Per- and Polyfluoroalkyl Substances (PFAS)

This fact sheet is part of a series of chemical fact sheets developed by TURI to help Massachusetts companies, community organizations and residents understand a chemical's use and health/environmental effects, as well as the availability of safer alternatives.

Overview

PFAS are widely used for their water- and stain-resistant properties and have been detected in Massachusetts drinking water. Persistence in the environment is a key concern regarding PFAS, earning them the name "forever chemicals." Key health endpoints of concern include effects on the endocrine system, including the liver and thyroid, as well as metabolic effects, developmental effects, neurotoxicity, and immunotoxicity.

In 2022, Massachusetts added a PFAS category to the Toxic or Hazardous Substances List under the Toxics Use Reduction Act (TURA). This regulatory action requires certain industries to track, report, and develop a plan to reduce their use of specific PFAS, encouraging safer alternatives and identification of opportunities to minimize environmental and public health impacts. Addition of this PFAS category to the TURA list adds an important, preventative approach to minimizing PFAS exposure in Massachusetts.

Defining PFAS

PFAS represent over 14,000 individual chemicals. Many definitions of PFAS are used by various regulatory programs. The TURA Science Advisory Board's recommendation to add a PFAS category under TURA relied heavily on the scope used by the Organization for Economic Co-operation and Development (OECD) in their 2018 study to identify certain PFAS that were believed to have been in commerce. The 2018 OECD definition included PFAS chemicals that contain a perfluoroalkyl moiety with three or more carbons or a perfluoroalkylether moiety with two or more carbons, identifying over 4,700 individual chemicals.

> **TURA definition:** The TURA category of *Certain Per- and Poly-Fluoroalkyl Substances Not Otherwise Listed* (referred to as "Certain PFAS NOL"), is defined as PFAS not otherwise listed that contain
>
> a perfluoroalkyl moiety with three or more carbons (e.g., $-C_nF_{2n}-$, $n \geq 3$; or $CF_3-C_nF_{2n}-$, $n \geq 2$) *or*
>
> a perfluoroalkylether moiety with two or more carbons (e.g., $-C_nF_{2n}OC_mF_{2m}-$ or $-C_nF_{2n}OC_mF_m-$, n and $m \geq 1$),
>
> wherein for the example structures shown, the dash (–) is not a bond to a hydrogen and may represent a straight or branched structure.

In 2021, after the TURA category was defined, OECD broadened their definition to the following: "PFASs are defined as fluorinated substances that contain at least one fully fluorinated methyl or methylene carbon atom (without any H/Cl/Br/I atom attached to it), i.e., with a few noted exceptions, any chemical with at least a perfluorinated methyl group ($-CF_3$) or a perfluorinated methylene group ($-CF_2-$) is a PFAS." This 2021 OECD definition has become one of the most widely accepted definitions of PFAS.

It is important to note that the TURA category definition is less broad than the current OECD definition due to the timing of its development. Other regulatory agencies, such as the EPA, use different PFAS definitions.

Hazards

Chronic Health Effects

Observed chronic health effects based on peer reviewed scientific studies include reproductive effects (decreased fertility)[1], developmental effects (low birth weight, accelerated puberty, or behavioral change)[2], increased risk of cancers (specifically prostate, kidney, and testicular)[4], decreased immune response[5], liver/metabolic effects[6] and risk of obesity. Notably, PFOA is linked to kidney and testicular cancer, ulcerative colitis, and pregnancy-induced hypertension (PIH), while PFOS is associated with immunotoxicity and thyroid effects. Other PFAS compounds like GenX and PFBA are linked to kidney and liver toxicity respectively.

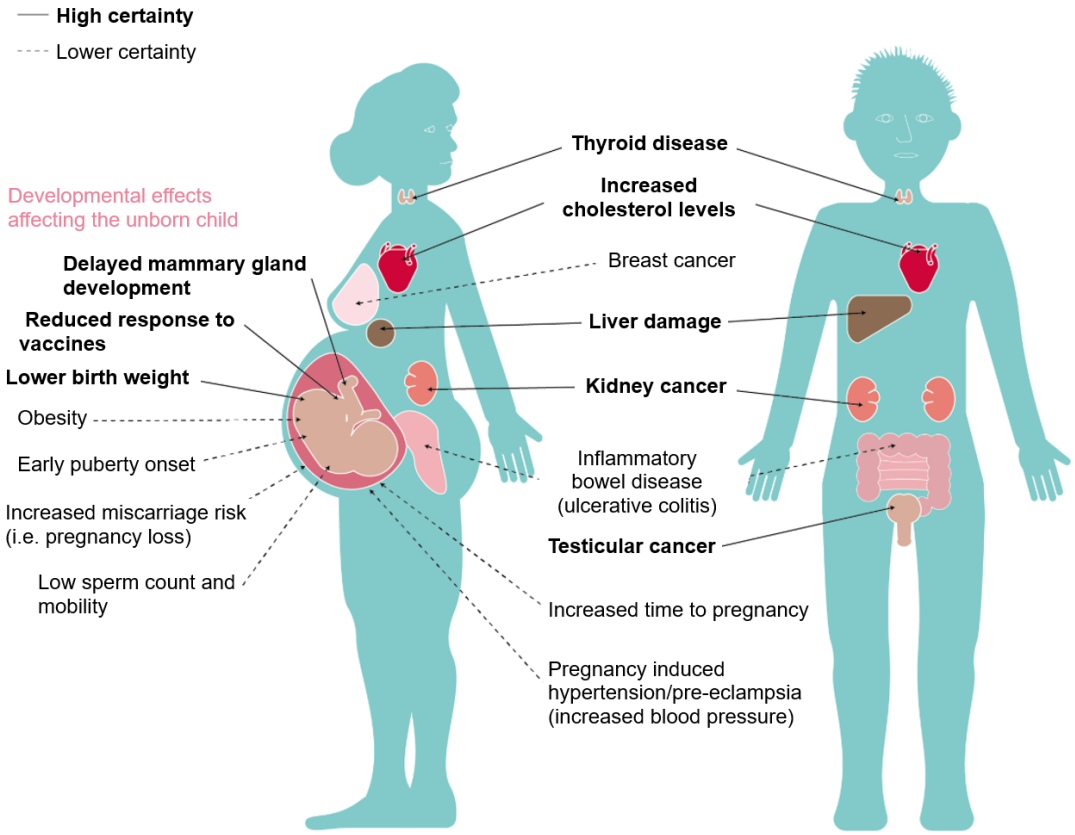

Figure 1: PFAS Impact on Human Health.

Source: European Environment Agency 2019.[3]

Sources and Exposure

PFAS exposure for the general population occurs through drinking water, food (especially fish, shellfish, and livestock from contaminated areas), consumer products, and dust. Other sources include PFAS-coated textiles, cleaning products, and food contact materials.

- PFAS contamination primarily stems from their production and use, including fluoropolymer manufacturing, firefighting foams, textiles, and paper applications.[7,8] Less is known about releases from uses like oil extraction, mining, and medical or pharmaceutical production.[9]
- PFAS in consumer products, food contact materials, drugs, and medical devices can contaminate air, dust, and food.[6,9]
- PFAS emissions arise from industrial wastewater, air releases, and wastewater treatment plants, contaminating air, soil, water, and sludge.[10,11]
- The use of contaminated sewage sludge as fertilizer has caused PFAS pollution in soil and water in the US and other countries.[12] Additional sources of PFAS pollution include recycling PFAS-containing materials, such as food contact items, and the release of volatile fluorinated gases during waste incineration.[9]
- In Massachusetts, over 150 public water systems including community water systems, non-transient non-community water systems, and transient non-community water systems detected "PFAS6" over 20 parts per trillion (ppt).[13]

Worker Health

Workers may be exposed to PFAS differently than the general public, such as through direct contact with concentrated products or inhaling PFAS at their workplaces. Common occupations in the US where workplace exposures may occur include chemical manufacturers,[14,15] firefighters,[16,17,18] plastics processing and extrusion workers,[19] and ski wax technicians.[15,20] TURI funded a grant for studying PFAS exposure among firefighters which found twofold higher levels of PFAS in blood as compared to the general population.[21] PFAS were measured in the majority of their gear and skin wipe samples.[20]

Identifying PFAS Use in Industry

It can be difficult for manufacturing facilities to know whether they use products containing PFAS. Chemical manufacturers frequently designate certain chemicals as confidential business information (CBI). One third of the PFAS on the 2020 TSCA inventory were CBI. Safety data sheets (SDS) may not include specific PFAS information, instead using language such as "proprietary" or "fluorinated blend." Additionally, SDSs do not include constituents present in very low concentrations. The potential presence of PFAS may be inferred if some version of the word fluorine is in the product name, its components, or its breakdown products.

PFAS Uses and Releases

Use in the United States

The EPA has identified at least 1,462 PFAS covered by the TSCA Section 8(a)(7) rule. 770 of these are on the active use inventory in U.S. commerce.[22,23] PFAS are widely used in the U.S. for their resistance to heat, water, and grease. Key applications include nonstick cookware, stain-resistant fabrics, and waterproof gear. PFAS are also used in aerospace applications, automotive coatings, and firefighting foams.

In food packaging, PFAS are used for grease-proofing items such as fast-food wrappers and microwave popcorn bags. Regulatory efforts, including FDA initiatives, have led to PFAS phase-out in some of these products due to health concerns. This reduction represents progress toward lowering public exposure to harmful PFAS.[24]

Use in Massachusetts

The major uses of PFAS in Massachusetts reported under TURA are in fire suppression equipment, rubber products,

Table 1: PFAS Use Reported Under TURA, 2023

Facility Name	Location	Use (pounds)	Releases (pounds)
Fire Suppression Equipment			
Kidde Fenwal Inc	Ashland	1,583,555	1,018
Rubber Products			
Cri-Tech Inc	Hanover	1,108,486	0
Titeflex Commercial Inc	Springfield	410,427	0
Wire and Cable			
Judd Wire Inc	Turners Falls	572,380	0
Mechanical Packing			
AW Chesterton Co	Groveland	25,277	34
Membranes			
Entegris Inc	Bedford	11,188	4,367
Totals		**3,711,313**	**5,419**

and wire and cable products, with smaller uses in mechanical packing and membranes, as shown in Table 1.

Toxics Use Reduction Options

To reduce PFAS use, companies should consider phasing out nonessential applications or substituting safer alternatives when possible. Many PFAS uses can be replaced with functional alternatives.[25] The TURA program has worked with researchers and companies to develop safer alternatives to PFAS for some applications. Facilities can also adopt a variety of techniques, such as improving operations and maintenance or production unit modification, to reduce PFAS use and byproducts in manufacturing.

Textile and fabric treatment

PFAS are widely used in textiles for stain resistance and water repellency, often for cosmetic purposes.[26] Some companies have successfully eliminated certain PFAS in some of their product lines, such as in less technical outdoor gear.[27] Alternatives like siloxanes, urethanes, paraffins, and dendrimers are under development, though they may vary in performance and breathability compared to PFAS-based treatments.[28] Research continues to identify safer substitutes, particularly for protective gear like firefighter clothing and military uniforms, where performance is critical.

TURI, in collaboration with UMass Lowell and the Haartz Corporation, is developing PFAS-free water- and oil-repellent coatings for automotive upholstery. This work is being conducted through TURI's academic research grant program.[29]

Fume suppressants and metal finishing

PFAS, such as PTFE, are used in electroless nickel plating to enhance lubricity. PFAS have also been used as fume suppressants in hexavalent chromium plating and chromic acid anodizing to control the release of toxic vapors.[30] Non-fluorinated alternatives are being developed. Fluorine-free options and process modifications, like closed systems or improved ventilation, are potential solutions. Transitioning to safer alternatives for hexavalent chromium would eliminate the need for fume suppressants altogether.

Food packaging and food contact paper

PFAS are commonly used in food packaging for grease resistance, raising concerns about contamination in food and compost. Proposed alternatives include uncoated paper, paper with alternative coatings (e.g., wax, clay, silicone), and non-paper materials like aluminum foil. [31,32]

TURI provided an academic research grant to the UMass Lowell Department of Chemistry to develop and evaluate PFAS-free coating alternatives for food contact applications, focusing on bilayer systems demonstrating promising hydrophobic and oleophobic properties. [33]

Microelectronics

PFAS are used as surfactants in microelectronics. TURI, in collaboration with UMass Lowell, Transene Company and the Massachusetts Office of Technical Assistance, developed safer alternatives to PFAS in etching solutions for the microelectronics industry. The research identified a safer alternative that cost less while still meeting strict performance requirements. This alternative has been adopted by over 90% of the company's customers.[34,35]

Other fluoropolymer coatings

Fluoropolymer coatings are used in medical devices, like catheters and guidewires, to reduce friction and provide durable finishes. They are also used in cookware. PTFE coatings often release PFAS surfactants during curing. Alternatives like silica-based sol-gel coatings are being explored.[36] For cookware, safer options include cast iron, stainless steel, and ceramic.

Fluoropolymer resins and processing aids

Fluoropolymer resins are used in products requiring heat resistance, low friction, or chemical durability, such as wire and cable insulation. Alternatives include sulfone polymers, polyamides, thermoplastic elastomers, and low-smoke halogen-free resins.[37] Additionally, fluorinated compounds are often used as processing aids to produce non-fluorinated resins which can result in the presence of PFAS in downstream products.[38] An example of this is PFAS in artificial turf carpet.[39] There are now many non-fluorinated processing aids available.[40]

Aqueous Film-Forming Foam (AFFF)

AFFF, commonly used by airports, the military, and fire departments, is a major source of PFAS contamination.[41] Fluorine-free foams (F3) are increasingly available and

used for training and by airports worldwide.[42] Reports highlight over 90 fluorine-free options that are cost-competitive and effective.[43] Efforts, including those by MassDEP and the US Department of Defense, focus on testing and transitioning to F3 alternatives to protect health and the environment.

Surface cleaning

Solvent blends using HFEs and trans-DCE (trans-1,2-dichloroethylene) are common replacements for traditional chlorinated solvents which are currently being phased out. HFEs meet the TURA definition of PFAS and are not preferable replacements. Performance evaluations conducted by the TURI lab demonstrate that safer and feasible alternatives to solvent-based degreasing include aqueous and semi-aqueous processes, including the use of soaking or ultrasonic equipment. The TURI lab can utilize Hansen Solubility Parameters, a solvent modeling tool, to identify safer solvents and is currently demonstrating vacuum vapor degreasing technology in conjunction with safer solvents

Refrigerants

The current shift away from HFC fluorinated gases in refrigeration toward low-global warming potential (GWP) fluorinated alternatives (such as HFOs) is important yet presents an unnecessary hazard. While HFOs are not covered under the Certain PFAS NOL category, they do meet many commonly accepted definitions of PFAS as well as increasing trifluoroacetic acid (TFA) precursor emissions.[44] (Note that HFOs *are* covered under the TURA C1-C4 Halogenated Hydrocarbons Category.)

Viable non-fluorinated alternatives (including carbon dioxide, ammonia, and hydrocarbons) offer lower lifecycle impacts without producing persistent contaminants. They are market ready as performance and safety standards evolve to accommodate their use.[45,46]

Regulatory Context

Due to their toxicity, PFAS are increasingly subject to regulations. Selected state, federal and international regulations are noted in the tables below.

TABLE 2: Massachusetts Regulations & Guidelines	
Toxics Use Reduction Act	Certain PFAS NOL listed under TURA
Drinking water	In 2024, MassDEP adopted the EPA regulations for public water systems including maximum contamination levels (MCL) of 4 ppt for PFOA and PFOS, and 10 ppt for PFNA, PFHxS, and GenX.[47] This is lowered from the 2020 Massachusetts MCL, which was 20 nanograms per liter (ng/L), or 20 parts per trillion (ppt) for the sum of the concentrations of six specific PFAS (PFOS, PFOA, PFHxS, PFNA, PFHpA, and PFDA, also known as “PFAS6”).

TABLE 3: Other State Regulations & Guidelines	
Minnesota	Amara’s Law,[48] enacted in Minnesota in 2023, bans the sale of products with intentionally added PFAS starting January 1, 2025, in categories like cookware, cosmetics, and textiles. By January 1, 2026, manufacturers must report PFAS use to the state, and by 2032, a full ban will take effect unless PFAS use is deemed unavoidable by regulators. This law, named after Amara Strande, aims to eliminate PFAS exposure and make Minnesota a leader in regulating "forever chemicals."
Maine	Maine initially enacted a law in 2021 requiring manufacturers to report products containing intentionally added PFAS by January 1, 2023. This deadline was later extended to January 1, 2025, to provide more time for implementation and compliance. However, on April 16, 2024, Maine passed significant amendments to this law, eliminating the general reporting requirement that was scheduled to take effect on January 1, 2025, but retaining phased product

TABLE 3: Other State Regulations & Guidelines	
	bans, starting with carpets and fabric treatments. By 2032, all PFAS-containing products will be banned unless deemed a "currently unavoidable use," with exceptions for HVAC and refrigerants until 2040.[49]
Others	Other state regulations can be found at Interstate Technology Regulatory Council (ITRC) which lists a PFAS Regulatory Program Summary Table (see external data tables).

TABLE 4: U.S. Regulations and Guidance Values *(Not Comprehensive)*	
ACGIH	The American Conference for Governmental Industrial Hygienists (ACGIH®) has established recommendations called Threshold Limit Values (TLVs) for three PFAS in air in occupational settings: PFIB, PFBE, and APFO (a salt of PFOA).
SNURs	PFOS and PFOA are no longer made in the U.S. but may be in imported products. The EPA has issued significant new use rules (SNUR) and tightened low volume exemption processes under TSCA to limit new PFAS.[50]
UCMR	As of 2025, the EPA's Unregulated Contaminant Monitoring Rule (UCMR) 5 monitoring has detected PFAS in over 9,300 public water systems, highlighting widespread contamination across the U.S.[51]
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 reference doses (RfDs).[52]
ATSDR	In 2018 ATSDR published the Toxicological Profile for Perfluoroalkyls. The toxicological profile characterizes the toxicology and adverse health effects information for PFAS, and includes peer-reviewed profiles that summarize key literature on their toxicological properties.[53]
DOD	The Department of Defense ceased land-based AFFF use in training and testing and set up a PFAS Task Force to ensure coordinated efforts to address PFAS.[54]
TRI	EPA's Toxic Release Inventory requires facilities to report the use, processing, or manufacturing of over 200 PFAS chemicals, at a 100-pound threshold. As of 2025, the *de minimis* exemption for listed PFAS was removed, meaning even minimal concentrations must be reported under TRI. Additional PFAS are automatically added when Final Toxicity Values or Significant New Use Rules are determined.[55]

TABLE 5: International Policies	
Canada	Canada's government has moved to manage PFAS as a class by adding most non-fluoropolymer PFAS to Schedule 1 under the Canadian Environmental Protection Act. It proposed a phased prohibition approach starting with a ban on PFAS in firefighting foams, then extending to consumer and other uses as safer alternatives are identified.[56]As part of this regulation, 163 PFAS will be newly tracked through the National Pollutant Release Inventory starting in 2025, supporting informed risk management and consultation rounds.[57]
China	In 2011, China restricted PFOS and PFOA production and promoted alternative research. By 2014, the country banned the production, use, and trade of PFOS, its salts, and PFOSF, with limited exemptions.[58]
European Union	PFOA, PFHxS, PFNA, APFO, and related salts are listed as Substances of Very High Concern under the EU's REACH regulation. Other PFAS, such as PFDA, PFUnDA, and PFDoD have also been proposed for this designation in ECHA's Registry of Intentions.[59]

The rules and regulations for PFAS use are constantly evolving. The alliance Safer States monitors environmental and public health regulations, particularly around toxic chemicals like PFAS. It also provides clear, state-by-state information on policies and actions aimed at reducing PFAS exposure. The site highlights how various states,

including Massachusetts, are taking legislative and regulatory steps to restrict PFAS in consumer products, drinking water, and industrial processes. Massachusetts is featured for its proactive measures, such as setting enforceable drinking water standards and supporting safer alternatives.

More information regarding the reporting of the Certain PFAS NOL category under TURA can be found in the TURA Reporting Instructions here: MassDEP Toxics Use Reduction Policies & Guidance | Mass.gov

Note: Information in this fact sheet should not be used for compliance purposes.

Acronyms

APFO	Ammonium perfluorooctanoate
GenX	Trade name for technology used to make non-PFOA fluoropolymers, e.g., hexafluoropropylene oxide dimer acid (HFPO-DA) and its ammonium salt
HFCs	Hydrofluorocarbons
HFEs	Hydrofluoroethers
HFOs	Hydrofluoroolefins
PFAS6	The sum of 6 PFAS: PFOS, PFOA, PFHxS, PFNA, PFHpA, and PFDA
PFBA	Perfluorobutanoic acid
PFBE	Perfluorobutyl ethylene
PFBS	Perfluorosulfonate
PFDA	Nonadecafluorodecanoic acid

PFDoD	Perfluorododecanoic acid
PFHpA	Perfluoroheptanoic acid
PFHxS	Perfluorohexane sulfonate
PFIB	Perfluoroisobutylene
PFNA	Perfluorononanoic acid
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctane sulfonic acid
PFOSF	Perfluorooctane sulfonyl fluoride
PFUnDA	Perfluoroundecanoic acid
PTFE	Polytetrafluoroethylene
TFA	Trifluoroacetic acid

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