conducted detailed research using other resources. This research is described below.

Massachusetts data available from Tier II:

EPCRA Tier II requires reporting of any chemical with a Safety Data Sheet if it is stored at 10,000 pounds or more at a facility (the threshold is 500 pounds for extremely hazardous

substances). A review of the 2015 Tier II data for Massachusetts shows approximately 15 records for PFAS chemicals. Over half of these records were for fire-fighting foams. Fewer were for fluoropolymers or fluoroelastomers.

A review of the 2017 Tier II data shows 48 records for PFAS chemicals, although this may include some duplicates.

Three facilities submitted a combined total of 16 reports for semifluorinated PFAA precursors or related compounds. Two facilities reported on perfluorinated PFAA precursors; one was a fire protection equipment distributor and the other was a chemical distributor for the electronics sector.

One manufacturing facility reported on perfluoroalkane sulfonyl compounds used for a buffered oxide etch with surfactant. One military-related facility reported on a fluorotelomer related compound, also used as a surfactant.

Fifteen of the records are for fluoropolymers (17 total entries, but 2 appear to be duplicates).

Nine facilities reported storing AFFF. Three are military/aerospace sites and five are energy-related businesses. One is a solar energy facility.

Interestingly, Tier II reporting does not fully correspond to the information that facilities have given to TURA staff member in interviews. For example, of six facilities interviewed by one staff member in 2019, two gave answers that did not correspond to their Tier II reporting. One facility stated it did not use PFAS, although it has reported PFAS use under Tier II. Another facility, which produces coated fabrics for the military, stated that it does use PFAS, but this facility had not reported under Tier II (possibly due to being under threshold). Thus, the Tier II data do not necessarily provide a comprehensive overview of all PFAS use.

Of the facilities that reported under Tier II in 2017, some would be likely to be required to report under TURA. Specifically, the manufacturing facilities and the chemical distributors would be likely to be subject to TURA, if their use of these chemicals exceeds the relevant threshold. TURA program staff estimate that of the Tier II reporters, approximately six would be expected to file under TURA. In addition, as we have observed, there are other facilities that may be using PFAS but not reporting under Tier II.

Table 3 shows the number of 2017 Tier II chemical reports, organized by chemical structure as described by the OECD New Comprehensive Global Database of PFASs.[15] This table does not include the reports for AFFF.[16]

An additional 3 entries remain unlisted in Table 3 because the Tier II data lacked detail. One such example was listed only as “fluoro chemicals” without a Chemical Abstract Service (CAS) number.

Additional research on Massachusetts use of PFAS

Due to the high prevalence of proprietary chemical information on safety data sheets, the TURA program has conducted a broader search with the intention of producing a broader, but not

comprehensive, list of facilities that appear to manufacture in Massachusetts and are likely, but not confirmed, to use or manufacture per- and polyfluoroalkyl substances. This additional search is based upon the publicly available information on company products and processes that correspond with descriptions of PFAS use found in information produced by the OECD,[17] the U.S. Environmental Protection Agency (EPA),[18] the Interstate Technology Regulatory Council (ITRC),[19] and the New York State Pollution Prevention Institute (NYSP2I).[20] As of January, 2019, the TURA program has identified approximately 242 such facilities in certain industry sectors, as shown in Table 4.

Specifically, the TURA program took the following approach to identifying potential PFAS users in Massachusetts. First, program staff used three databases – Hoover Online, ReferenceUSA, and A to Z -- to search for businesses in Massachusetts operating under specific SIC or NAICS codes.

- The following SIC codes were included in the search: 2821 (Plastics Materials and Resins), 3479 (Metal Coating and Allied Services), and 3999 (Manufacturing Industries), SIC 2295 (Coated Fabrics, Not Rubberized) and SIC 5172 (Petroleum Products).
- The following NAICS codes were used in the search: 322220 (Paper Bag and Coated and Treated Paper Manufacturing), NAICS 334419 (Other Electronic Component Manufacturing), NAICS 335999 (All Other Miscellaneous Electrical Equipment and Component Manufacturing), and NAICS 335929 (Other Communication and Energy Wire Manufacturing).

These SIC and NAICS codes were selected as a means to gather preliminary information, but are not expected to cover all the relevant industry sectors. Reporting requirements under TURA would provide more useful and reliable information on PFAS use in Massachusetts.

To further learn about possible PFAS use, the TURA program visited the web pages of the businesses identified from the database search, and noted which businesses had a high probability of using PFAS based on their product profile.

Table 3: Possible Use or Manufacture of Per- and Polyfluoroalkyl Substances in Massachusetts

Sector Code and Description	**Facilities in TURA Covered SIC Codes Identified as Possible PFAS Users, January 2019**
Plastics Materials and Resins	28
Metal Coating and Allied Services	8
Manufacturing Industries	6
Coated Fabrics, Not Rubberized	25
Petroleum Products	10
Paper Products	30
Electronic Component Manufacturing, Electrical Equipment and Component Manufacturing	135
Total	**242**

Note: These estimates are based on a review of several databases and are not comprehensive. TURA reporting would provide more reliable information.

The TURA program did not review possible PFAS use among in other manufacturing use areas such as textile and leather coating, paper products, resins, synthetic rubber, films, and adhesives. Reviewing these sectors could yield additional numbers of possible users.

Estimating total users

To estimate the number of facilities likely to be subject to TURA, once a proposed grouping has been developed, TURA program staff will check the quantity reported by each Tier II filer that is in a TURA covered sector, and integrate this with other information available to the program.

Regulatory context

Due to the emerging nature of scientific knowledge about health and environmental impacts of PFAS, as well as revelations about water supply contamination in an increasing number of geographic areas, a variety of regulatory processes are on-going. A number of current regulatory actions are described here. This review is not comprehensive and regulatory actions are continually evolving In addition, there may be inconsistencies in state information in this document due to timing of updates of such activity on websites and in publications.

International

International agreements. PFOS as well as its salts and perfluorooctanyl sulfonyl fluoride have been placed on Annex B of the Stockholm Convention on Persistent Organic Pollutants and are targeted for phaseout globally, with some exemptions.[21] In addition, PFOA, its salts, and PFOA-related compounds as well as PFHxS (C6), its salts and PFXxS-related compounds are currently under review for possible addition to the Convention.[22]In September 2018, the UN Stockholm Convention on Persistent Organic Pollutants Review Committee (POPRC) recommended listing PFOA, its salts, and PFOA-related compounds in Annex A of the treaty, which calls for global elimination. The Committee also recommended removing exemptions for some applications of PFOS; and taking PFHxS, its salts and related compounds "to the next review stage, which requires a risk management evaluation…"[23] [24] [25]

A committee of the UN's Rotterdam Convention - which governs the prior informed consent of the importation and exportation of hazardous chemicals - also recommended the listing of PFOA, its salts, and PFOA-related compounds in September 2018.[26]

European Union. PFOA, PFHxS and its salts, PFNA and its salts, and ammonium pentadecafluorooctanoate (APFO, the ammonium salt of PFOA) are listed on the Candidate List of Substances of Very High Concern for Authorization under the EU's REACH regulation.[27] In addition, a number of other PFAS have been added to ECHA's Registry of Intentions for SVHC designation. These include nonadecafluorodecanoic acid (PFDA), henicosafluoroundecanoic acid (PFUnDA), tricosafluorododecanoic acid (PFDoDA) and several others.[28] PFOS is regulated in the EU as a persistent organic pollutant.

Canada. In October 2018, the Canadian government, through its health department and environment department, initiated development of amendments to its toxic substances

regulations "to further restrict the manufacture, use, sale, offer for sale and import of…three oil and water repellents (PFOS, PFOA and LC-PFCA)."[29]

China. In 2011, China restricted the production of PFOS and PFOA and encouraged research and development on alternatives. In 2014, China's environmental protection ministry banned "production, transportation, application, imports and exports of PFOS, its salts, and perfluorooctane sulfonyl fluoride (PFOSF), except for specific exemptions and acceptable use."[30]

Federal

EPA – UCMR. EPA has collected data on selected PFAS under its Unregulated Contaminant Monitoring Rule 3 (UCMR 3) (77 FR 26072, 2012). UCMR allows EPA "to collect data for contaminants that are suspected to be present in drinking water and do not have health-based standards set under the Safe Drinking Water Act (SDWA)."[31] Under UCMR 3, EPA has required testing for PFOS, PFOA, PFHxS, PFNA, PFHpA, and PFBS in all larger drinking water systems.[32]

EPA – health advisory for PFOS and PFOA. For PFOS and PFOA, EPA has developed a health advisory of 70 ppt (equivalent to ng/L) for lifetime exposure to the sum of PFOS and PFOA in public drinking water. "EPA's health advisories are non-enforceable and non-regulatory" and are designed to provide technical information to states and other public health officials.[33]

EPA – SNURs. PFOS and PFOA are no longer manufactured within the US, although they are present in some products imported into the US. EPA has issued a significant new use rule (SNUR) for these and other substances.

EPA – PFAS Action Plan. In February 2019, EPA released a "Per- and Polyfluoroalkyl Substances (PFAS) Action Plan." The main actions the EPA announced are initiating steps to:

- evaluate the need for a maximum contaminant level (MCL) for PFOA and PFOS;
- begin the necessary steps to propose designating PFOA and PFOS as "hazardous substances" through one of the available federal statutory mechanisms;
- develop groundwater cleanup recommendations for PFOA and PFOS at contaminated sites; and
- develop toxicity values or oral reference doses (RfDs) for GenX chemicals and perfluorobutane sulfonic acid (PFBS).[34]

EPA- Draft Toxicity Assessment for GenX and PFBS. In November 2018 the EPA released Draft Toxicity Assessments for PFBS and GenX. These documents provided comprehensive toxicity reviews as well as draft RfDs.

ATSDR. The Agency for Toxic Substances & Disease Registry (ATSDR) published "Toxicological Profile for Perfluoroalkyls: Draft for Public Comment" in June 2018; the public comment period closed on August 20, 2018. The toxicological profile characterizes the

toxicology and adverse health effects information for perfluoroalkyls. It includes peer-reviewed profiles that review key literature about their toxicological properties.[35]

State[3]

A number of states are in the process of developing new regulations and programs to address PFAS. This includes developing regulations and programs to:

- monitor and study PFAS
- label or disclose products containing PFAS
- limit or ban the use of PFAS
- specify that certain product types must be free of PFAS; and
- regulate PFAS levels in groundwater or drinking water.

This section summarizes these areas of activity at the state level. Examples are also shown in the tables in Appendix C and Appendix D.

Monitoring. The North Carolina legislature funded the monitoring and treatment of PFAS, particularly "GenX" substances.[36] [37] GenX is the trade name for a fluoroether-based processing aid technology. According to the U.S. EPA, in 2008, the agency received new chemical notices under the Toxic Substance Control Act from the manufacturer "for two chemical substances that are part of the GenX process (Hexafluoropropylene oxide (HFPO) dimer acid and the ammonium salt of HFPO dimer acid)."[38] These chemicals are generally referred to as GenX.

New Hampshire's Department of Environmental Services is investigating a number of sites in the state for the presence of PFAS in groundwater. These include landfills, industrial sites, fire departments and training facilities, and a wastewater treatment facility.[39]

The Washington Department of Health "plans to test several hundred water systems in the state for trace contamination of more than a dozen chemicals found in some firefighting foams."[40]

PFAS chemicals are included in the California Environmental Contaminant Biomonitoring Program, also known as Biomonitoring California.[41] A scientific guidance panel makes recommendations about priority chemicals for biomonitoring.[42]

Firefighting foam. The State of Washington banned the use of PFAS-containing Class B firefighting foam (designed for flammable liquid fires) for training effective July 1, 2018. A ban on the manufacture, sale, and distribution of PFAS-containing Class B firefighting foam, with certain exemptions, takes effect on July 1, 2020.[43] In Minnesota, the use of Class B firefighting foam with intentionally added PFAS will be prohibited for use in testing and training, unless otherwise required by law and with provisions for appropriate controls, among other requirements related to firefighting foam.[44]

Food packaging. In 2018, the State of Washington passed a law prohibiting all PFAS in paper food packaging. The law will take effect in 2022, after the state identifies safer alternatives and

[3] Note: This summary is current as of April 2, 2019.

considers feedback from an external review process.[45] A bill in the New York State Senate would prohibit "the manufacture, sale, or distribution of food packages in which PFAS chemicals are present in any amount."[46] A bill in Vermont, also introduced, like New York's, in February 2019, requires the health department to analyze whether there are safer alternatives to food packaging to which PFOA or PFAS have been added, and if so, would prohibit their manufacture and sale.[47] A bill introduced in the New Jersey legislature in February 2019 directs the state environmental agency "to study and, if necessary, regulate perfluoroalkyl and polyfluoroalkyl substances in food packaging."[48] In Massachusetts, a bill was introduced in 2019, H.3839, which would ban the sale and distribution of food packaging to which PFAS have been intentionally added. [49]Bills and laws on this topic frequently specify that a ban is contingent on identifying safer alternatives.

Labeling and disclosure. While many regulatory actions focus on PFAS in water and in products, others focus on labeling of products containing PFAS, or address PFAS as part of chemical action plans and through designation as a hazardous waste. For example, in November 2017, PFOS and PFOA were listed as known to the state to cause reproductive toxicity under California's Proposition 65 law.[50] The State of Washington requires the reporting of PFOA and related substances, and PFOS and its salts, in children's products. [51] As part of the State of Washington's actions on PFAS-containing firefighting foam, as of July 1, 2018, manufacturers and sellers of PFAS-containing firefighting Personal Protective Equipment (PPE) "must notify purchasers in writing if the equipment contains PFAS and the reasons for using the chemicals."[52]

Environmentally Preferable Purchasing (EPP) policies. The Minnesota Pollution Control Agency works with the state's administrative department to develop specifications that aim to reduce environmental impacts of products and service contracts (often referred to as Environmentally Preferable Purchasing policies). In Minnesota, many state contracts are used by public entities in the state, as well as some non-profits. Specifications include that compostable food ware products "must not contain perfluoroalkyl and polyfluoroalkyl (PFAS)."[53] The State of Washington law that addresses PFAS in firefighting foam and PPE also directs the state's Department of Ecology and Department of Enterprise Services to develop preferred purchasing guidance. The guidance is meant to assist additional public sector partners to avoid purchasing firefighting foams and firefighting PPE that contain PFAS.[54]

Drinking water action levels, Maximum Contaminant Levels (MCLs), and groundwater cleanup standards. Because PFAS have been found as widespread contaminants in many public water supplies, many state level regulatory authorities are working to develop MCLs or other regulatory standards. Most or all of these regulatory efforts address chemicals in the carboxylic and sulfonic acids category. Some states have relied primarily on EPA's health advisory, while others have worked to develop more protective standards and/or have undertaken to address a larger number of PFAS.

Some states regulate specific PFAS chemicals individually. Others are regulating some PFAS chemicals as a group. For example, the Connecticut Department of Public Health has developed a Drinking Water Action Level for private wells in the state "in which the sum of five PFAS chemicals (PFOA and PFOS, plus perfluorononanoic acid, PFNA, perfluorohexane sulfonate, PFHxS, and perfluoroheptanoic acid, PFHpA) should not exceed the limit of 70 ppt."[55]

Michigan has made important progress in identifying PFAS contamination and is working to identify upstream users and past users of PFAS. Michigan's "Rule 57 Water Quality Values" includes procedures for calculating water quality values to protect humans, wildlife, and aquatic life. Values that are determined include Human Noncancer Value (HNV).[56] The state developed these values for drinking and non-drinking water for PFOA and PFOS in surface waters in 2011 and 2014 respectively. Under the state's Industrial Pretreatment Program PFAS Initiative, publicly owned treatment works are required to survey industrial users with potential sources of PFAS and conduct follow-up sampling of probable sources.[57]

Vermont adopted a health advisory level of 20 ppt for the sum of five PFAS (the same five as are addressed by Connecticut) in drinking water. Vermont's health department advises, "If your water has been tested and the total sum of the five PFAS is more than 20 ppt, we recommend not using your water for drinking, food preparation, cooking, brushing teeth, preparing baby formula, or any other manner of ingestion. Use bottled water instead or water from a known safe source. Do not use water containing the five PFAS over 20 ppt to water your garden. The PFAS could be taken up by the vegetables."[58]

In 2017, the Minnesota Department of Health released updated guidance values for PFOA and PFOS. They are health recommendations to local officials who are operating public water supplies and private well owners in areas with PFAS in groundwater. In September 2018, New Jersey adopted a statewide drinking water standard for PFNA with an MCL of 13 ppt.[59] Water systems in New Jersey were required to start testing in the first quarter of 2019. A ground water quality standard for PFNA of 0.01 µg/L (equivalent to 10 ng/L or 0.01 ppb) was adopted under amendments to New Jersey's Ground Water Quality Standards Rules in January 2018. Also in 2018, PFNA was added to New Jersey's List of Hazardous Substances.[60] In 2017, New Jersey established a drinking water guidance value for PFOA of 14 ppt. In 2017, the New Jersey Drinking Water Quality Institute published a draft health-based recommendation of 13 ppt for PFOS, and in 2018 the New Jersey Department of Environmental Protection accepted the recommended PFOS MCL.[61].

In December 2018, the New York State Drinking Water Quality Council recommended standards for PFOA and PFOS. The next step is for the Health Department to start a rulemaking process.[62]

The New Hampshire Department of Environmental Services has adopted maximum contaminant levels for drinking water for four PFAS chemicals. These standards are designed to be "protective for the most sensitive populations over a lifetime of exposure."[63] The new standards are as follows: Perfluorohexane sulfonic acid (PFHxS) at 18 parts per trillion (ppt); perfluorononanoic acid (PFNA) at 11 ppt; perfluorooctane sulfonic acid (PFOS) at 15 ppt; and perfluorooctanoic acid (PFOA) at 12 ppt.[64]

Massachusetts: Approach to regulating drinking water. In Massachusetts, MassDEP's Office of Research and Standards (ORS) has developed a set of recommendations regarding an approach to regulating PFAS in drinking water.[65] The recommendations, published in June 2018, note that all of the PFAS for which EPA has conducted testing under UCMR 3 have been found in Massachusetts water supplies. ORS has recommended that EPA's Health Advisories (HAs) and Reference Doses (RfDs) for PFOS and PFOA be applied to three other PFAS (PFNA, PFHxS, and PFHpA), and that "an additive toxicity approach be used for these compounds when they

occur together." For PFBS, ORS has recommended an interim approach of using the Minnesota standard.

In October 2018, MassDEP received a "Petition for Rulemaking to Establish a Treatment Technique Drinking Water Standard" for PFAS from two environmental organizations. The petitioners requested that MassDEP adopt a treatment technique drinking water standard for the entire class of PFAS; adopt the Vermont Department of Health's Advisory for five PFAS of 20 ppt as an interim MCL; and "at minimum, adopt individual MCLs for each PFAS chemical that poses a risk to public water systems in Massachusetts." [66]

In January 2019, the agency responded that it will initiate the process to develop a drinking water MCL for a group of PFAS. The process will be informed by MassDEP's work to develop groundwater cleanup standards.[67]

Health risk limit values. Minnesota has developed Health Risk Limit values for PFOS, PFOA, PFBA and PFBS. Minnesota has also examined information about PFHxS, but has not developed a Human Risk Limit value for this chemical.[68]

The Texas Risk Reduction Program (TRRP) "has derived risk-based inhalation exposure limits (RBELs) for select PFAS. These RBELs are applicable to PFAS that may volatilize from soil to air at remediation sites managed under the TRRP rule (Texas Commission on Environmental Quality [TCEQ], 2017)," according to the Interstate Technology Regulatory Council.[69]

Cleanup. In 2016, New York regulated PFOA as a hazardous substance, then regulated PFOS. The regulation "requires the proper storage of the substances and limited releases to the environment, and enabled the state to use its legal authority and resources of the State Superfund program to advance investigations and cleanups of impacted sites. The Final Rule for PFOA and PFOS became effective on March 3, 2017," according to the New York State Department of Environmental Conservation.[70]

Multi-agency task forces. At least two states have established multi-agency PFAS task forces. In Maine, an executive order created the Governor's Task Force on the Threats of PFAS Contamination to Public Health and the Environment. The purpose of the Task Force is to identify the extent of PFAS exposure in Maine, examine the risks of PFAS to Maine residents and the environment, and recommend approaches to most effectively address this risk.[71] The Task Force's 11 members include representatives of several state agencies, the state public health association, and additional organizations.[72] In Michigan, the PFAS Action Response Team was created in 2017 as a temporary body. In 2019, the governor signed an executive order establishing the team as an advisory body within the state's environmental agency. It includes representatives of seven state agencies, and is charged with providing recommendations and coordinating efforts in this area.[73]

Approaches to grouping

A workshop held in Zürich, Switzerland in November 2017 brought together researchers and regulators from around the world to work towards better coordination to address PFASs. The group made a number of recommendations. One is that, given "the large number of substances in the PFAS family…actions need to address groups of PFASs rather than individual chemicals."[74] Such a grouping approach "requires a better mechanistic understanding of the physicochemical

and toxicological properties of PFASs as well as additional data that can be used to support grouping approaches for PFASs."

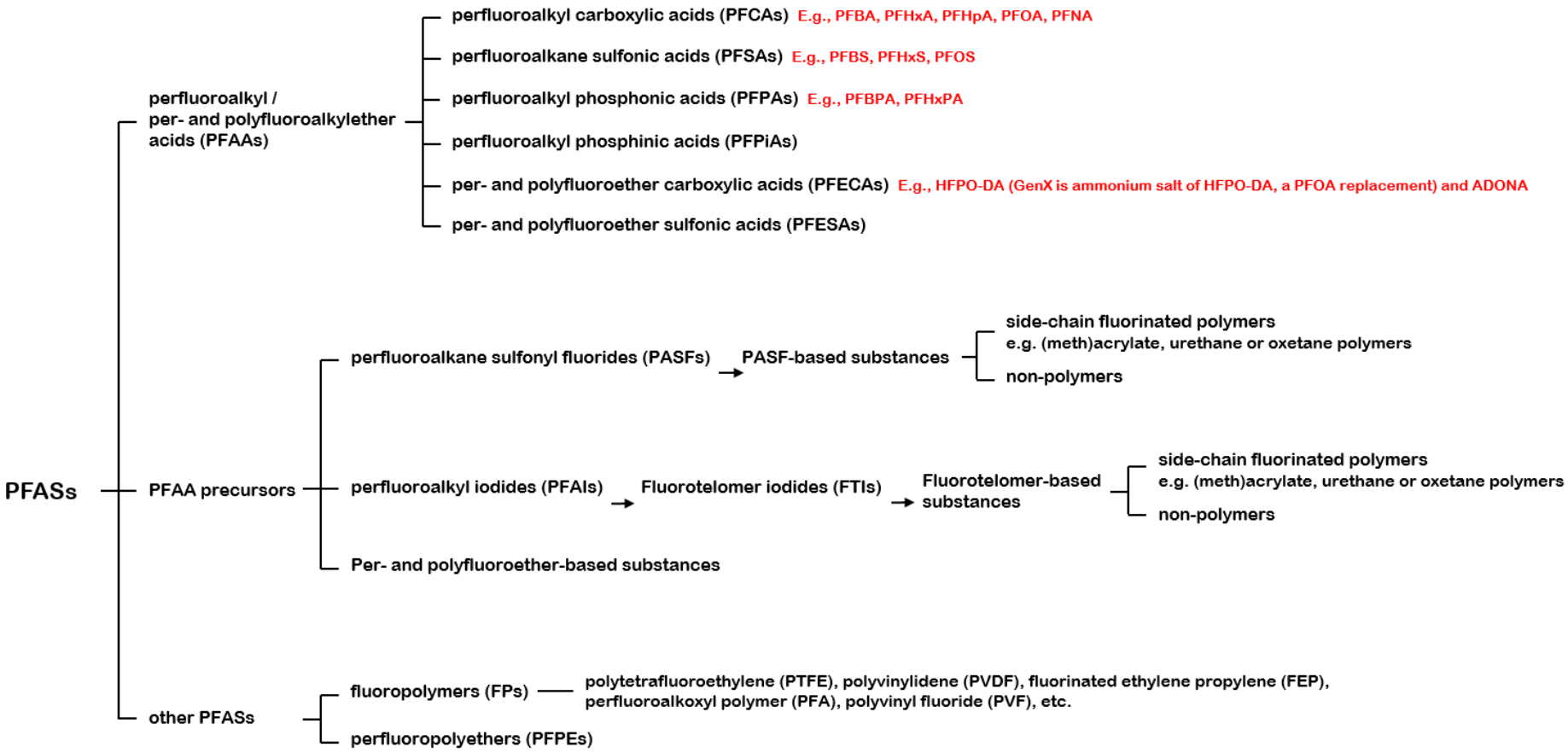
The group supports regulation focused on high persistence in the environment, which "can lead to a continuous and nearly irreversible accumulation of PFASs in the environment and, in turn, increased exposure and risks to humans and wildlife…" Participants agreed on the importance of reducing, and eventually phasing out, nonessential uses of PFASs. This there is not a generally accepted definition of "essential uses," goals include defining this with regard to PFASs, and working to develop safe alternatives to PFASs that avoid regrettable substitutions.[75]

As noted above, Connecticut is one example of a state that is regulating some PFAS chemicals as a group. The Connecticut Department of Public Health has developed a Drinking Water Action Level for private wells in the state "in which the sum of five PFAS chemicals (PFOA and PFOS, plus perfluorononanoic acid, PFNA, perfluorohexane sulfonate, PFHxS, and perfluoroheptanoic acid, PFHpA) should not exceed the limit of 70 ppt."[76]

Appendix A

This flow chart is simplified and adapted from a flow chart published by OECD.[77] TURI has added the example notations in red font.

Commonly recognized per- and polyfluoroalkyl substances (PFAS)



Other Highly Fluorinated Substances that match the definition of PFAS, but have not yet been commonly regarded as PFAS

OECD has identified a number of other highly fluorinated **s**ubstances that match the definition of PFAS, but have not yet been commonly regarded as PFAS. These include the perfluorinated alkanes, perfluorinated alkenes and their derivatives, perfluoroalkyl alcohols, perfluoroalkyl ketones, semi-fluorinated ketones, side-chain fluorinated aromatics, as well as some "hydrofluorocarbons (HFCs), hydrofluoroethers (HFEs), and hydrofluoroolefins (HFOs) that have a perfluoroalkyl chain of a certain length."[78]

Appendix B

The table below shows key studies that were reviewed by the SAB and on which the SAB has relied in establishing a basis for concern about the health endpoint in question. The SAB's review included many additional studies beyond those noted here, including studies that show effects as well as studies that show no effect. The full set of references consulted by the SAB is shown in the SAB's bibliography.

	PFNA	PFOA	PFHpA	PFHxA	PFHxS	PFBA	PFBS	GenX	Adona	PFPA/PFPiA*
Cancer		C8 Health Study						Rae 2015		
Immunotoxicity		C8 Health Study					Corsini 2012	Rushing 2017		
Thyroid		C8 Health Study		Ren 2016	Jain 2013 Weiss 2009	Bjork and Wallace '09 Butenhoff 2012	Feng 2017			
Endocrine (other than thyroid)				Wolf 2008 Rosenmai 2016	Das 2017, Rosenmai 2017	Foreman 2009	Gorrochategui 2014			
Hematological		C8 Health Study				Butenhoff 2012 Van Otterdijk 2007				
Liver/metabolic	Das 2017		Wolf 2012, ATSDR 2018	Loveless 2009	Butenhoff 2009	Foreman 2009 Bjork and Wallace 2009 Wolf 2008 Rosenmai 2016		Sheng 2018, Wang 2017, DuPont 2008	Gordon 2011, Cheng 2018	
Reproductive		C8 Health Study						DuPont 2010, Conley 2019		
Developmental	Das 2015		Kim 2015	Loveless 2009 Iwai 2014		Das 2008	Feng 2017 Lieder 2009			
Neurodevelopmental					Maisonet 2012 Joensen 2009 Viberg 2013					

					Lee and Viberg 2013 Yang 2016					
Neurotoxicity	Oulhote 2016			Loveless 2009 Klaunig 2015	Zhang 2016 Lee and Yang 2014 Viberg 2013		Slotkin 2008			
Asthma					Dong 2013		Dong 2013			
Other	Mutagenicity: Yahia 2016			Kidney: Leider 2009			Kidney: NICNAS 2017			
* SAB work still in process										

Appendix C: State Actions to Address PFAS: Examples

April 17, 2019 (current as of April 2, 2019)

State	Actions
California	• **Biomonitoring:** PFASs are included in the state's biomonitoring program.[4] • **Labelling and disclosure:** In 2017, PFOS and PFOA were listed as known to the state to cause reproductive toxicity under Proposition 65.
Connecticut	• **Drinking water:** The state's public health department developed a Drinking Water Action Level for private wells in the state in which the sum of five PFAS chemicals (PFOA, PFOS, PFNA, PFHxS) should not exceed the limit of 70 ppt.
Massachusetts	• **Drinking water:** o MassDEP's Office of Research and Standards published recommendations in June 2018 that EPA's Health Advisories and Reference Doses for PFOS and PFOA also be applied to PFNA, PFHxS, and PFHpA, and that an additive toxicity approach be used. For PFBS, it recommended an interim approach of using the Minnesota standard. o In response to a citizen petition, in January 2019, MassDEP stated that it will initiate the process to develop a drinking water MCL for a group of PFAS. This will apply to "those PFAS where a threat to human health has been identified, analytical methods exist for their detection, and appropriate treatment technologies are available. Currently, MassDEP understands those PFAS to include PFOA, PFOS, PFHxS, PFHpA and PFNA," according to the agency.[5]
Minnesota	• **Environmentally Preferable Purchasing.** Two state agencies that develop specifications for state contracts include the provision that compostable food ware products must not contain PFAS. • **Health Risk Limit values**: Minnesota developed Health Risk Limit values for PFOS, PFOA, PFBA and PFBS. Minnesota has also examined information about PFHxS, but has not developed a Human Risk Limit value for it. • **Guidance values for drinking water and groundwater**. In 2017, the Minnesota Department of Health released updated guidance values for PFOA and PFOS. They are health recommendations to local officials who are operating public water supplies and private well owners in areas with PFAS in groundwater.
New Hampshire	• **Drinking water**. In December 2018, New Hampshire's Department of Environmental Services began the rulemaking process to establish MCLs and Ambient Groundwater Quality Standards for PFOA, PFOS, PFNA, and PFHxS. Public hearings were scheduled to take place in March 2019, with final proposals anticipated to be filed by summer.

[4] The full list of PFAS the state tests for is at: https://biomonitoring.ca.gov/sites/default/files/downloads/DesignatedChemicalsList_February2019.pdf

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New Jersey	• **Drinking water:** o In 2018, New Jersey adopted a statewide drinking water standard for PFNA with an MCL of 13 ppt. Water systems in New Jersey were required to start testing in the first quarter of 2019. o A ground water quality standard for PFNA of 0.01 µg/L (equivalent to 10 ng/L or 0.01 ppb) was adopted under amendments to New Jersey's Ground Water Quality Standards Rules in 2018. o In 2018, PFNA was added to New Jersey's List of Hazardous Substances. o In 2017, New Jersey established a drinking water guidance value for PFOA of 14 ppt. o In 2017, the NJ Drinking Water Quality Institute published draft recommendations for a health-based MCL for PFOS of 13 ng/L. In June 2018, the state accepted the recommended MCL.
New York	• **Cleanup:** In 2016, New York regulated PFOA as a hazardous substance, then regulated PFOS. The regulation "requires the proper storage of the substances and limited releases to the environment, and enabled the state to use its legal authority and resources of the State Superfund program to advance investigations and cleanups of impacted sites." The Final Rule for PFOA and PFOS became effective on March 3, 2017. • **Drinking water:** In December 2018, the New York State Drinking Water Quality Council recommended standards for PFOA and PFOS. The next step is for the Health Department to start a rulemaking process.
North Carolina	• **Monitoring and treatment.** The state legislature funded the monitoring and treatment of PFAS, particularly GenX.
Texas	• **Health Risk Limit values:** The Texas Risk Reduction Program (TRRP) has derived risk-based inhalation exposure limits (RBELs) for select PFAS. These RBELs are applicable to PFAS that may volatilize from soil to air at remediation sites managed under the TRRP rule (Texas Commission on Environmental Quality [TCEQ], 2017).
Vermont	• **Drinking water**: A health advisory level is 20 ppt for the sum of five PFAS (five PFAS chemicals (PFOA, PFOS, PFNA, PFHxS) in drinking water.
Washington	• **Testing:** The Washington Department of Health plans to test several hundred water systems in the state for trace contamination of chemicals found in some firefighting foams. • **Bans and restrictions:** o The state banned the use of PFAS-containing Class B ***firefighting foam*** (designed for flammable liquid fires) for training effective July 1, 2018. o A ban on the manufacture, sale, and distribution of PFAS-containing Class B ***firefighting foam*** takes effect on July 1, 2020. o In 2018, the state passed a law prohibiting all PFAS in ***paper food packaging***. The law will take effect in 2022, after the state identifies safer alternatives and considers feedback from an external review process. • **Environmentally Preferable Purchasing.** The law addressing PFAS in firefighting foam and PPE directs two state agencies to develop guidance to assist public sector agencies to avoid purchasing these products containing PFAS. • **Labeling and disclosure:** o The state requires the reporting of PFOA and related substances, and PFOS and its salts, in ***children's products***. o As of July 1, 2018, manufacturers and sellers of PFAS-containing ***firefighting Personal Protective Equipment*** must notify purchasers in writing if the equipment contains PFAS and the reasons for using the chemicals.

Appendix D: State Actions Addressing Drinking Water Levels or Limits for PFAS: Examples (Current as of: April 15, 2019)

	PFNA (C9)	PFOA (C8)	PFOS (C8)	PFHpA (C7)	PFHxA (C6)	PFHxS (C6)	PFBA (C4)	PFBS (C4)	Additive values	Action and year
STATE										
CT	A	A	A	A		A			70 ppt	Drinking water action level (2016)
MA	A	A	A	A		A			70 ppt for the five PFAS, individually or added together	Recommendation (2018)
MN		35 ppt	27 ppt					2 ppb		Drinking water guidance (2017)
NH	23 ppt	38 ppt / A	70 ppt / A			85 ppt			38 for PFOA individually; 70 for PFOS individually; 70 ppt for PFOA + PFOS added together	Proposed standards (2018)
NJ	13 ppt*	14 ppt**	13***							*Drinking water standard (2018) **Drinking water guidance value (2017) ***Health-based MCL (2018)
NY		10 ppt	10 ppt							Recommended MCL (2018)
VT	A	A	A	A		A			20 ppt for the five PFAS added together	Health advisory level (2018)

"A" indicates additive values.

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