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Regulation of different types of PFAS

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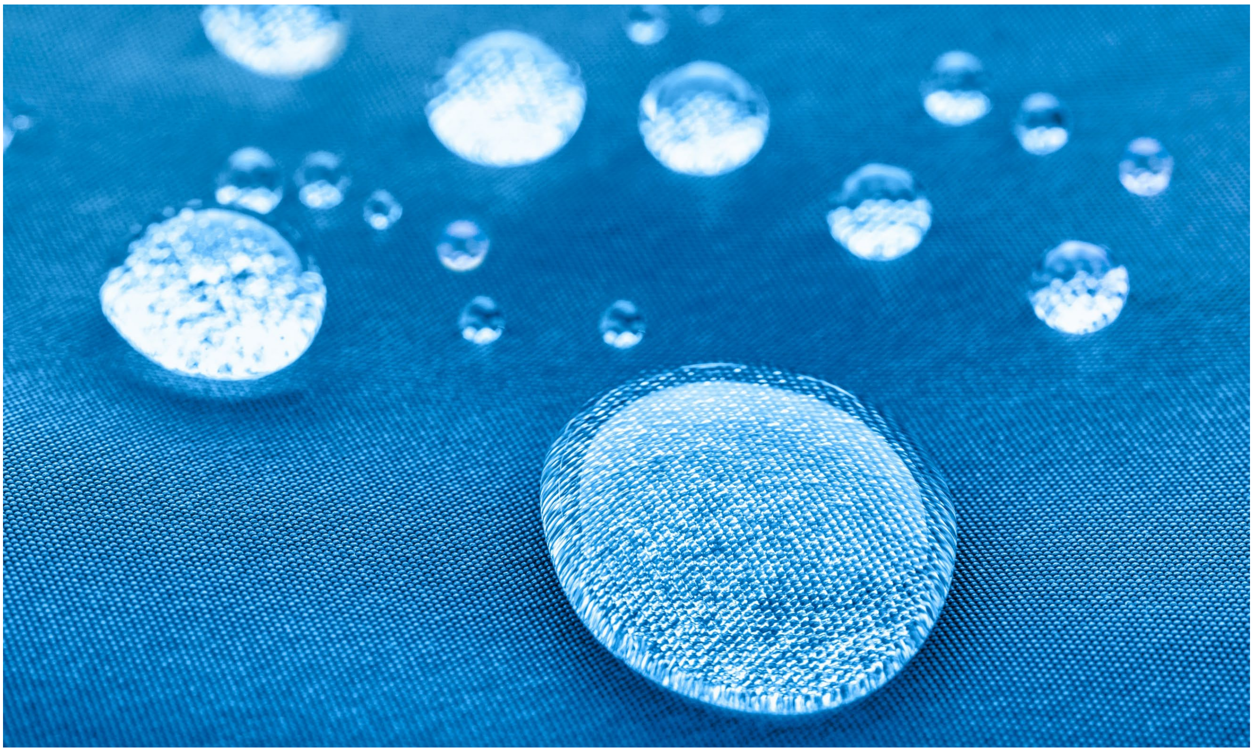

Key points

- PFAS (per and polyfluoroalkyl substances) form a class of thousands of environmentally persistent chemicals used in a wide range of applications. Some PFAS types, such as PFOS, are associated with adverse effects on human health and have prompted considerable community concern in NSW.
- Regulated PFAS such as PFOS have often been replaced with other types of PFAS. Some of these are less toxic in animal tests than the PFAS they have replaced. However, for most PFAS little health data is available, and there are major challenges in determining which types warrant restriction.
- Some scientists argue that filling the health evidence gaps for all PFAS types would be too costly and slow using standard chemical-by-chemical evaluation procedures. They propose that all PFAS should instead be restricted as a class on the basis of their environmental persistence. Other scientists argue that not all PFAS are harmful to health and many are essential for important technology.
- Scientists disagree not only on how to evaluate the risks of different types of PFAS, but on which particular substances should be considered PFAS.
- Three types of PFAS are regulated in drinking water in Australia and a fourth will be regulated later this year. Some overseas jurisdictions regulate and report on more types of PFAS in drinking water; in some cases dozens of individual types are regulated.
- Some jurisdictions argue that the health effects of exposure to different types of PFAS are likely to be cumulative and therefore apply regulatory limits to the sum of the concentrations of regulated PFAS.
- Some jurisdictions are beginning to restrict the use of all PFAS types, but it is not yet technically feasible to monitor drinking water levels for all types of PFAS.

Contents

1. Introduction

Per- and polyfluoroalkyl substances (PFAS) are often referred to as 'forever chemicals' because they persist for long periods when released into the environment.[1] They are widely used in industrial and consumer applications and are frequently detected in both the environment and human blood samples.[2] Three particular types of PFAS have been listed under the Stockholm Convention on Persistent Organic Pollutants,[3] which is a global treaty to eliminate or reduce releases of chemicals that are toxic, resist degradation, accumulate within organisms and migrate long distances through the environment (Box 1).[4]

These 3 types of PFAS will be banned from use in Australia from July 2025.[5] They are the only types of PFAS currently covered by the Australian Drinking Water Guidelines, which are used in NSW's drinking water regulatory framework.[6] However, there are thousands of other types of PFAS, some of which appear to be as toxic as PFOS, PFOA or PFHxS.[7]

Box 1. Year each PFAS was listed under the Stockholm Convention

PFOS	PFOA	PFHxS
2009	2019	2022

The question of which of these many types of PFAS should also be restricted from use or monitored in the environment is an active regulatory debate. For example, the regulation of additional PFAS types has been raised in submissions and evidence to the Select Committee on PFAS Contamination of Waterways and Drinking Water Supplies Throughout NSW.[8] This committee was established on 25 September 2024 in response to the detection of elevated PFAS levels in a dam that supplies drinking water to parts of the Blue Mountains.[9] Evidence presented at a committee hearing revealed that although Water NSW

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[1] Z Wang et al., *A Never-Ending Story of Per- and Polyfluoroalkyl Substances (PFASs)?*, *Environmental Science & Technology*, 2017, 51(5):2508–2518, doi: 10.1021/acs.est.6b04806.

[2] J Glüge et al., An overview of the uses of per- and polyfluoroalkyl substances (PFAS), *Environmental Science: Processes & Impacts*, 2020, 22:2345–2373, doi: 10.1039/D0EM00291G; S Kurwadkar et al., Per- and polyfluoroalkyl substances in water and wastewater: A critical review of their global occurrence and distribution, *Science of the Total Environment*, 2022, 809:151003, doi:10.1016/j.scitotenv.2021.151003; DA Grunfeld et al., Underestimated burden of per- and polyfluoroalkyl substances in global surface waters and groundwaters, *Nature Geoscience*, 2024, 17:340–346, doi: 10.1038/s41561-024-01402-8.

[3] *Stockholm Convention on Persistent Organic Pollutants*, opened for signature 23 May 2001, UNTS, 2256, p 119 (entered into force 17 May 2004); PFOS was listed in 2009, PFOA in 2019 and PFHxS in 2022.

[4] Secretariat of the Stockholm Convention, *Overview*, n.d., accessed 30 January 2025.

[5] *Industrial Chemicals Environmental Management (Register) Amendment (2023 Measures No. 1) Instrument 2023* (Cth).

[6] National Health and Medical Research Council (NHMRC), *Australian Drinking Water Guidelines*, National Resource Management Ministerial Council, Australian Government, 2011.

[7] ITRC, *PFAS Technical and Regulatory Guidance Document and Fact Sheets: 7 - Human and Ecological Health Effects of select PFAS*, Updated September 2023, accessed 4 April 2025; ITRC, *PFAS Technical and Regulatory Guidance Document and Fact Sheets: 17.2 Additional Information for Human Health Effects*, Updated September 2023, accessed 4 April 2025.

[8] For example, engineering professor Denis O'Carroll recommended that drinking water be monitored for a much wider range of PFAS, D O'Carroll, *Submission to Inquiry into PFAS Contamination in Waterways and Drinking Water Supplies throughout New South Wales*, 7 November 2024, p 4.

[9] C Faehrmann, Select Committee on PFAS Contamination in Waterways and Drinking Water Supplies Throughout New South Wales, *NSW Hansard*, 25 September 2024.

tests for 30 types of PFAS and Sydney Water tests for 45 types, they each only publicly report values for the 3 types that are subject to drinking water guidelines.[10]

Some other jurisdictions regulate or report on additional PFAS types in their drinking water beyond PFOS, PFOA and PFHxS. For example, in England and Wales water companies must report on the levels of 48 types of PFAS in drinking water.[11]

There are substantial tradeoffs involved in selecting which types of PFAS types to monitor and regulate in drinking water, including between potential health impacts and increased water management costs.[12] Such tradeoffs are difficult to weigh in the face of significant regulatory challenges raised by the unique chemical properties of PFAS and uncertainties about the health impacts of different PFAS types.

The purpose of this paper is to inform discussions about which types of PFAS should be regulated in NSW by exploring case studies from overseas jurisdictions. Because this is a complex and technical issue, background information about PFAS and their regulation is provided to assist interpretation and application of these case studies. This background:

- Provides a brief introduction to the class of PFAS
- Outlines the commonly regulated types of PFAS and key category distinctions that are particularly relevant to regulation
- Introduces 3 current debates about which types of PFAS should be restricted.

Two sets of case studies are then presented:

- Approaches taken by different jurisdictions in selecting which PFAS to regulate through drinking water guideline values or statutory limits
- Regulations that apply to all PFAS as a single class.

This paper does not cover debates about how to determine a safe level of exposure to PFAS or why jurisdictions vary significantly in their PFAS risk evaluations.[13] Only considerations directly related to

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[10] K Power, Select Committee on PFAS Contamination in Waterways and Drinking Water Supplies throughout New South Wales, Transcript, 5 February 2025, p 47-49.

[11] Drinking Water Inspectorate (DWI), *Guidance on the Water Supply (Water Quality) Regulations 2016 (as amended) for England and Water Supply (Water Quality) Regulations 2018 for Wales specific to PFAS (per- and polyfluoroalkyl substances) in drinking water*, UK Government, version 1.1, March 2025.

[12] NM Brennan et al., Trends in the Regulation of Per- and Polyfluoroalkyl Substances (PFAS): A Scoping Review, *International Journal of Environmental Research and Public Health,* 2021, 18(20):10900, doi: 10.3390/ijerph182010900.

[13] These evaluations vary both because of scientific uncertainty and a wide range of contextual factors, see Interstate Technology & Regulatory Council (ITRC), *PFAS Technical and Regulatory Guidance Document and Fact Sheets - 8.3 Differences in the Available Regulations, Advisories, and Guidance*, updated September 2023, accessed 7 February 2025; SG Hughes, Environmental Council of the States (ECOS), *Processes & Considerations for Setting State PFAS Standards*, 2024; B Ruffle et al., US and international per- and polyfluoroalkyl substances surface water quality criteria: A review of the status, challenges, and implications for use in chemical management and risk assessment, *Integrated Environmental Assessment and Management*, 2024, 20(1): p 26–58, doi: 10.1002/ieam.4776; J Reinikainen et al., Inconsistencies in the EU regulatory risk assessment of PFAS call for readjustment, *Environment International*, 2024, 186:108614, doi: 10.1016/j.envint.2024.108614; GB Post, Recent US State and Federal Drinking Water Guidelines for Per- and Polyfluoroalkyl Substances, *Environmental Toxicology and Chemistry,* 40(3):550–563, doi: 10.1002/etc.4863.

protecting human health are discussed, although similar challenges arise when considering threats to ecosystems.[14]

Because of the large number of acronyms related to different types of PFAS, this paper does not use the full chemical name at first mention in the text.[15] Readers are referred to section 6.3 for chemical names and abbreviations.[16]

[14] GT 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,* 2021, 40(3):564–605, doi: 10.1002/etc.4869.

[15] In this paper the term 'PFAS type' is used to refer to an individual PFAS chemical, including closely related chemicals such as salts, acids, ionised forms and isomers. 'PFAS group' is used to refer to any grouping of multiple PFAS types.

[16] The different sources for these case studies often use different abbreviations for the same chemical. Where possible, PFAS types in source materials were first identified by CAS registration number and then were assigned a consistent abbreviation.

2. Types of PFAS

2.1 PFAS are widely-used chemicals that have prompted health concerns

PFAS form a large and diverse class of manufactured chemicals that have come to public attention because of concerns about their effects on human health and the environment (Box 2).

Box 2. Examples of PFAS that have attracted media attention

	PFOA	PFOS	GenX
Example use	Processing aid for manufacture of non-stick cookware	Ingredient in certain firefighting foams	Processing aid for manufacture of non-stick cookware
Example media attention	Class action lawsuit against DuPont for PFOA contamination of drinking water from Teflon manufacturing in West Virginia, US[17]	PFOS contamination of groundwater in Australia from firefighting foam used on military bases[18]	Contamination of drinking water in North Carolina, US, from a DuPont/Chemours GenX manufacturing site[19]

In general terms, PFAS have chemical structures that are rich in strong carbon-fluorine bonds that are highly resistant to degradation.[20] This chemical stability and other unique properties are particularly useful for making products resistant to water, oil, heat, and other chemicals. As a result, PFAS are used in a diverse range of industrial and consumer applications, such as waterproof textiles, food packaging, cosmetics, ski wax, metal electroplating, cable coatings, semi-conductor manufacture, aviation hydraulic fluids, and foam for fighting petroleum fires.[21] PFAS are also used as processing

[17] N Rich, The Lawyer Who Became DuPont's Worst Nightmare, *The New York Times Magazine*, 1 October 2016, accessed 5 February 2025.

[18] I Roe et al., Commonwealth settles $132.7 million class action over PFAS contamination across Australia, *ABC*, 15 May 2023, accessed 5 February 2025.

[19] D Gelles and E Steel, How chemical companies avoid paying for pollution, *New York Times,* 21 October 2021, accessed 5 February 2025.

[20] There is no consensus technical definition of PFAS (see section 3), but widely-used definitions generally include the presence of a perfluorinated alkyl group (that is, a fully-fluorinated carbon group) of some type, see ITRC, *PFAS Technical and Regulatory Guidance Document and Fact Sheets: 2.2 Chemistry, Terminology, and Acronyms*, updated September 2023, accessed 9 March 2025.

[21] J Glüge et al., An overview of the uses of per- and polyfluoroalkyl substances (PFAS), *Environmental Science: Processes & Impacts,* 2020, 22:2345–2373, doi: 10.1039/D0EM00291G; LGT Gaines, Historical and current usage of per- and polyfluoroalkyl substances (PFAS): A literature review,*American Journal of Industrial Medicine,* 2023, 66(5): 353–378, doi: 10.1002/ajim.23362; PFAS is only used in firefighting foams that are intended for flammable fuel fires. These include aqueous film-forming foams (AFFF), ITRC, *PFAS Technical and Regulatory Guidance Document and Fact Sheets: 3 - Firefighting Foams*, updated September 2023, accessed 9 March 2025.

aids, which are substances used during manufacture of a product but which are not intended to be incorporated into the final product.

The stability of PFAS also makes them environmentally persistent. PFAS can enter the environment from many sources and can spread long distances from their source.[22] Sources of exposure for people can include the workplace (such as chemical plants, firefighting training sites and ski maintenance workshops), through drinking and eating (particularly fish and shellfish), or via consumer products and household dust.[23]

Concerns about the health risks of exposure were first raised for PFOS and PFOA.[24] Studies in humans and animals suggest that exposure to PFOS or PFOA above certain levels is linked to adverse effects on the liver, immune system, cardiovascular system, as well as low birth weight and higher risk for certain types of cancer.[25] Although there is a broad consensus on some of these health effects, such as the association with moderately higher cholesterol levels, scientists disagree on the overall strength of the evidence that PFOS and PFOA exposure leads to human disease.[26]

The health effects of some other types of PFAS show similarities to the effects of PFOS and PFOA.[27] There is little health evidence publicly available for the vast majority of PFAS types.[28]

2.2 There are many types of PFAS

How PFAS are defined in technical terms has considerable implications for regulators, as discussed further in section 3.4. The first widely-used technical definition of PFAS was published in 2011, with the intent of bringing some consistency to the way scientists describe the broad class of chemicals to

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[22] MG Evich et al., Per- and polyfluoroalkyl substances in the environment, *Science*, 2022, 375: eabg9065, doi: 10.1126/science.abg9065.

[23] K Lucas et al., Occupational exposure and serum levels of per- and polyfluoroalkyl substances (PFAS): A review, *American Journal of Industrial Medicine,* 2023, 66(5):379-392, doi: 10.1002/ajim.23454; D Trudel et al., Estimating consumer exposure to PFOS and PFOA, *Risk Analysis,* 2008, 28(2): 251–269, doi: 10.1111/j.1539-6924.2008.01017.x; EFSA Panel on Contaminants in the Food Chain et al., Risk to human health related to the presence of perfluoroalkyl substances in food, *EFSA Journal,* 2020, 18(9): e06223, doi: 10.2903/j.efsa.2020.6223; JL Domingo and M Nadal, Human exposure to per- and polyfluoroalkyl substances (PFAS) through drinking water: A review of the recent scientific literature, *Environmental Research,* 2019, 177:108648, doi: 10.1016/j.envres.2019.108648.

[24] US Environmental Protection Agency (US EPA), *EPA and 3M Announce Phase Out of PFOS* [media release], US Government, 16 May 2000, accessed 7 March 2025; US EPA, *Fact Sheet: 2010/2015 PFOA Stewardship Program*, updated 6 March 2025, accessed 9 March 2025.

[25] US EPA, *Human Health Toxicity Assessment for Perfluorooctane Sulfonic Acid (PFOS) and Related Salts*, US Government, 2024; US EPA, *Human Health Toxicity Assessment for Perfluorooctanoic Acid (PFOA) and Related Salts*, US Government, 2024.

[26] For example, for discussion of the uncertainty on whether the reported health effects are linked with disease, see Expert Health Panel for PFAS, *Full Report*, Department of Health and Aged Care, Australian Government, 2018 and TG Hagen et al., Australian Case Studies Involving Exposure to PFOS, in DJ Paustenbach and K Feinberg (eds), *Human and Ecological Risk Assessment: Theory and Practice,* 3rd edn, John Wiley & Sons, 2024.

[27] ITRC, *PFAS Technical and Regulatory Guidance Document and Fact Sheets: 7 - Human and Ecological Health Effects of select PFAS*, Updated September 2023, accessed 7 March 2025.

[28] ITRC, *PFAS Technical and Regulatory Guidance Document and Fact Sheets: 7 - Human and Ecological Health Effects of select PFAS*, Updated September 2023, accessed 7 March 2025.

which PFOS and PFOA belong.[29] Since then, however, several other competing definitions have been developed, and there is no consensus on exactly which chemicals should be considered PFAS.[30]

Depending on the definition chosen, there are somewhere between thousands and millions of potential PFAS.[31] Which of these PFAS have actually been produced and released to the environment is unknown. In 2018 the Organisation for Economic Co-operation and Development (OECD) identified 4,730 PFAS that may have been on the market globally.[32] Of the PFAS identified by the OECD, major PFAS manufacturers considered only 256 to be commercially relevant, as opposed to those that were never commercialised or that were only made in research quantities.[33] In Australia, 522 PFAS are listed as potentially manufactured or imported for industrial use.[34]

Different PFAS differ substantially in their chemical properties.[35] For example, some PFAS are solids, some liquids and some are gases; some are water soluble and some are insoluble. They also differ in their behaviour in the environment and within the human body. Figure 1 provides a simplified classification scheme for PFAS that emphasises the groups that will be discussed further in this paper, including the 3 groups that are most commonly regulated in drinking water:

- **PFCAs** and **PFSAs** – the most studied PFAS types, such as PFOS, PFOA and PFHxS
- **Ether PFAS** – replacements for PFOS and PFOA
- **Fluorotelomer substances** – PFAS types widely used for surface treatments and firefighting foam that can degrade to form PFCAs (see section 2.3.1). Also known as fluorotelomers.

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[29] RC Buck et al., Perfluoroalkyl and polyfluoroalkyl substances in the environment: Terminology, classification, and origins, *Integrated Environmental Assessment and Management,* 2011, 7(4):512–541, doi: 10.1002/ieam.258.

[30] C Hogue, How to define PFAS, *Chemical & Engineering News,* 1 July 2022, accessed 7 March 2025; E Hammel et al., Implications of PFAS definitions using fluorinated pharmaceuticals, *iScience*, 2022, 25(4):104020, doi: 10.1016/j.isci.2022.104020.

[31] EL Schymanski et al. Per- and Polyfluoroalkyl Substances (PFAS) in PubChem: 7 Million and Growing, *Environmental Science & Technology,* 2023, 57(44):16918-16928, doi: 10.1021/acs.est.3c04855; SJ Barnabas et al. Extraction of chemical structures from literature and patent documents using open access chemistry toolkits: a case study with PFAS, *Digital Discovery,* 2022, 1:490-501, doi: 10.1039/D2DD00019A.

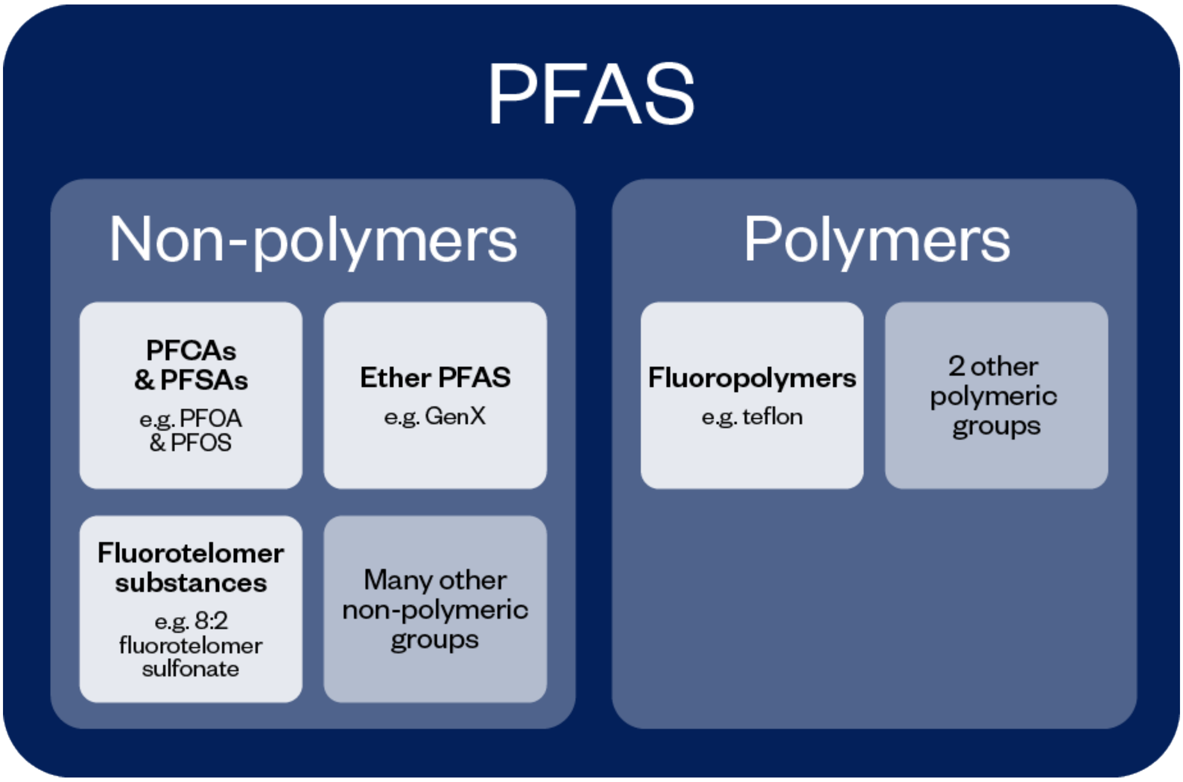
[32] Organisation for Economic Co-operation and Development (OECD), *Summary report on the new comprehensive global database of Per- and Polyfluoroalkyl Substances (PFASs)*, 2018, OECD Series on Risk Management of Chemicals, doi:10.1787/1a14ad6c-en.

[33] RC Buck et al., Identification and classification of commercially relevant per- and poly-fluoroalkyl substances (PFAS), *Integrated Environmental Assessment and Management,* 2021, 17(5):1045–1055, doi: 10.1002/ieam.4450.

[34] Australian Industrial Chemicals Introduction Scheme (AICIS), *Submission from the Department of Health and Aged Care Australian Industrial Chemicals Introduction Scheme (AICIS) to the Senate Select Committee on PFAS (per- and polyfluoroalkyl substances)*, 2024, p 9.

[35] IT Cousins et al. Strategies for grouping per- and polyfluoroalkyl substances (PFAS) to protect human and environmental health, *Environmental Science: Processes & Impacts*, 2020, 22:1444-1460, doi: 10.1039/D0EM00147C.

Figure 1. PFAS groups



2.3 Four key distinctions between PFAS types are relevant to regulation

This section describes 4 distinctions between different types of PFAS that are particularly relevant to regulation and the regulatory debates introduced in section 3.

2.3.1 Precursors versus terminal degradation products

Some PFAS, known as precursors, can break down in the environment to form other types of PFAS. PFAS that do not break down any further, such as PFOS and PFOA, are known as terminal degradation products. Many precursors generate mixtures of degradation products. For example, fluorotelomer substances produce a range of degradation products, including PFCAs.[36]

If a precursor can form a regulated PFAS type during degradation, it is typically covered by the same regulations as the corresponding terminal degradation product. For example, 8:2 fluorotelomer substances can form PFOA during degradation and therefore are restricted under the Stockholm Convention listing for PFOA.[37]

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[36] RC Buck et al., Perfluoroalkyl and polyfluoroalkyl substances in the environment: Terminology, classification, and origins, *Integrated Environmental Assessment and Management,* 2011, 7(4):512–541, doi: 10.1002/ieam.258.

[37] Stockholm Convention Persistent Organic Pollutants Review Committee (POP Review Committee), *Updated indicative list of substances covered by the listing of perfluorooctanoic acid (PFOA), its salts and PFOA-related compounds*, POP Review Committee Seventeenth Meeting, UNEP/POPS/POPRC.17/INF/14/Rev.1, 2022, p 9-29.

2.3.2 Persistence versus bioaccumulation

The properties of persistence and bioaccumulation are often confused in public discussions of PFAS, but these separate properties are central to several significant regulatory debates.

Persistence is the amount of time a chemical is likely to remain in the environment before it is broken down.[38] A persistent chemical remains intact for a long period of time.[39] Almost all PFAS are either persistent or degrade to form other PFAS that are persistent (terminal degradation products).[40]

Bioaccumulation occurs when an organism absorbs a substance faster than it can be eliminated. A bioaccumulative substance will gradually accumulate inside an organism that ingests it.[41] Some but not all PFAS are considered bioaccumulative by standard criteria.[42]

Neither persistence nor bioaccumulation determine the toxicity of a chemical, which is the degree to which it causes harm to an organism after exposure.[43] However, bioaccumulation of a chemical may increase the risk of toxic effects by increasing the duration or extent of the organism's exposure.[44] A persistent chemical that is also toxic or bioaccumulative is more difficult to manage than a non-persistent chemical because it may be very difficult or costly to remove from the environment once released.[45]

2.3.3 Long-chain versus short-chain

Current regulatory debates also relate to regulation of a subset of PFAS known as short-chain PFAS. 'Chain length' refers to the number of carbons linked together in the backbone of PFCAs and PFSAs and their precursors. These PFAS are classified as either long-chain or short-chain (see Appendix 6.1 for a list of long-chain and short-chain PFCAs and PFSAs).[46]

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[38] Australian Government Department of Climate Change, Energy, the Environment and Water (DCCEEW), *Glossary of IChEMS terms*, n.d., accessed 7 February 2025.

[39] In Australia a chemical is classified as persistent in water if it takes 60 days or longer for half of it to be degraded or transformed, DCCEEW, *Australian Environmental Criteria for Persistent, Bioaccumulative and/or Toxic Chemicals*, Australian Government, 2022, p 2.

[40] Z Wang et al., *A Never-Ending Story of Per- and Polyfluoroalkyl Substances (PFASs)?, Environmental Science & Technology,* 2017, 51(5):2508–2518, doi: 10.1021/acs.est.6b04806; IT Cousins et al., *The high persistence of PFAS is sufficient for their management as a chemical class, Environmental Science: Processes & Impacts,* 2020, 22:2307–2312, doi: 10.1039/D0EM00355G.

[41] DCCEEW, *Glossary of IChEMS terms*, n.d., accessed 7 February 2025.

[42] See section 3.2. Also see JM Conder, Are PFCAs Bioaccumulative? A Critical Review and Comparison with Regulatory Criteria and Persistent Lipophilic Compounds, *Environmental Science & Technology*, 2008 52(4):995–1003, doi:10.1021/es070895g.

[43] DCCEEW, *Glossary of IChEMS terms*, n.d., accessed 7 February 2025.

[44] Australian and New Zealand Guidelines for Fresh and Marine Water Quality, *Toxicant default guideline values for water quality in aquatic ecosystems - Accounting for local conditions*, updated 29 March 2023, accessed 10 February 2025.

[45] AL Ling, Estimated scale of costs to remove PFAS from the environment at current emission rates, *Science of The Total Environment,* 2024, 918:170647, doi: 10.1016/j.scitotenv.2024.170647.

[46] Throughout this paper 'chain-length' refers to the total number of carbons in the backbone; however, chain length can also be described in terms of the number of perfluoroalkyl carbons. This is the same number as total carbons in the case of PFSAs, but for PFCAs there is 1 fewer perfluoroalkyl carbons compared to total carbons, OECD, *Synthesis paper on per and polyfluorinated chemicals*, 2013.

The chain length definition was originally developed to highlight differences in toxicity and bioaccumulation between short-chain and long-chain types.[47] When ingested by animals, including humans, long-chain PFAS are more bioaccumulative; for instance, they are cleared from the bloodstream much more slowly than short-chain PFAS (Table 1).[48] Long-chain PFAS also generally cause adverse health effects in animals at lower doses than do short-chain PFAS.[49]

Table 1. Estimated PFAS elimination half-lives in humans

Chain length	Classification	PFAS	Half-life
8	Long-chain	PFOS	3.3-27 years
8	Long-chain	PFOA	2.1-10 years
4	Short-chain	PFBS	665 hours
4	Short-chain	PFBA	72-81 hours

Source: Agency for Toxic Substances and Disease Registry
An elimination half-life is the time it takes to eliminate half of the concentration of a chemical from the body.

Though short-chain PFAS are less bioaccumulative in animals, they are more bioaccumulative than long-chain PFAS in above-ground plant tissues, such as leaves and fruit.[50]

2.3.4 Polymers versus non-polymers

PFAS are usually divided into 2 broad categories: polymeric and non-polymeric.[51] Polymers are large molecules composed of sequences of many repeating units connected together. Non-polymers are all other types of PFAS, including the types regulated in water.

Fluoropolymers are one of the 3 groups of polymeric PFAS.[52] Fluoropolymers are solid plastics, such as PTFE (Teflon).[53] A major current debate concerns whether they should be regulated in the same way as other PFAS (see section 3.4.1).

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[47] OECD, *Synthesis paper on per and polyfluorinated chemicals*, 2013, p 5.

[48] Agency for Toxic Substances and Disease Registry (ATSDR), *Toxicological Profile for Perfluoroalkyls*, US Department of Health and Human Services, 2021, p 559; JW Martin et al., Progress toward understanding the bioaccumulation of perfluorinated alkyl acids, *Environmental Toxicology and Chemistry,* 2013, 32(11):2421–2423, doi: 10.1002/etc.2376; JM Conder, Are PFCAs Bioaccumulative? A Critical Review and Comparison with Regulatory Criteria and Persistent Lipophilic Compounds, *Environmental Science & Technology*, 2008 52(4):995–1003, doi: 10.1021/es070895g; MG Evich et al., Per- and polyfluoroalkyl substances in the environment, *Science*, 2022, 375(6580):eabg9065, doi: 10.1126/science.abg9065.

[49] ITRC, *PFAS Technical and Regulatory Guidance Document and Fact Sheets: 7 - Human and Ecological Health Effects of select PFAS*, updated September 2023, accessed 7 March 2025; GT 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*, 2020, 40(3):564–605, doi: 10.1002/etc.4869

[50] L Lesmeister et al., Extending the knowledge about PFAS bioaccumulation factors for agricultural plants – A review, *Science of The Total Environment,* 2021, 766:142640, doi: 10.1016/j.scitotenv.2020.142640.

[51] RC Buck et al., Perfluoroalkyl and polyfluoroalkyl substances in the environment: Terminology, classification, and origins, *Integrated Environmental Assessment and Management,* 2011, 7(4):512–541, doi: 10.1002/ieam.258.

[52] The other 2 polymer groups are side-chain fluorinated polymers (which can be precursors to PFCAs and PFSAs) and the polymeric perfluoropolyethers, OECD, *Synthesis Report on Understanding Side-Chain Fluorinated Polymers and Their Life Cycle*, OECD Series on Risk Management of Chemicals, 2022; OECD, *Synthesis Report on Understanding Perfluoropolyethers (PFPEs) and Their Life Cycle*, OECD Series on Risk Management of Chemicals, 2024.

[53] S Jacobs and DS Kosson, *Assessment of Fluoropolymer Production and Use With Analysis of Alternative Replacement Materials*, prepared for the US Department of Energy, 2024.

2.4 Environmental levels can only be measured for a small number of PFAS types

Drinking water regulations depend on the capabilities of current measurement techniques. Analysing PFAS concentrations for the purposes of regulatory compliance requires specialised methods.[54] To accurately measure concentrations of PFAS, laboratories use 'target analysis' that compares the environmental sample to known quantities of PFAS called reference standards.[55] Using target analysis, jurisdictions can generally only measure the concentration of 30-50 PFAS types for which both reference standards and certified methods are available.[56] The number and diversity of types that can be quantified has increased over time, as can be seen from commonly-used PFAS analysis methods developed and validated by the US Environmental Protection Agency (US EPA) (Table 2). These methods typically cost hundreds of dollars per sample.[57]

Table 2. PFAS types that can be quantified with selected US EPA analysis methods

Method	Year published	Total	Long-chain PFCAs / PFSAs	Short-chain PFCAs / PFSAs	Ether PFAS	Fluoro-telomers	Other
537	2008	14	9	3	-	-	2
537.1	2018	18	9	3	4	-	2
533	2019	25	8	6	8	3	-
1633A[58]	2024	40	13	6	8	6	7

Source: NSW Parliamentary Research Service

In addition to these quantitative methods, there are a variety of 'non-target' methods that are able to detect the presence of many more types of PFAS, without being able to determine a concentration for each type.[59] Such methods are typically used for screening, site investigations and research projects rather than for ensuring regulatory compliance.

2.5 Long-chain PFAS types are being phased out

PFOS, PFOA, PFHxS and other long-chain PFAS are sometimes referred to as 'legacy' PFAS because they have been the subject of regulatory restrictions and industry phase-outs for more than 20 years.

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[54] ITRC, *PFAS Technical and Regulatory Guidance Document and Fact Sheets: 11 - Sampling and Analytical Methods*, updated September 2023, accessed 25 March 2025; National Chemicals Working Group of the Heads of EPA Australia and New Zealand (HEPA), *PFAS National Environmental Management Plan version 3.0*, Australian, New Zealand and state and territory governments, 2025, p 185–193.

[55] X Trier et al., The Critical Role of Commercial Analytical Reference Standards in the Control of Chemical Risks: The Case of PFAS and Ways Forward, *Environmental Health Perspectives,* 2025, 133(1), doi: 10.1289/EHP13705.

[56] HEPA, *PFAS National Environmental Management Plan version 3.0*, Australian, New Zealand and state and territory governments, 2025, p 181; up to 70 PFAS types can be measured by certain commercial laboratories in the US, KE Pelch et al, 70 analyte PFAS test method highlights need for expanded testing of PFAS in drinking water, *Science of The Total Environment,* 2023, 876:162978, doi: 10.1016/j.scitotenv.2023.162978.

[57] For example in 2023 US EPA method 533 cost per sample was USD $376, US EPA, *Economic Analysis for the Proposed Per- and Polyfluoroalkyl Substances National Primary Drinking Water Regulation*, US Government, 2023, p 534.

[58] This method approves the inclusion of additional PFAS types beyond the original 40 without requiring EPA review, as long as all performance criteria are met, US EPA, *Method 1633A, Revision A, Analysis of Per- and Polyfluoroalkyl Substances (PFAS) in Aqueous, Solid, Biosolids, and Tissue Samples by LC-MS/MS*, US Government, 2024, p 1.

[59] ITRC, *PFAS Technical and Regulatory Guidance Document and Fact Sheets: 11.2.2 – Qualitative Techniques*, updated September 2023, accessed 25 March 2025; D Megson, A systematic review for non-targeted analysis of per- and polyfluoroalkyl substances (PFAS), *Science of The Total Environment,* 2025, 960:178240, doi: 10.1016/j.scitotenv.2024.178240.

The phase out of legacy PFAS began through industry actions in 2000, when, under pressure from the US EPA, 3M announced it would stop manufacturing PFOS, PFOA, PFHxS and related substances (such as precursors).[60] At the time 3M had been the world's major producer of these PFAS.[61] In 2006, the US EPA invited 8 major PFAS manufacturers and processors (including 3M) to eliminate emissions of PFOA-related substances by 2015.[62] All participating companies report that they achieved the program goals.[63] A similar program operated in Canada between 2010 and 2015.[64]

In addition to these industry phase outs, some jurisdictions have now banned the manufacture and use of PFOS, PFOA and PFHxS, including China, the EU, Japan, New Zealand and the UK.[65] Between 2009 and 2022 PFOS, PFOA and PFHxS were listed under the Stockholm Convention.[66] Parties to the convention that have ratified these listings are required to take measures to reduce or eliminate releases of listed substances, although implementation and reporting varies between countries.[67] The Stockholm Convention's 2023 effectiveness evaluation concluded that some specific uses of PFOS still occur, but PFOS manufacture is likely to have ended in 2020.[68] The Stockholm Convention has not yet evaluated effectiveness of the PFOA and PFHxS restrictions.

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[60] 3M also phased out PFDS-related substances at the same time, 3M, *3M Phasing Out Some of its Specialty Materials* [media release], 16 May 2000, archived by US EPA, EPA-HQ-OPPT-2002-0051; US EPA, *EPA and 3M Announce Phase Out of PFOS* [media release], 16 May 2000, accessed 28 March 2025; W Weppner, *Letter to EPA regarding the phase out plan for POSF-based products*, 7 July 2000, archived by US EPA, EPA-HQ-OPPT-2002-0051, D Barboza, E.P.A. Says It Pressed 3M for Action on Scotchgard Chemical, *New York Times*, 19 May 2000, accessed 8 March 2025.

[61] OECD, *Co-operation on Existing Chemicals: Hazard Assessment of Perfluorooctane Sulfonate (PFOS) and its Salts*, Joint Meeting of the Chemicals Committee and the Working Party on Chemicals, Pesticides and Biotechnology, 2002, p 11-12; POP Review Committee, *Report of the Persistent Organic Pollutants Review Committee on the work of its second meeting: Risk profile on perfluorooctane sulfonate*, UNEP/POPS/POPRC.2/17/Add.5, 2006, p 8; POP Review Committee, *Report of the Persistent Organic Pollutants Review Committee on the work of its fifteenth meeting: Risk management evaluation on perfluorohexane sulfonic acid (PFHxS), its salts and PFHxS related compounds*, UNEP/POPS/POPRC.15/7/Add.1, 2019, p 9; K Prevedouros, Sources, Fate and Transport of Perfluorocarboxylates, *Environmental Science & Technology*, 2005, 40(1):32–44, doi: 10.1021/es0512475.

[62] US EPA, *Fact Sheet: 2010/2015 PFOA Stewardship Program*, updated 6 March 2025, accessed 26 March 2025.

[63] US EPA, *EPA's Non-CBI Summary Tables for 2015 Company Progress Reports*, US Government, 2017.

[64] Environment and Climate Change Canada, *Perfluorocarboxylic acids and their precursors: environmental performance agreement overview*, updated 28 November 2018, accessed 8 March 2025.

[65] «重点管控新污染物清单（2023年版）» [List of New Pollutants for Priority Control (2023 Edition)] (People's Republic of China), December 29, 2022; *Regulation (EU) 2019/1021 of the European Parliament and of the Council of 20 June 2019 on persistent organic pollutants (recast)* [2019] OJ L 169/45, annex I (EU); *Commission Delegated Regulation (EU) 2020/784 of 8 April 2020 amending Annex I to Regulation (EU) 2019/1021 of the European Parliament and of the Council as regards the listing of perfluorooctanoic acid (PFOA), its salts and PFOA-related compounds* [2020] OJ L 188I/1 (EU); *Commission Delegated Regulation (EU) 2023/1608 of 30 May 2023 amending Annex I to Regulation (EU) 2019/1021 of the European Parliament and of the Council as regards the listing of perfluorohexane sulfonic acid (PFHxS), its salts and PFHxS-related compounds*, [2023] OJ L198/24 (EU); *Order for Enforcement of the Act on the Regulation of Manufacture and Evaluation of Chemical Substances (Cabinet Order No. 202 of 1974)* (Japan); *Hazardous Substances and New Organisms Act 1996* (NZ), sch 2A; *Retained regulation (EU) 2019/1021 of the European Parliament and of the Council of 20 June 2019 on persistent organic pollutants (recast)* (UK), annex I.

[66] *Stockholm Convention on Persistent Organic Pollutants*, opened for signature 23 May 2001, UNTS, 2256, p 119 (entered into force 17 May 2004); PFOS, PFOA, PFHxS.

[67] *Stockholm Convention on Persistent Organic Pollutants*, opened for signature 23 May 2001, UNTS, 2256, p 119 (entered into force 17 May 2004), art 3; Secretariat of the Stockholm Convention, *Reporting Dashboard*, Part D, Fifth reporting cycle (2019-2022), accessed 26 March 2025.

[68] Secretariat of the Stockholm Convention, *Report on the second effectiveness evaluation of the Stockholm Convention on Persistent Organic Pollutants*, 2025, p 13, p 99.

In recent decades levels of PFOS and PFOA in human blood samples have substantially declined in many places, including the United States, Europe and Australia.[69] However, because of the persistence of historical emissions, PFOS and PFOA remain among the most commonly detected PFAS in the environment.[70]

PFCAs with chains longer than PFOA are also increasingly regulated. In 2016, the Canadian government prohibited the import, manufacture, use, sale and offer for sale of long-chain PFCAs with chain lengths between 9 and 21.[71] In 2021 the EU implemented similar restrictions on PFCAs with chain lengths between 9 and 14.[72] In addition, the Stockholm Convention's committee of government-designated experts have recommended listing PFCAs with chain lengths between 9 and 21.[73] This recommendation will be considered by parties to the convention in May 2025.[74]

2.5.1 Australian bans on PFOS, PFOA and PFHxS come into effect in 2025

Australia ratified the Stockholm Convention in 2004, but has not yet ratified any amendments, including the PFAS listings.[75] In 2019, the Australian Government indicated that to ratify the listings, Australia must first be able to meet the associated management obligations.[76] This included establishment of a national standard for the environmental risk management of industrial chemicals (the Industrial Chemicals Environmental Management Standard, IChEMS). IChEMS has since been established by the Australian Government and is now in the process of being implemented by states and territories.[77]

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[69] M Land et al., What is the effect of phasing out long-chain per- and polyfluoroalkyl substances on the concentrations of perfluoroalkyl acids and their precursors in the environment? A systematic review, *Environmental Evidence,* 2018, 7:4, doi: 10.1186/s13750-017-0114-y; G Taucare et al., Temporal trends of per- and polyfluoroalkyl substances concentrations: Insights from Australian human biomonitoring 2002–2021 and the U.S. NHANES programs 2003–2018*, Environmental Research,* 2024, 262(1):119777, doi: 10.1016/j.envres.2024.119777.

[70] M Land et al., What is the effect of phasing out long-chain per- and polyfluoroalkyl substances on the concentrations of perfluoroalkyl acids and their precursors in the environment? A systematic review, *Environmental Evidence,* 2018, 7:4, doi: 10.1186/s13750-017-0114-y; ITRC, *PFAS Technical and Regulatory Guidance Document and Fact Sheets: 6 Occurrence*, updated September 2023, accessed 8 April 2025.

[71] *Regulations Amending the Prohibition of Certain Toxic Substances Regulations, 2012* (Canada), SOR/2016-252, Sch 2.1; various exemptions are provided, including for certain firefighting foams, manufactured items and any product in which the long-chain PFCAs are present 'incidentally' (long-chain PFCAs can be formed as an unintentional by-product during manufacture of certain fluorotelomers and fluoropolymers), *Prohibition of Certain Toxic Substances Regulations, 2012* (Canada), SOR/2012-285), s 6(1), s 6(2.2), 6(2.4); in 2022 the government proposed repealing the exemptions for firefighting foam and manufactured items, *Prohibition of Certain Toxic Substances Regulations, 2022*, *Canada Gazette,* pt 1, vol 156, no 20.

[72] *Commission Regulation (EU) 2021/1297 of 4 August 2021 amending Annex XVII to Regulation (EC) No 1907/2006 of the European Parliament and of the Council as regards perfluorocarboxylic acids containing 9 to 14 carbon atoms in the chain (C9-C14 PFCAs), their salts and C9-C14 PFCA-related substances* [2021] OJ L 282/29, Annex (EU).

[73] POP Review Committee, *Decision POPRC-19/2: Long-chain perfluorocarboxylic acids, their salts and related compounds*, 2023; POP Review Committee, *Decision POPRC-20/3: Long-chain perfluorocarboxylic acids, their salts and related compounds*, 2024.

[74] Secretariat of the Stockholm Convention, *Conferences of the Parties to the Stockholm Convention, 12th meeting, Recommendation by the Persistent Organic Pollutants Review Committee to list long-chain perfluorocarboxylic acids, their salts and related compounds in Annex A to the Stockholm Convention and draft text of the proposed amendment: Note by the Secretariat*, UNEP/POPS/COP.12/14, 2024.

[75] C.N.514.2004, Stockholm Convention on Persistent Organic Pollutants, Ratification, Australia [2004].

[76] Australian Government PFAS Taskforce, *International cooperation*, published 17 October 2019, accessed 12 November 2024.

[77] *Industrial Chemicals Environmental Management (Register) Act 2021* (Cth); DCCEEW, *Industrial Chemicals Environmental Management Standard – IChEMS,* updated 29 October 2024, accessed 12 November 2024; DCCEEW, *Australia's industrial chemicals roadmap - Better environmental management of chemicals*, updated 27 September 2023, accessed 13 November 2024.

In the IChEMS framework, the Australian Government sets national environmental risk management standards by listing industrial chemicals in one of 7 schedules of the IChEMS Register.[78] Schedule 7 includes industrial chemicals likely to cause serious or irreversible harm to the environment with no essential uses.[79] In December 2023, PFOS, PFOA and PFHxS were listed in schedule 7, with prohibitions on the import, export, manufacture or use of these chemicals that will come into effect on 1 July 2025.[80] Long-chain PFCAs with chain lengths between 9 and 21 are expected to be priorities for consideration of scheduling in the future.[81]

In March 2024, the NSW Parliament passed the *Environmental Legislation Amendment (Hazardous Chemicals) Act 2024*.[82] This Act implements IChEMS in NSW, including the pending prohibition on PFOS, PFOA and PFHxS.

In addition to the forthcoming national restrictions, NSW restricts certain uses of long-chain PFAS firefighting foam.[83] Long-chain PFAS firefighting foam is defined as containing a minimum concentration of PFCAs with chain lengths greater than 8 (that is, PFOA and above) or PFSAs with chain lengths greater than 6 (that is, PFHxS and above).[84] Long-chain PFAS firefighting foam cannot be used without applying for an exemption, except by certain authorities in fighting a fire involving a combustible accelerant or by persons fighting a fire on a watercraft.[85] Firefighting foam that contains any type of PFAS (not just long-chain) cannot be used for training or demonstration or in portable fire extinguishers.[86]

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78 *Industrial Chemicals Environmental Management (Register) Instrument 2022* (Cth); DCCEEW, *Setting standards under IChEMS*, updated 16 July 2024, accessed 13 November 2024.

79 *Industrial Chemicals Environmental Management (Register) Instrument 2022* (Cth), sch 7.

80 *Industrial Chemicals Environmental Management (Register) Amendment (2023 Measures No. 1) Instrument 2023* (Cth); exceptions to these prohibitions include cases of unintentional trace contamination, use for research or laboratory purposes, or use in circumstances in which the article (that is, a finished good) is already in use on or before 1 July 2025.

81 DCCEEW, *Setting standards under IChEMS*, n.d. accessed 9 December 2024.

82 *Environmental Legislation Amendment (Hazardous Chemicals) Act 2024* (NSW).

83 *Protection of the Environment Operations (General) Regulation 2022* (NSW), ch 9, pt 5; NSW Environment Protection Agency, *Regulation of PFAS firefighting foams*, updated 25 May 2023, accessed 14 November 2024.

84 *Protection of the Environment Operations (General) Regulation 2022* (NSW), s 146.

85 *Protection of the Environment Operations (General) Regulation 2022* (NSW), s 148.

86 Unless used for fighting a fire involving a combustible accelerant by a relevant authority or those with an exemption or a fire on a watercraft, *Protection of the Environment Operations (General) Regulation 2022* (NSW), s 147, 148.

3. Debates about which types of PFAS to restrict

The unique chemical properties of PFAS make them difficult to regulate. This has prompted many contentious scientific and regulatory debates about the best ways to evaluate and manage the risks of exposure. This section focuses on 3 debates that relate to which of the many types of PFAS warrant restriction, starting with an outline of some major challenges that have shaped these debates.

3.1 There are major challenges in determining which PFAS to restrict

There are substantial challenges involved in selecting which particular chemicals from the thousands of PFAS types should be subject to regulations such as use restrictions and environmental monitoring. These challenges include:

- **The health impacts of many PFAS are uncertain**
  There are only a few dozen PFAS types for which substantial health data is available.[87] Given that generating comprehensive health data for a compound takes significant time and resources, regulators are faced with making decisions based on relatively little information about the long-term risks of exposure to the full range of PFAS in the environment.
- **Regulations may prompt regrettable substitutions**
  Some regulators are concerned about the potential for replacement PFAS to be 'regrettable substitutions', which describes a toxic chemical being phased out and replaced with another chemical that also turns out to be toxic.[88] This can occur, for instance, when a regulated chemical is replaced by an unregulated one or when a chemical for which there is extensive health data is replaced by one about which less is known. For instance, PFHxS was initially used by some manufacturers in China and Italy as a substitute for PFOS, until PFHxS too became the target of restrictions.[89]
- **There is uncertainty around which types of PFAS people are exposed to**
  Many types of PFAS are in commercial use, but information about the identity of these chemicals in products is typically proprietary. In addition, some PFAS products, such as certain firefighting foams, are complex mixtures of PFAS that change composition as they degrade in the environment. Because only certain PFAS can be quantified, it is therefore challenging for regulators and scientists to know which types of PFAS are likely to be emitted and which types people are most exposed to.

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[87] ITRC, *PFAS Technical and Regulatory Guidance Document and Fact Sheets: 7 - Human and Ecological Health Effects of select PFAS*, Updated September 2023, accessed 7 March 2025.

[88] National Research Council, *A Framework to Guide Selection of Chemical Alternatives*, The National Academies Press, 2014, p 10; A Maertens et al., *Avoiding Regrettable Substitutions: Green Toxicology for Sustainable Chemistry*, *ACS Sustainable Chemistry & Engineering*, 2021, 9(23):7749–7758, doi: 10.1021/acssuschemeng.0c09435.

[89] POP Review Committee, *Report of the Persistent Organic Pollutants Review Committee on the work of its fifteenth meeting: risk management evaluation on perfluorohexane sulfonic acid (PFHxS), its salts and PFHxS related compounds*, UNEP/POPS/POPRC.15/7/Add.1, 2019, p 9-11.

- **Environmental contamination can be difficult to reverse**
  PFAS contamination of the environment can be irreversible or costly to reverse.[90] The risk of such contamination, and the potential for PFAS to accumulate in the environment over time, means some regulators are willing to restrict PFAS types that might otherwise be considered of low risk to health at current levels.

3.2 Should less bioaccumulative and less toxic PFAS be restricted?

The first regulatory debate relates to the widespread replacement of legacy PFAS with other kinds of PFAS, such as short-chain PFAS and ether PFAS (Box 3).[91]

Some replacement PFAS, such as short-chain PFAS, have been chosen on the basis that they are less bioaccumulative and less toxic than legacy PFAS in animal tests.[92] Current evidence for short-chain PFAS suggests some have similar types of health effects as long-chain PFAS, but these effects only become evident at higher doses.[93] This is hypothesised to be because short-chain PFAS do not bioaccumulate in the animal's tissues to the same extent, and therefore equivalent exposure only occurs when higher doses are reached.[94]

However, some scientists and regulators argue that short-chain PFAS and other replacement PFAS should be restricted in the same way as legacy PFAS because, even if they are less bioaccumulative or less toxic, they are still environmentally persistent and therefore human exposure will cumulatively increase over time.[95] Other experts argue that this is not a scientifically valid approach to assessing the health risks of PFAS, which vary in their toxicity, bioaccumulation and other relevant properties.[96]

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[90] IT Cousins et al., The precautionary principle and chemicals management: The example of perfluoroalkyl acids in groundwater, *Environment International,* 2016, 94:331-340, doi: 10.1016/j.envint.2016.04.044.

[91] Z Wang et al., Fluorinated alternatives to long-chain perfluoroalkyl carboxylic acids (PFCAs), perfluoroalkane sulfonic acids (PFSAs) and their potential precursors, *Environment International,* 2013, 60: 242–248, doi: 10.1016/j.envint.2013.08.021.

[92] R Renner, The long and the short of perfluorinated replacements, *Environmental Science & Technology,* 2006, 40(1): 12–13, doi: 10.1021/es062612a; JS Bowman, Fluorotechnology Is Critical to Modern Life: The FluoroCouncil Counterpoint to the Madrid Statement, *Environmental Health Perspectives,* 2015, 123(5): A112–A113, doi: 10.1289/ehp.1509910.

[93] ITRC, *PFAS Technical and Regulatory Guidance Document and Fact Sheets: 7 - Human and Ecological Health Effects of select PFAS*, updated September 2023, accessed 7 January 2025; National Toxicology Program, *NTP Technical Report on the Toxicity Studies of Perfluoroalkyl (Revised)*, US Government, 2022; National Toxicology Program, *NTP Technical Report on the Toxicity Studies of Perfluoroalkyl Carboxylates (Perfluorohexanoic Acid, Perfluorooctanoic Acid, Perfluorononanoic Acid, and Perfluorodecanoic Acid) Administered by Gavage to Sprague Dawley (Hsd:Sprague Dawley SD) rats*, US Government, 2022.

[94] MI Gomis et al., Comparing the toxic potency in vivo of long-chain perfluoroalkyl acids and fluorinated alternatives, *Environment International,* 2018, 113:1–9, doi: 10.1016/j.envint.2018.01.011.

[95] IT Cousins et al., The precautionary principle and chemicals management: The example of perfluoroalkyl acids in groundwater, *Environment International,* 2016, 94: 331-340, doi: 10.1016/j.envint.2016.04.044; IT Cousins et al., Why is high persistence alone a major cause of concern?, *Environmental Science: Processes & Impacts*, 2019, 21: 781-792, doi: 10.1039/C8EM00515J; IT Cousins et al., The high persistence of PFAS is sufficient for their management as a chemical class, *Environmental Science: Processes & Impacts,* 2020, 22: 2307-2312, doi: 10.1039/D0EM00355G; SA Bălan et al., Regulating PFAS as a Chemical Class under the California Safer Consumer Products Program, *Environmental Health Perspectives,* 129(2), doi: 10.1289/EHP7431.

[96] JK Anderson et al., Grouping of PFAS for human health risk assessment: Findings from an independent panel of experts, *Regulatory Toxicology and Pharmacology,* 2022, 134:105226, doi: 10.1016/j.yrtph.2022.105226; RC Buck et al., Identification and classification of commercially relevant per- and poly-fluoroalkyl substances (PFAS), *Integrated Environmental Assessment and Management,* 2021, 17(5):1045–1055, doi: 10.1002/ieam.4450.

Box 3. Examples of replacements for legacy PFAS

PFOS ➢ PFBS

Example use: Stain repellent treatments

To phase out PFOS-related substances in its products, 3M replaced them with PFBS-related equivalents.[97] PFBS is a short-chain PFSA that is less bioaccumulative and toxic than PFOS.[98]

PFOA ➢ GenX

Example use: Processing aid for manufacture of Teflon

GenX is the trade name for the ether PFAS known as HFPO-DA in combination with its ammonium salt.[99] It is less bioaccumulative than PFOA.[100] The US EPA considers there is 'suggestive evidence' that GenX has the potential to cause cancer.[101]

8:2 fluorotelomers ➢ 6:2 fluorotelomers

Example use: Firefighting foam for flammable fuel fires

When PFOA was phased out in the US, many manufacturers replaced 8:2 fluorotelomer substances (which can degrade to PFOA) with short-chain substitutes such as 6:2 fluorotelomer substances (which do not degrade to PFOA).[102] There are a variety of different types of 6:2 fluorotelomer substances, which may differ in their health effects.[103]

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[97] R Renner, The long and the short of perfluorinated replacements, *Environmental Science & Technology,* 40(1):12–13, doi: 10.1021/es062612a; GW Olsen et al., Decline in Perfluorooctanesulfonate and Other Polyfluoroalkyl Chemicals in American Red Cross Adult Blood Donors, 2000–2006, *Environmental Science & Technology,* 2008, 42(13): 4989–4995, doi: 10.1021/es800071x; 3M no longer uses PFBS in its Scotchgard stain repellent products and will discontinue PFAS manufacturing by the end of 2025, 3M Company, *PFAS & Their Uses*, updated 28 January 2025, accessed 27 March 2025.

[98] US EPA, *Human Health Toxicity Assessment for Perfluorooctanoic Acid (PFOA) and Related Salts*, US Government 2024, p XXV, p 3-16–3-17; US EPA, *Human Health Toxicity Values for Perfluorobutane Sulfonic Acid (CASRN 375-73-5) and Related Compound Potassium Perfluorobutane Sulfonate (CASRN 29420-49-3)*, US Government, 2021, p 3, p9–10.

[99] The Chemours Company, *What is GenX? | Get the Facts*, n.d., accessed 7 January 2025.

[100] SA Gannon et al., Absorption, distribution, metabolism, excretion, and kinetics of 2,3,3,3-tetrafluoro-2-(heptafluoropropoxy)propanoic acid ammonium salt following a single dose in rat, mouse, and cynomolgus monkey - ScienceDirect, *Toxicology,* 2016, 340:1–9, doi: 10.1016/j.tox.2015.12.006; DJ Wallis et al., Estimation of the Half-Lives of Recently Detected Per- and Polyfluorinated Alkyl Ethers in an Exposed Community, *Environmental Science & Technology,* 2023, 57(41):15348–15355, doi: 10.1021/acs.est.2c08241.

[101] US EPA, *Human Health Toxicity Values for Hexafluoropropylene Oxide (HFPO) Dimer Acid and Its Ammonium Salt (CASRN 13252-13-6 and CASRN 62037-80-3) Also Known as "GenX Chemicals"*, US Government, 2021, p xii.

[102] Alliance for Telomer Chemistry Stewardship, *Facts About C6 Fluorotelomers*, American Chemistry Council, n.d., accessed 7 January 2025; ITRC, *PFAS Technical and Regulatory Guidance Document and Fact Sheets: 3 - Firefighting Foams*, updated September 2023, accessed 9 March 2025; W Zhang, Biotransformation of perfluoroalkyl acid precursors from various environmental systems: advances and perspectives, *Environmental Pollution,* 2021, 272: 115908, doi: 10.1016/j.envpol.2020.115908.

[103] ITRC, *PFAS Technical and Regulatory Guidance Document and Fact Sheets: 17.2 Additional Information for Human Health Effects*, updated September 2023, accessed 7 January 2025.

Another prominent argument is that any PFAS types that are both persistent and mobile in the environment should be restricted.[104] Both short-chain and long-chain PFAS can spread through water and soil, but short-chain types are considered even more mobile in the environment than long-chain types.[105] The combination of persistence and mobility was used in the EU as the basis for regulating 2 PFAS types (PFBS and GenX) that do not meet the EU criteria for classification as bioaccumulative, which had previously been one of the key grounds for restricting long-chain PFAS.[106]

This rationale was also used in the successful proposal to restrict the short-chain PFHxA and related substances in certain products in the EU, which will come into effect between 2026 and 2029.[107] The restrictions will also apply to a range of widely-used 6:2 fluorotelomer-derived substances, which can form PFHxA during degradation.[108] The restriction proposal acknowledged that risk assessments suggest current exposures do not pose a risk for human health, but argued PFHxA's persistence introduces uncertainty about the long-term risk, and 'at the point of time the effects are triggered, it will be very difficult to negate the consequences due to the irreversibility of the exposure'.[109]

3.3 Should all PFAS be restricted as a class?

Considerable debate surrounds whether PFAS should continue to be assessed individually or should instead all be restricted as a class. In 2015, 206 scientists and other experts were listed as signatories to the Madrid Statement, which called for limits on the production and use of all types of PFAS and for the development of non-fluorinated alternatives.[110] A reply by a fluorochemical industry group argued that short-chain PFAS are not expected to harm human health or the environment and

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[104] M Neumann and I Schlieber, *Protecting the sources of our drinking water from mobile chemicals*, Umwelt Bundesamt (German Environment Agency), German Government, 2017; S Brendel et al., Short-chain perfluoroalkyl acids: environmental concerns and a regulatory strategy under REACH, *Environmental Sciences Europe,* 2018, 30:9, doi: 10.1186/s12302-018-0134-4; SE Hale et al., Persistent, mobile and toxic (PMT) and very persistent and very mobile (vPvM) substances pose an equivalent level of concern to persistent, bioaccumulative and toxic (PBT) and very persistent and very bioaccumulative (vPvB) substances under REACH, *Environmental Sciences Europe,* 2020, 32:155, doi: 10.1186/s12302-020-00440-4.

[105] MG Evich et al., Per- and polyfluoroalkyl substances in the environment, *Science*, 2022, 375(6580):eabg9065, doi: 10.1126/science.abg9065.

[106] In 2019 and 2020 PFBS and GenX were added to the 'Candidate List of substances of very high concern for Authorisation' (a candidate list for restrictions in the EU) on the basis of an 'equivalent level of concern' to the hazard criteria that were previously used to list various long-chain PFAS (these criteria included one or more of 'persistent, bioaccumulative and toxic', 'very persistent and very bioaccumulative' or 'toxic for reproduction'); the justification for this equivalent level of concern included persistence and mobility, European Chemicals Agency (ECHA*),* Candidate List of substances of very high concern for Authorisation, *2,3,3,3-tetrafluoro-2-(heptafluoropropoxy)propionic acid, its salts and its acyl halides*, 16 July 2019, *Perfluorobutane sulfonic acid (PFBS) and its salts*, 16 January 2020.

[107] *Commission Regulation (EU) 2024/2462 of 19 September 2024 amending Annex XVII to Regulation (EC) No 1907/2006 of the European Parliament and of the Council as regards undecafluorohexanoic acid (PFHxA), its salts and PFHxA-related substances* [2024] OJ L 2024/2462 (EU); Bundesanstalt für Arbeitsschutz und Arbeitsmedizin (BAuA, German Federal Institute for Occupational Safety and Health), *Annex XV Restriction Report - Proposal for a restriction - Undecafluorohexanoic acid (PFHxA), its salts and related substances*, version 1, 2019.

[108] *Commission Regulation (EU) 2024/2462 of 19 September 2024 amending Annex XVII to Regulation (EC) No 1907/2006 of the European Parliament and of the Council as regards undecafluorohexanoic acid (PFHxA), its salts and PFHxA-related substances* [2024] OJ L 2024/2462, annex (EU); ECHA Committee for Risk Assessment (RAC) and Committee for Socio-economic Analysis (SEAC), *Opinion on an Annex XV dossier proposing restrictions on undecafluorohexanoic acid (PFHxA), its salts and related substances*, 2021, p 24-27, 32-37.

[109] BAuA, *Annex XV Restriction Report - Proposal for a restriction - Undecafluorohexanoic acid (PFHxA), its salts and related substances*, version 1, 2019, p 2.

[110] A Blum et al., The Madrid Statement on Poly- and Perfluoroalkyl Substances (PFASs), *Environmental Health Perspectives,* 2015, 123(5): A107–A111, doi: 10.1289/ehp.1509934; 2 related statements are the 2014 Helsingor Statement and the 2018 Zurich Statement.

that PFAS are essential technology for many aspects of modern life.[111] Other industry scientists have argued that the numbers of PFAS in commercial use is often overestimated, and it is incorrect to say that there are too many PFAS types to use established risk assessment methods.[112]

A 2020 article set out arguments for managing PFAS as a class.[113] These included:

- Testing for health effects one at a time will cause substantial delays in protective actions
- Continued PFAS emissions will increase environmental concentrations, and therefore increase potential for harm
- Restricting all PFAS will incentivise development of non-fluorinated alternatives
- Restricting all PFAS reduces the likelihood of regrettable substitutions of legacy PFAS with other PFAS
- Restricting all PFAS could be simpler and less expensive to implement, for example in the use of less expensive testing methods.

A 2023 article argued against managing PFAS as a class, in the context of proposed PFAS restrictions in the EU (see section 5.1.2).[114] Arguments included:

- Different types of PFAS differ substantially in their properties
- The mechanisms underlying PFAS toxicity may vary between different PFAS types
- Not all PFAS bioaccumulate
- There are few alternatives to PFAS
- Restricting all PFAS could result in the use of alternative chemicals that are not well understood and may be more toxic than PFAS
- PFAS such as fluoropolymers are essential for the transition to renewable energy sources, so a ban may have unintended environmental consequences.

Case studies of several jurisdictions that are attempting to regulate all PFAS as a class are presented in section 5.

3.4 Which chemicals count as PFAS for regulatory purposes?

It is unclear how to draw the line between PFAS and a range of other chemical substances that contain carbon and fluorine. Even for chemicals that are universally agreed to be PFAS, there are

[111] JS Bowman, Fluorotechnology Is Critical to Modern Life: The FluoroCouncil Counterpoint to the Madrid Statement, *Environmental Health Perspectives,* 2015, 123(5): A112–A113, doi: 10.1289/ehp.1509910.

[112] RC Buck et al., Identification and classification of commercially relevant per- and poly-fluoroalkyl substances (PFAS), *Integrated Environmental Assessment and Management,* 2021, 17(5):1045–1055, doi: 10.1002/ieam.4450

[113] CF Kwiatkowski et al., Scientific Basis for Managing PFAS as a Chemical Class, *Environmental Science & Technology Letters,* 2020, 7(8): 532–543, doi: 10.1021/acs.estlett.0c00255.

[114] F Spyrakis and TA Dragani. The EU's Per- and Polyfluoroalkyl Substances (PFAS) Ban: A Case of Policy over Science. *Toxics*. 2023; 11(9):721, doi: 10.3390/toxics11090721.

some that are argued to be so different in their chemical and toxicological properties compared to currently restricted PFAS types that they should not be grouped together for regulatory purposes.

This section introduces 3 of the most prominent debates concerning which chemicals should be considered PFAS for regulatory purposes.

3.4.1 Fluoropolymers

Fluoropolymers are a type of polymeric PFAS (Figure 1). They are used as plastic coatings and lubricants in a wide range of applications, such as cookware, electrical wiring, seals and gaskets, fuel lines, valves, pumps and personal protective equipment.[115]

The chemical properties of fluoropolymers are distinct from the non-polymeric types of PFAS that are regulated in water. For example, fluoropolymers are relatively inert solids that are insoluble in water and unlikely to be bioavailable (absorbed by living things) or bioaccumulative.[116] Fluoropolymer manufacturers argue these plastics should not be grouped with other PFAS for the purposes of regulation.[117]

In contrast, some scientists supportive of regulating PFAS as a class argue that fluoropolymers should not be exempted from regulatory attention, in part because the manufacture of fluoropolymers is linked to emission of non-polymer PFAS, including as manufacturing byproducts or from the use of non-polymeric PFAS as processing aids.[118] For example, fluoropolymer manufacture may have been the largest source of PFOA emissions before PFOA was phased out from use.[119]

Fluoropolymer manufacturers argue that concerns about emissions of the PFAS processing aids that have replaced legacy PFAS are being addressed by improvements in manufacturing practice, including emissions abatement and use of non-PFAS replacements.[120]

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[115] S Jacobs and DS Kosson, *Assessment of Fluoropolymer Production and Use With Analysis of Alternative Replacement Materials*, 2024, ES-3-4.

[116] SH Korzeniowski et al., A critical review of the application of polymer of low concern regulatory criteria to fluoropolymers II: Fluoroplastics and fluoroelastomers, *Integrated Environmental Assessment and Management,* 2023, 19(2): 326–354, doi: 10.1002/ieam.4646.

[117] Plastics Europe Fluoropolymer Product Group, *EU PFAS restriction*, n.d., accessed 7 January 2025; A Scott, The battle over PFAS in Europe, *Chemical & Engineering News*, 18 September 2023.

[118] R Lohmann et al., Are Fluoropolymers Really of Low Concern for Human and Environmental Health and Separate from Other PFAS?, *Environmental Science & Technology,* 2020, 54(20): 12820–12828, doi: 10.1021/acs.est.0c03244.

[119] K Prevedouros et al., Sources, Fate and Transport of Perfluorocarboxylates, *Environmental Science & Technology,* 2005, 40(1): 32–44, doi: 10.1021/es0512475; OECD, *Working Towards A Global Emission Inventory of PFASs: Focus on PFCAs – Status Quo and the Way Forward*, OECD Series on Risk Management, 2015.

[120] SH Korzeniowski et al., A critical review of the application of polymer of low concern regulatory criteria to fluoropolymers II: Fluoroplastics and fluoroelastomers, *Integrated Environmental Assessment and Management,* 2023, 19(2): 326–354, doi: 10.1002/ieam.4646; AH Tullo, How fluoropolymer makers are trying to hold on to their business, *Chemical & Engineering* News, 5 March 2023; B Ameduri et al., Developments in Fluoropolymer Manufacturing Technology to Remove Intentional Use of PFAS as Polymerization Aids, *International Chemical Regulatory and Law Review*, 2023, 6(1): 18–28.

3.4.2 TFA

In 2021 the OECD published a new technical definition of PFAS that was more general than previous definitions and was chemically 'coherent and consistent'.[121] The OECD report stated that the aim of broadening the definition was clarity and ease of implementation, noting that the term 'PFAS' is a 'broad, general, non-specific term, which does not inform whether a compound is harmful or not.'[122] Among the many substances newly included under the revised definition were certain PFCAs and PFSAs with very short chain lengths (sometimes referred to as 'ultrashort-chain PFAS'), such as the 2-carbon PFCA trifluoroacetic acid (TFA).

TFA is highly soluble in water, rapidly excreted from the human body and unlikely to bioaccumulate.[123] Animal tests suggest very high doses are required to induce mild effects on the liver.[124] It has been argued that TFA should not be included in definitions of PFAS for regulatory purposes because of its low toxicity.[125]

Others argue that TFA's rising concentrations, persistence, mobility and the possibility of irreversible impacts warrant precautionary regulatory restrictions.[126] They argue, for instance, that the major methods for removing PFAS from water are not suitable for removing TFA.[127] TFA can be present in the environment and in human blood at much higher concentrations than short and long-chain PFAS, and environmental levels appear to have been increasing rapidly in recent decades.[128] For example, TFA concentrations in streams in California and Alaska in the US increased by an average of 6-fold between 1998 and 2021.[129]

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[121] The definition is: 'fluorinated substances that contain at least one fully fluorinated methyl or methylene carbon atom (without any H/Cl/Br/I atom attached to it)', OECD, *Reconciling Terminology of the Universe of Per- and Polyfluoroalkyl Substances: Recommendations and Practical Guidance*, OECD Series on Risk Management, 2021, p 9; summarised in Z Wang et al., A New OECD Definition for Per- and Polyfluoroalkyl Substances, *Environmental Science & Technology*, 2021, 55(23): 15575–15578, doi: 10.1021/acs.est.1c06896.

[122] OECD, *Reconciling Terminology of the Universe of Per- and Polyfluoroalkyl Substances: Recommendations and Practical Guidance*, OECD Series on Risk Management, 2021, p 31.

[123] JC Boutonnet, Environmental Risk Assessment of Trifluoroacetic Acid, *Human and Ecological Risk Assessment: An International Journal,* 1999, 5(1), 59–124, doi: 10.1080/10807039991289644.

[124] W Dekant and R Dekant, Mammalian toxicity of trifluoroacetate and assessment of human health risks due to environmental exposures, *Archives of Toxicology*, 2023, 97: 1069–1022, doi: 10.1007/s00204-023-03454-y.

[125] TJ Wallington et al., The case for a more precise definition of regulated PFAS , *Environmental Science: Processes & Impacts,* 2021, 23: 1834–1838, doi: 10.1039/D1EM00296A.

[126] HPH Arp et al., The Global Threat from the Irreversible Accumulation of Trifluoroacetic Acid (TFA), *Environmental Science & Technology,* 2024, 58(45):19925–19935, doi: 10.1021/acs.est.4c06189.

[127] MdlA Garavagno, Trifluoroacetic Acid: Toxicity, Sources, Sinks and Future Prospects, *Sustainability*, 2024, 16(6): 2382, doi: 10.3390/su16062382.

[128] IJ Neuwald et al., Ultra-Short-Chain PFASs in the Sources of German Drinking Water: Prevalent, Overlooked, Difficult to Remove, and Unregulated, *Environmental Science & Technology*, 56(10): 6380–6390, doi: 10.1021/acs.est.1c07949; G Zheng et al., Elevated Levels of Ultrashort- and Short-Chain Perfluoroalkyl Acids in US Homes and People, *Environmental Science & Technology,* 57(42): 15782–15793, doi: 10.1021/acs.est.2c06715; HPH Arp et al., The Global Threat from the Irreversible Accumulation of Trifluoroacetic Acid (TFA), *Environmental Science & Technology,* 2024, 58(45):19925–19935, doi: 10.1021/acs.est.4c06189.

[129] TM Cahill, Increases in Trifluoroacetate Concentrations in Surface Waters over Two Decades, *Environmental Science & Technology,* 56(13): 9428–9434, doi: 10.1021/acs.est.2c01826.

The most well-known and likely the largest source of TFA in the environment is the degradation of certain types of refrigerants.[130] TFA is produced by the breakdown of some ozone-friendly refrigerants, such as hydrofluoroolefins. These refrigerants are replacements for chlorofluorocarbons (CFCs) that were phased out globally under the Montreal Protocol because of their effects on the atmospheric ozone layer.[131] TFA is also a breakdown product of a variety of other fluorinated chemicals.[132]

The health and environmental threat posed by TFA originating from CFC replacements is periodically evaluated by the UN Environment Programme's Environmental Effects Assessment Panel.[133] The panel's 2022 assessment report concluded projected increases in the environmental levels of TFA due to use of chemicals under the purview of the Montreal Protocol 'are well below the threshold for concern with respect to human and environmental health'.[134]

3.4.3 Fluorinated pesticides and medicines

Under the OECD's 2021 PFAS definition, approximately 7 million compounds in the US government's PubChem database are classified as PFAS, compared to approximately 230,000 under a previous widely-used definition provided by Buck et al. 2011.[135] Examples include hundreds of pharmaceuticals, such as the cancer drug alpelisib, the COVID-19 drug nirmatrelvir (part of Paxlovid), and the antidepressant fluoxetine (Prozac).[136] Some pesticides and herbicides, such as flufenacet, also fall under the expanded OECD 2021 PFAS definition.[137] Some of the pharmaceutical and agricultural chemicals classed as PFAS also generate TFA as a breakdown product.[138]

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[130] K Adlunger et al., *Reducing the input of chemicals into waters: trifluoroacetate (TFA) as a persistent and mobile substance with many sources*, Umwelt Bundesamt (German Environment Agency), 2021, p 18; ML Hanson, et al., Trifluoroacetic Acid in the Environment: Consensus, Gaps, and Next Steps, *Environmental Toxicology and Chemistry,* 2024, 43(10): 2091–2093, doi: 10.1002/etc.5963; MdlA Garavagno, Trifluoroacetic Acid: Toxicity, Sources, Sinks and Future Prospects, *Sustainability*, 2024, 16(6): 2382, doi: 10.3390/su16062382.

[131] ML Hanson, et al., Trifluoroacetic Acid in the Environment: Consensus, Gaps, and Next Steps, *Environmental Toxicology and Chemistry,* 2024, 43(10): 2091–2093, doi: 10.1002/etc.5963; Environmental Effects Assessment Panel (EEAP), *Environmental Effects of Stratospheric Ozone Depletion, UV Radiation, and Interactions with Climate Change: 2022 Assessment Report*, United Nations Environment Programme (UNEP), Montreal Protocol on Substances that Deplete the Ozone Layer, 2023, p 277-293.

[132] K Adlunger et al., *Reducing the input of chemicals into waters: trifluoroacetate (TFA) as a persistent and mobile substance with many sources*, Umwelt Bundesamt (German Environment Agency), 2021.

[133] UNEP Ozone Secretariat, *Environmental Effects Assessment Panel (EEAP)* , n.d., accessed 2 April 2025.

[134] EEAP, *Environmental Effects of Stratospheric Ozone Depletion, UV Radiation, and Interactions with Climate Change: 2022 Assessment Report*, UNEP, Montreal Protocol on Substances that Deplete the Ozone Layer, 2023, p 292.

[135] EL Schymanski et al. Per- and Polyfluoroalkyl Substances (PFAS) in PubChem: 7 Million and Growing, *Environmental Science & Technology,* 2023, 57(44):16918-16928, doi: 10.1021/acs.est.3c04855

[136] E Hammel et al., Implications of PFAS definitions using fluorinated pharmaceuticals, *iScience*, 2022, 25(4):104020, doi: 10.1016/j.isci.2022.104020.

[137] BAuA, Netherlands National Institute for Public Health and the Environment (RIVM), Swedish Chemicals Agency, Norwegian Environment Agency, Danish Environmental Protection Agency (PFAS Restriction Dossier Submitters), *Annex A to the Annex XV Restriction Report - Proposal for A Restriction: PFAS*, version 2, 2023, p 279; there are also a small number of pesticides that are considered PFAS under all definitions, notably the insecticide sulfluramid, which is a PFOS precursor, Y Guida et al., Confirming sulfluramid (EtFOSA) application as a precursor of perfluorooctanesulfonic acid (PFOS) in Brazilian agricultural soils, *Chemosphere,* 2023, 325: 138370, DOI: 10.1016/j.chemosphere.2023.138370.

[138] B Barbu, Are fluorinated drugs PFAS?, *Chemical & Engineering News*, 21 August 2024, accessed 2 April 2025; K Adlunger et al., *Reducing the input of chemicals into waters: trifluoroacetate (TFA) as a persistent and mobile substance with many sources*, Umwelt Bundesamt (German Environment Agency), German Government, 2021.

Some environmental advocates have called for the pesticides that are now classed as PFAS to be more stringently regulated and monitored.[139] As described in section 5.1, regulators using the OECD's PFAS definition or related definitions have usually exempted medicines, and in some cases agricultural chemicals, from PFAS class-wide restrictions on the grounds that their health effects are already evaluated under existing regulations.

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[139] There are also separate concerns about PFAS used as non-active ingredients in pesticide formulations and the contamination of non-PFAS pesticides with PFAS originating from some types of plastic containers, N Donley et al., Forever Pesticides: A Growing Source of PFAS Contamination in the Environment, *Environmental Health Perspectives,* 2024, 132(7), CID: 075003, doi: 10.1289/EHP13954.

4. Case studies: PFAS types regulated in drinking water

This section outlines some of the challenges of selecting which PFAS types to regulate in drinking water and then presents case studies from different jurisdictions, including Australia, that illustrate a range of approaches taken to these challenges.

4.1 There are additional challenges for regulating PFAS in drinking water

On average, drinking water in Australia is estimated to make a relatively minor contribution to a person's total PFOS and PFOA exposure.[140] However, for communities affected by high levels of water contamination, drinking water can become the major source of exposure.[141] Sources of drinking water contamination can include industrial emissions, firefighting foam, wastewater treatment plants, landfill leachate and the application of contaminated biosolids.[142] These sources typically include a range of PFAS types.

Because of the limits of current analysis methods, it is only possible to set limits on environmental levels of a small fraction of the PFAS types that can be addressed by other types of regulations, such as manufacturing bans. For instance, more than 350 chemicals are named in a non-exhaustive list of substances covered by the Stockholm Convention listing for PFOA, its salts and related compounds (such as precursors).[143] While it is feasible for a manufacturer to stop making any number of banned chemicals, a regulator or water utility can only comply with concentration limits for those chemicals that it can measure.

There are also challenges in understanding whether or not people are likely to be exposed to a particular PFAS. Before setting a statutory limit for a contaminant, most jurisdictions will consider whether there is a realistic risk that the contaminant may be present in the regulated locations at concentrations of concern. In the case of PFAS, monitoring data to support these considerations is limited to the 30-50 PFAS types that can be routinely measured. The relatively high expense of PFAS analysis also limits the extent of monitoring that can be undertaken by regulators.

4.2 Jurisdictions have taken different approaches to selecting which PFAS to regulate

In response to the challenges of regulating PFAS in drinking water, regulators have taken a range of approaches. Some jurisdictions have set statutory drinking water concentration limits or non-statutory guideline values for particular PFAS. Most commonly, these limits apply to PFOS, PFOA and in some cases PFHxS. For example, Japan has a provisional target value for the sum of PFOS and

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[140] J Thompson et al., Concentrations of PFOS, PFOA and other perfluorinated alkyl acids in Australian drinking water, *Chemosphere,* 2011, 83(10): 1320—1325, doi: 10.1016/j.chemosphere.2011.04.017.

[141] EM 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,* 2018, 29:131–147, doi: 10.1038/s41370-018-0094-1.

[142] AO De Silva, PFAS Exposure Pathways for Humans and Wildlife: A Synthesis of Current Knowledge and Key Gaps in Understanding, *Environmental Toxicology and Chemistry*, 2021, 40(3): 631–657, doi: 10.1002/etc.4935.

[143] POP Review Committee Seventeenth meeting, *Updated indicative list of substances covered by the listing of perfluorooctanoic acid (PFOA), its salts and PFOA-related compounds*, UNEP/POPS/POPRC.17/INF/14/Rev.1*, 2022.

PFOA in drinking water of 50 nanograms per litre (ng/L).[144] Other jurisdictions regulate a much wider range of PFAS types. In some cases, the additional PFAS have been singled out because there is public concern about a particular source of contamination or because there is evidence that the PFAS types occur in drinking water at levels of concern. Other jurisdictions have opted to regulate all PFAS that can be measured.

Some jurisdictions use a 'sum of PFAS' value that applies to the sum of the concentrations of a specified set of PFAS. These are intended to reflect the fact that PFAS contamination typically consists of mixtures of different PFAS, and these may have cumulative effects.[145] The sum of PFAS approach assumes that the regulated PFAS share common mechanisms of toxicity and that the level of exposure to each PFAS can be added together to estimate their cumulative health effects (known as 'additive' toxicity). However, there is significant uncertainty in these and other assumptions underlying the use of summed PFAS guideline values.[146]

This section illustrates all of these approaches to the selection of which PFAS types to regulate in drinking water through 6 jurisdictional case studies: Australia, the US, Minnesota, Canada, the EU and the UK. To assist analysis of the lists of regulated PFAS, the Research Service has classified each type into one of the 3 groups introduced in section 2.2 (or 'other'): PFCAs and PFSAs; ether PFAS and fluorotelomers.[147]

4.2.1 Australia/NSW

The Australian context differs from the other jurisdictions considered in this section in that there has been no domestic manufacture of PFAS, and most cases of contamination are linked to the use of firefighting foam.[148] This means there is much lower risk of exposure to certain PFAS types, such as PFOA.[149]

In the Australian drinking water regulatory framework, the NHMRC determines health-based drinking water guideline values that indicate the level of a contaminant that does not result in any significant risk to the health of the consumer over a lifetime of consumption. These guidelines values are

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[144] This will become a legally enforceable water quality standard in April 2026, N Sugiura, Government to enforce stricter PFAS standards in water systems, *The Asahi Shimbun,* 24 December 2024, accessed 2 April 2025.

[145] US EPA, *Framework for Estimating Noncancer Health Risks Associated with Mixtures of Per- and Polyfluoroalkyl Substances (PFAS)*, US Government, 2024.

[146] PE Goodrum et al., Application of a Framework for Grouping and Mixtures Toxicity Assessment of PFAS: A Closer Examination of Dose-Additivity Approaches, *Toxicological Sciences,* 2021, 179(2): 262–278, doi: 10.1093/toxsci/kfaa123; AF Ojo et al., Assessing the human health risks of per- and polyfluoroalkyl substances: A need for greater focus on their interactions as mixtures 2021, *Journal of Hazardous Materials*, 407: 124863, doi: 10.1016/j.jhazmat.2020.124863.

[147] To make category determinations, Chemical Abstracts Service (CAS) registration numbers were compared against the OECD PFAS global database. For the few PFAS not listed in the OECD database, category determinations were made through information in the primary scientific literature.

[148] For example, no domestic manufacturing was reported for any of the PFAS types listed as assessed by the predecessor to the AICIS, AICIS, *Per- and Polyfluoroalkyl Substances (PFAS),* updated 8 November 2024, accessed 14 February 2025; TG Hagen, Australian Case Studies Involving Exposure to PFOS in DJ Paustenbach and K Feinberg (eds), *Human and Ecological Risk Assessment: Theory and Practice,* 3rd edition, John Wiley and Sons, 2024.

[149] TG Hagen, Australian Case Studies Involving Exposure to PFOS in DJ Paustenbach and K Feinberg (eds), *Human and Ecological Risk Assessment: Theory and Practice,* 3rd edition, John Wiley and Sons, 2024.

incorporated into the Australian Drinking Water Guidelines, which provide guidance to state and territory water regulators and suppliers.[150]

The drinking water guideline values are used by states and territories in various ways within their own regulatory systems, for example triggering risk management actions when the values are exceeded. In NSW the guideline values are implemented largely through various requirements to act in accordance with the Australian Drinking Water Guidelines that are imposed on suppliers of drinking water through the *Public Health Act 2010*[151] and on water utilities via their operating licences.[152]

Currently there are 2 drinking water guidelines for PFAS: one for PFOA and one for the sum of PFOS and PFHxS (Table 3). PFHxS does not have a separate guideline value because they are based on 'tolerable daily intake' values that were established by Food Standards Australia and New Zealand (FSANZ) in 2017. In determining these tolerable daily intake levels, FSANZ concluded there was insufficient evidence on which to base a determination for PFHxS. As a precautionary and interim measure, FSANZ decided to apply the PFOS tolerable daily intake value to the sum of PFOS and PFHxS levels.[153]

In October 2024 NHMRC proposed changes to the guideline values, following a review of recent guidance and reports from overseas regulatory agencies (including the US EPA).[154] Table 3 shows the proposed changes, including lowering the guideline values for PFOA and PFOS and setting new guideline values for PFHxS (separate from PFOS) and for PFBS. NHMRC found that PFAS concentrations well above the guideline values have been measured in some bores near contaminated sites, but other water supplies generally have low or undetectable concentrations of the regulated PFAS (Table 3).

The NHMRC considered the health effects of GenX exposure but did not determine a guideline value because it concluded there was insufficient information to determine the risk posed by GenX contamination in Australia. This was both because there were no toxicity studies deemed suitable for deriving a health-based guideline and because there was no data available on whether GenX is

[150] NHMRC, *Australian Drinking Water Guidelines*, Australian Government, 2011.

[151] The *Public Health Act 2010* requires any supplier of drinking water to have a quality assurance program, s 25; the *Public Health Regulation 2022* requires this to include 'a process for controlling the potential health risks in accordance with the Framework for Management of Drinking Water Quality, as set out in the Australian Drinking Water Guidelines', s 45; the framework provides generic guidance on designing water quality management systems, including the use of guideline values, NHMRC, *Australian Drinking Water Guidelines,* 2011, p 12-67; the *Public Health Act* also separately prohibits the supply of drinking water via a reticulated water system (that is, a piped water network) that is 'not fit for human consumption', s 15.

[152] The public water utilities Sydney Water, Hunter Water and WaterNSW are subject to water quality management conditions in their operating licences. For instance, under the *Sydney Water Act 1994*, Sydney Water's operating licence must include water quality standards, s 14(1)(c); the operating licence requires Sydney Water to maintain a water quality management system for drinking water that is consistent with any health-based requirements for drinking water specified by NSW Health and the Australian Drinking Water Guidelines (or an update approved by IPART). If there is an inconsistency between the two sets of requirements, the requirements of NSW Health apply, *Sydney Water Operating Licence 2024–2028*, p 17; the operating licences for Hunter Water and WaterNSW impose similar requirements for drinking water quality management; private water utilities also have conditions in their operating licences requiring that they operate their infrastructure in a way consistent with the Australian Drinking Water Guidelines, *Water Industry Competition Act 2006*, s 8H(1)(c)(ii), *Water Industry Competition (General) Regulation 2024*, s 5.

[153] NHMRC, *Australian Drinking Water Guidelines*, Australian Government, 2011, p 863.

[154] NHMRC, *NHMRC Review of PFAS in Australian drinking water*, n.d., accessed 19 November 2024.

present in Australian drinking water. GenX has not been made or imported for commercial industrial use in Australia.[155]

During the review process, the NHMRC also examined approaches taken in other jurisdictions to deriving a total PFAS or sum of PFAS value for mixtures:

> NHMRC and the Water Quality Advisory Committee had concerns about the feasibility of implementing a guideline value for a PFAS sum/mixture with the current options available, given the limited health evidence available for other PFAS. Therefore, no single total/sum guideline value for a PFAS mixture has been proposed at this time but it may be reconsidered should further evidence and methods become available.[156]

The final revised guidelines are expected to be published in 2025 and are likely to be adopted in NSW.[157]

Table 3. Australia: Current and proposed drinking water guideline values and maximum concentrations detected in Australian water supplies (ng/L)

PFAS	Current value	Proposed value	Max detected in drinking water supplies	Max detected in contaminated bores	Group
PFOA	560	200	9.7	10,500	Long-chain PFCA
PFOS	70 (with PFHxS)	4	16.4	136,000	Long-chain PFSA
PFHxS	70 (with PFOS)	30	19.1	54,300	Long-chain PFSA
PFBS	No guideline	1000	2.2	6,250	Short-chain PFSA
HFPO-DA (GenX)	No guideline	No guideline	Unknown	Unknown	Ether PFAS

Source: NHMRC

4.2.2 United States

In the US, contamination of drinking water from industrial PFAS emissions dates back to the 1950s.[158] The US EPA has estimated that around 83-105 million people in the US are served by water systems that exceed the new statutory drinking water limits for PFAS that are described in this section.[159]

[155] NHMRC, *Draft fact sheet on Per- and poly-fluoroalkyl substances (PFAS)*, October 2024, accessed 19 November 2024.
[156] NHMRC, *Questions and answers on review of PFAS in drinking water*, n.d., accessed 24 January 2025.
[157] In 2024 NSW Minister for Water, Rose Jackson, MLC, stated that any changes to the guideline values will be adopted in NSW, C Fellner et al., 'Enormous implications': Australia's tap water clean-up could cost billions, *Sydney Morning Herald,* 22 October 2022, accessed 19 November 2024.
[158] For example, from the 1950s through to the 1970s, PFAS waste from 3M's manufacturing activities resulted in groundwater contamination in parts of Minnesota, Minnesota Pollution Control Agency (MPCA), *East Metro | 3M PFAS contamination*, updated 3 August 2022, accessed 7 April 2025.
[159] *PFAS National Primary Drinking Water Regulation*, (US), 89 Fed Reg 32532, 32600, (26 April 2024).

4.2.2.1 Limits for individual PFAS types

In 2024 the US EPA set its first statutory maximum contaminant levels (MCLs) for PFAS in drinking water.[160] An MCL is the maximum permissible level of a contaminant in water delivered through public water systems (which are systems over a certain size that provide water for human consumption).[161] Public water systems must comply with the MCLs by 2029.[162]

Setting an MCL is a 2-step process: first the US EPA sets an 'MCL goal', which is the level at which no anticipated health effects occur.[163] The MCL goal is not an enforceable regulatory limit. An enforceable MCL is then set at a level that is as 'close as feasible' to the MCL goal, taking costs into consideration.[164] In setting the MCL the US EPA evaluates water treatment costs as well as the level at which it is feasible to reliably measure the contaminant.[165]

The US EPA set MCLs for 5 individual PFAS types (Table 4). For 3 of these PFAS, the MCL was set at the same value as the MCL goal. However, for PFOS and PFOA, the MCL goal was determined to be zero. This determination was made on the basis that PFOA and PFOS were classified by the US EPA as 'likely to be carcinogenic to humans', and the long-standing practice of the agency is to set the MCL goal at zero for contaminants that are known or likely carcinogens.[166] Given an MCL goal of zero, the MCL for PFOS and PFOA was therefore set at the lowest concentration that can be reliably measured within specific limits of precision and accuracy (the 'practical quantitation level'), which for both was determined to be 4 ng/L.[167]

Table 4. US: Individual maximum contaminant levels for drinking water

PFAS	MCL goal (ng/L)	MCL (ng/L)	Group
PFOS	0	4	Long-chain PFSA
PFOA	0	4	Long-chain PFCA
PFHxS	10	10	Long-chain PFSA
PFNA	10	10	Long-chain PFCA
HFPO-DA (GenX)	10	10	Ether PFAS

Source: US EPA

4.2.2.2 Limits for mixtures of PFAS

160 *PFAS National Primary Drinking Water Regulation* (US), 89 Fed Reg 32532 (26 April 2024).
161 *Safe Drinking Water Act*, 42, USC, § 300f (1996)
162 *National Primary Drinking Water Regulations* (US), 40 CFR § 141.6(l).
163 *Safe Drinking Water Act*, 42, USC, § 300g-1(b)(4)(A) (1996)
164 *Safe Drinking Water Act*, 42, USC, § 300g-1(b)(4)(B) (1996)
165 *PFAS National Primary Drinking Water Regulation*, (US), 89 Fed Reg 32532, 32573, (26 April 2024).
166 Unless there is evidence for a threshold dose below which no carcinogenic effects have been observed, *PFAS National Primary Drinking Water Regulation* (US), 89 Fed Reg 32532, 32563 (26 April 2024).
167 *PFAS National Primary Drinking Water Regulation Rulemaking* (US), 88 Fed Reg 18638, 18666 (29 March 2023).

In addition to the MCLs for individual PFAS, the US EPA set a MCL that applies to mixtures of 4 PFAS, known as the hazard index MCL (Table 5).

The reasons given by the US EPA for setting an MCL for mixtures were:

- Certain PFAS (including the 4 specified in the hazard index MCL) have similar health effects in several biological organs or systems
- Chemicals with similar adverse effects should be assumed to act in an additive manner unless data demonstrate otherwise
- There is a substantial likelihood that the 4 specified PFAS will occur as mixtures in drinking water at levels of public health concern.[168]

The hazard index MCL was set using an established method for assessing the cumulative risk from mixtures.[169] It applies to mixtures of 2 or more of the 4 specified PFAS. Calculating the hazard index for a mixture involves dividing the concentration of each PFAS by the relevant health-based water concentration (HBWC), which is the level below which adverse health effects are not likely to occur. These ratios are then added together to give the hazard index.[170] A hazard index of 1 or above exceeds the hazard index MCL, even if none of the 4 PFAS have individually exceeded their HBWC (Figure 2).[171]

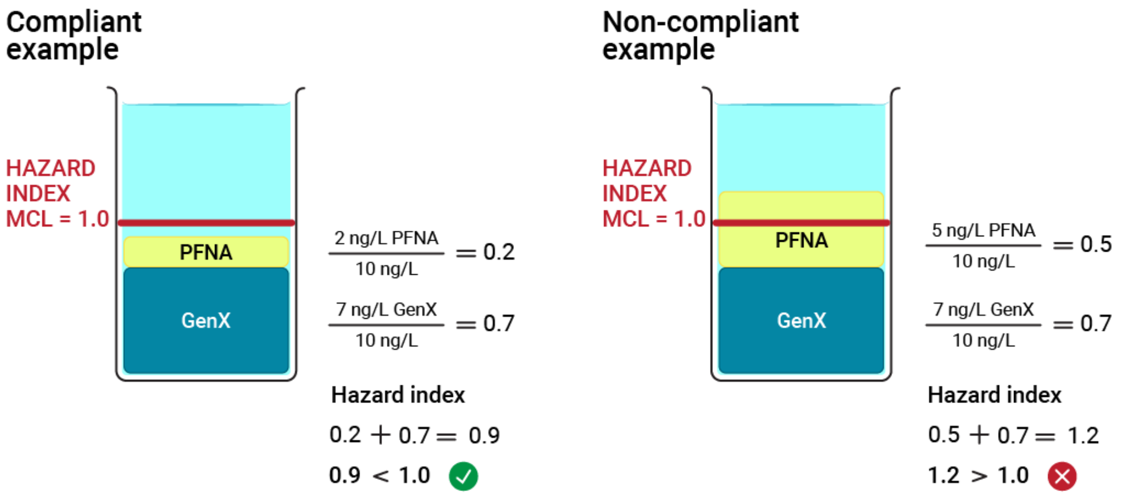
Table 5. US: PFAS to which the hazard index maximum contaminant level applies

PFAS	HBWC for hazard index (ng/L)	Individual MCL Goal (ng/L)	PFAS group
PFHxS	10	10	Long-chain PFSA
PFNA	10	10	Long-chain PFCA
PFBS	2000	Not applicable	Short-chain PFSA
HFPO-DA	10	10	Ether PFAS

Source: US EPA

[168] *PFAS National Primary Drinking Water Regulation* (US), 89 Fed Reg 32532, 32533 (26 April 2024).
[169] US EPA, *Framework for Estimating Noncancer Health Risks Associated with Mixtures of Per- and Polyfluoroalkyl Substances (PFAS)*, 2024, p 57-74.
[170] For a brief explanation of how to calculate the hazard index, see US EPA, *Understanding the Final PFAS National Primary Drinking Water Regulation*, US Government, 2024.
[171] *PFAS National Primary Drinking Water Regulation* (US), 89 Fed Reg 32532, 32533 (26 April 2024).

Figure 2. Examples of hazard index calculations



PFOS and PFOA were excluded from the hazard index MCL because in both cases their MCL goal (which would be used as their HBWC) is zero and hence lower than their practical quantitation limit.[172]

Three of the 4 PFAS in the hazard index MCL also have an individual MCL (with the same value as their HBWC). PFBS does not have an individual MCL because the US EPA has deferred its final determination.[173] This deferral is to determine whether PFBS, when considered on its own, would meet the statutory criteria for regulation under the relevant legislation.[174] The 3 statutory criteria are:

- The contaminant may have adverse health effects
- There is a substantial likelihood it occurs in public water systems at levels of concern
- Its regulation represents a meaningful opportunity for health risk reduction.[175]

The US EPA determined that all 3 criteria were met for the 5 PFAS for which it set an individual MCL, as well as for mixtures of PFHxS, PFNA, HFPO-DA and PFBS, but it decided to further consider whether or not there is a substantial likelihood PFBS will individually occur at levels of health concern.[176] National and state monitoring data suggests PFBS is frequently found in drinking water, but only at levels substantially below the HBWC of 2000 ng/L.[177]

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[172] PFAS National Primary Drinking Water Regulation, (US), 89 Fed Reg 32532, 32579 (26 April 2024).

[173] PFAS National Primary Drinking Water Regulation (US), 89 Fed Reg 32532, 32539 (26 April 2024).

[174] In the US EPA's original proposal, individual MCLs were not set for any of the 4 PFAS to which the hazard index MCL applied. Instead, the hazard index MCL was intended to regulate these PFAS both individually and in mixtures, PFAS National Primary Drinking Water Regulation Rulemaking (US), 88 Fed Reg 18638, 18668 (29 March 2023).

[175] The Safe Drinking Water Act provides that the US EPA shall publish an MCL goal and promulgate a national primary drinking water regulation (which can specify an MCL) for a contaminant if it determines the contaminant meets the listed criteria, 42, USC, § 300g-1(b)(1)(A) (1996).

[176] PFAS National Primary Drinking Water Regulation, (US), 89 Fed Reg 32532, 32539 (26 April 2024).

[177] PFAS National Primary Drinking Water Regulation Rulemaking (US), 88 Fed Reg 18638, 18650 (29 March 2023).

4.2.2.3 Selection of PFAS for regulation

During public consultation on the proposed regulations, many commenters recommended additional PFAS should be regulated. The US EPA responded:

> […] the agency is making final determinations for all PFAS with sufficiently available information to meet these statutory criteria [for regulation] either individually and/or as part of mixture combinations. As information becomes available, the agency will continue to evaluate other PFAS for potential future preliminary regulatory determinations.[178]

The US EPA also stated that other PFAS types are often found alongside the regulated PFAS, and many of these unregulated co-occurring PFAS are also likely to pose public health hazards. They argued that treating drinking water to remove the regulated PFAS would be anticipated to also remove the non-regulated PFAS, providing additional public health benefits.[179]

In addition to regulating PFAS via MCLs, the US EPA has a mandatory monitoring program for unregulated PFAS in drinking water via the Unregulated Contaminant Monitoring Rule (UCMR). Between 2013 and 2015, 6 PFAS were monitored in drinking water nationwide through this program (PFOA, PFOS, PFHxS, PFNA, PFBS and PFHpA).[180] The resulting data helped support development of the PFAS MCLs, including in establishing whether a PFAS type occurred in public water systems at levels of concern.[181] There are currently 29 PFAS being monitored under a new UCMR program for 2023-2025.[182] These 29 PFAS are all those that can be measured using US EPA methods 537.1 and 533 (see section 2.4).

4.2.3 Minnesota, US

Because the US did not have national MCLs for any PFAS before 2024, at least 30 US state governments have their own statutory limits or non-statutory guideline values for various PFAS types in water.[183] This includes Minnesota, the home state of 3M and one of the first jurisdictions in the world to develop health-based guideline values for PFAS.[184]

The Minnesota Department of Health sets non-statutory groundwater health-based values (HBVs) which can be promoted to statutory groundwater health risk limits (HRLs).[185] Both HBVs and HRLs are designed to represent the level of a contaminant that can be present in water and pose little or no

[178] *PFAS National Primary Drinking Water Regulation*, (US), 89 Fed Reg 32532, 32550 (26 April 2024).
[179] *PFAS National Primary Drinking Water Regulation Rulemaking* (US), 88 Fed Reg 18638, 18651 (29 March 2023).
[180] US EPA, *Third Unregulated Contaminant Monitoring Rule*, updated 10 June 2024, accessed 17 March 2025.
[181] *PFAS National Primary Drinking Water Regulation Rulemaking*, (US), 88 Fed Reg 18638, 18671 (29 March 2023).
[182] US EPA, *Fifth Unregulated Contaminant Monitoring Rule*, updated 11 March 2025, accessed 17 March 2025.
[183] Including drinking water, groundwater, surface water or fresh water regulations, ITRC, PFAS Environmental Media Values Excel file - updated November/December 2024, accessed 7 January 2025.
[184] In 2002 Minnesota was the first US state to derive health-based guideline values for PFOA (7,000 ng/L) and PFOS (1,000 ng/L), Minnesota Department of Health (MDH), *History of MDH Activities - Per- and Polyfluoroalkyl Substances*, updated 16 October 2024, accessed 4 April 2025; Minnesota Government, *Minnesota's PFAS Blueprint*, 2021, p 49.
[185] MDH, *Guidance Values and Standards for Contaminants in Drinking Water*, updated 30 July 2024, accessed 7 February 2025; MDH, *Health-Based Guidance Development Process*, updated 3 October, 2022, accessed 7 February 2025; the setting of HRLs is authorised for contaminants that have been detected during groundwater quality monitoring, *Groundwater Protection Act*, Minn Stat § 103H.201 (Minnesota).

health risk to humans who drink that water.[186] Unlike MCLs set by the US EPA, Minnesota's HBVs and HRLs are determined only on the basis of health effects, and they 'may be set at levels that are costly, challenging, or impossible for a water system to meet'.[187] These groundwater HRLs and HBVs are also used as non-statutory guideline values for drinking water.[188] There are 6 PFAS to which an individual groundwater HRL applies (Table 6).

Table 6. Minnesota: Groundwater health risk limits for individual PFAS

Long-chain PFCA/PFSAs		Short-chain PFCA/PFSAs	
PFAS	**Value (ng/L)**	**PFAS**	**Value (ng/L)**
PFHxS	47	PFBA	7000
PFOA	35	PFBS	100
PFOS	300	PFHxA	200

Source: Minnesota Department of Health

In 2024 the Department of Health set HBVs for PFOS and PFOA that are proposed to become statutory HRLs.[189] These HBVs were set followed the passing of a 2023 law by the Minnesota Legislature directing the Commissioner of Health to reduce the HRL value for PFOS to a maximum of 15 ng/L by July 2026.[190] The new HBVs are 0.0079 ng/L for PFOA[191] and 2.3 ng/L for PFOS, which are both lower than the US EPA's practical quantitation limits.[192]

To evaluate exposure to more than one of the regulated PFAS, Minnesota uses a method similar to the hazard index method of the US EPA.[193]

The PFAS that Minnesota has chosen to regulate correspond to those with the longest histories of environmental monitoring in the state (the one exception being the short-chain PFPeA, for which there is no HBV or HRL). The Department of Health states that it first developed methods to analyse water samples for PFOA and PFOS in 2003-2004 and that when new methods became available in 2006,

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[186] MDH, *How Health-Based Values and Health Risk Limits are Calculated*, updated 30 September 2024, accessed 11 February 2025.

[187] MDH, *Guidance Values and Standards for Contaminants in Drinking Water*, updated 30 July 2024, accessed 11 February 2025.

[188] MDH, *Guidance Values and Standards for Contaminants in Drinking Water*, updated 30 July 2024, accessed 11 February 2025.

[189] MDH, *PFAS and Health*, updated 20 November 2024, accessed 7 February 2025; D Gunderson, Minnesota finds increased health risk from 'forever chemicals', *MPR News*, 16 January 2024, accessed 7 February 2025; both the HRLs and HBVs for PFOA and PFOS apply at the same time, and both are available for use by state programs until the next rulemaking opportunity, when the new HBVs may be promoted to HRLs to replace the old HRLs, MDH, *Dual Guidance for Drinking Water*, updated 3 October 2022, accessed 7 February 2025.

[190] Act of 24 May 2023, ch 60 art 3 § 34, 2023 Minn Laws 1, 125 (Minnesota); MPCA, *New nation-leading measures protect Minnesotans from forever chemicals*, 17 October 2023, accessed 7 February 2025.

[191] In the case of PFOA, only the HBV based on lifetime cancer risk is listed. The HBVs based on short-term, subchronic and chronic exposure risks were all set at 0.25 ng/L, MDH, *Human Health-Based Water Guidance Table*, updated 3 February 2025, accessed 7 February 2025.

[192] *PFAS National Primary Drinking Water Regulation Rulemaking* (US), 88 Fed Reg 18638, 18680 (29 March 2023).

[193] MDH, *Evaluating Concurrent Exposures to Multiple Chemicals*, updated 3 October 2022, accessed 7 February 2025.

water monitoring programs expanded to include PFBA, PFBS, PFHxA, PFHxS and PFPeA.[194] HBVs or HRLs were subsequently developed for 4 of these PFAS.

A HBV for PFBA was first established in 2008 in response to concerns about local contamination of drinking water.[195] This PFBA contamination, thought to be from a 3M industrial waste site, was confirmed by the expanded 2006 monitoring program and prompted a 2007 state law that required the Commissioner of Health to report on the health effects for PFBA and other PFAS.[196]

4.2.4 Canada

Unlike the US and Minnesota, Canada has not used a standard chemical-by-chemical risk assessment approach to establishing PFAS drinking water guidelines, stating that this process 'takes many years to finalize' and that concerns about PFAS need to be addressed more quickly than the comprehensive guideline development process allows.[197]

In 2024 Health Canada established a national drinking water objective of 30 ng/L for the sum of 25 specified PFAS (Table 7).[198] This objective replaces previous PFOA and PFOS drinking water guidelines and screening values for 9 other PFAS. The drinking water objective will be used as an interim measure while guidelines are reviewed during decision-making on the regulation of PFAS as a class (see section 5.1.3). It is a non-enforceable guideline that may be used for water management by provincial and territorial governments.[199]

The 25 PFAS included under the objective are all those that can be measured using US EPA method 533, which is the analytical method recommended by Health Canada (see section 2.4).[200] The objective of 30 ng/L was determined based on levels that could be reasonably achievable by treatment and was set using a 'precautionary group-based approach':

> A traditional health-based approach was not adopted to derive the objective in part due to the rapidly evolving science. Further, the science is complex, there is currently no consensus regarding the most sensitive health effects, and approaches to hazard and risk assessment are varied. […] a substance-by-

[194] MDH, *History of MDH Activities - Per- and Polyfluoroalkyl Substances*, updated 16 October 2024, accessed 7 February 2025.

[195] MDH, *History of MDH Activities - Per- and Polyfluoroalkyl Substances*, updated 16 October 2024, accessed 7 February 2025; MDH, *Health Risk Limits for Perfluorochemicals - Report to the Minnesota Legislature*, 2008.

[196] L Benson, *Health Department delayed disclosure of further 3M chemical contamination*, *MPR News*, 1 April 2007, accessed 7 February 2025; Act of 3 May 2007, ch 37 2007 Minn Laws 1; MDH, *Health Risk Limits for Perfluorochemicals - Report to the Minnesota Legislature*, 2008.

[197] Health Canada, *Objective for Canadian drinking water quality per- and polyfluoroalkyl substances*, 27 August 2024, accessed 4 April 2025.

[198] Health Canada, *Objective for Canadian drinking water quality per- and polyfluoroalkyl substances*, 27 August 2024, accessed 16 January 2025.

[199] For example, the Ontario Government stated it is assessing the objective's 'applicability for use in Ontario and the best way to implement it', Ontario Ministry of the Environment, *Conservation and Parks, Minister's Annual Report on Drinking Water*, 2024; the Quebec Government states that the objective is not intended as a basis for regulation, Government of Québec, *Perfluoroalkyl and polyfluoroalkyl substances (PFAS)*, 19 August 2024, accessed 11 February 2025.

[200] US EPA, *Method 533: Determination of Per- and Polyfluoroalkyl Substances in Drinking Water by Isotope Dilution Anion Exchange Solid Phase Extraction and Liquid Chromatography/Tandem Mass Spectrometry*, US Government, 2019; Health Canada, *Objective for Canadian drinking water quality per- and polyfluoroalkyl substances*, Canadian Government, 2024, p 14.

substance assessment […] for each PFAS is not a sustainable approach for managing PFAS in drinking water.[201]

Table 7. Canada: National PFAS drinking water objective

	Long-chain PFCA/PFSAs	Short-chain PFCA/PFSAs	Ether PFAS	Fluoro-telomers
30 ng/L (sum of PFAS)	PFDA PFDoDA PFHpS PFHxS PFNA PFOA PFOS PFUnDA	PFBA PFBS PFHpA PFHxA PFPeA PFPeS	6:2 Cl-PFESA (F-53B) 8:2 Cl-PFESA (F-53B) ADONA HFPO-DA (GenX) NFDHA PFEESA PFMBA PFMPA	4:2 FTS 6:2 FTS 8:2 FTS

Source: Health Canada

4.2.5 European Union

The EU has also adopted a 'sum of PFAS' approach to drinking water regulation, although it is unclear how the regulatory values were developed and regulated PFAS selected. Many member states have introduced their own health-based PFAS drinking water regulations alongside the EU's regulations.

4.2.5.1 EU regulations

The 2020 revision of the EU Drinking Water Directive (DWD) requires member states, by 2026, to monitor and comply with one or both of 2 PFAS parameters:

- **Sum of PFAS** (100 ng/L)
  The sum of the concentrations of each of 20 specified PFAS (Table 8)
- **PFAS total** (500 ng/L)
  The totality of per- and polyfluoroalkyl substances (there is not yet a standardised method to measure this parameter - see section 5.2.2).[202]

The 20 PFAS that are specified in the sum of PFAS parameter include one PFCA and one PFSA for each of the chain lengths between 4 and 13 (Table 8). It is not clear why these particular PFAS were chosen; the basis on which they were selected is not indicated in the DWD or key related

[201] Health Canada, *Objective for Canadian drinking water quality per- and polyfluoroalkyl substances*, Canadian Government, 2024, p 26.
[202] *Directive (EU) 2020/2184 of the European Parliament and of the Council of 16 December 2020 on the quality of water intended for human consumption (recast)* [2020] OJ L 435/1, art 13 (EU).

documents.[203] The explanatory memorandum for the proposed law described the regulation of the group of 20 PFAS as a precautionary approach when compared to regulating just PFOS and PFOA.[204]

The parameter values of 100 ng/L (sum of PFAS) and 500 ng/L (PFAS total) do not seem to have been derived from detailed considerations of health data. The explanatory memorandum notes that the PFAS parameter values should be feasible to achieve as they are higher than values proposed or in force in some other jurisdictions.[205] One analysis of the scientific basis of EU's different PFAS regulatory thresholds concluded that 'It seems likely that the [PFAS drinking water parameter values] do not have an unequivocal scientific foundation but instead, they have been issued at least partly on the grounds of a political agreement.'[206]

4.2.5.2 Member state regulations

Some EU member states have added extra PFAS to the list of 20 PFAS types that are subject to the sum of PFAS limit in their jurisdiction (for example, Sweden and Italy, Table 8). In some cases, this is due to local concerns; for instance, Italy includes C6O4, a PFOA substitute used in Italy that was found to contaminate the River Po.[207] Sweden added 6:2 FTS to the list because this PFAS type was already subject to a Swedish Government non-statutory sum of PFAS guideline value established in 2016.[208]

Some member states and sub-national jurisdictions have also established a separate limit for the sum of PFOS, PFOA, PFNA and PFHxS, sometimes known as the PFAS-4, including Denmark, Germany, and Sweden.[209] These regulations followed development of a health-based guideline for the

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[203] Legislative Observatory European Parliament, *Procedure File: 2017/0332(COD)*; for example, the basis of the Sum of PFAS parameter and how its value was set are not mentioned in the directive itself nor in the following: European Commission, *Commission staff working document: Impact Assessment Accompanying the document Proposal for a Directive of the European Parliament and of the Council on the quality of water intended for human consumption (recast)*, SWD/2017/0449 final - 2017/0332 (COD), 2018; European Commission, *Study supporting the revision of the EU drinking water directive*, 2017; World Health Organisation Regional Office for Europe, *Drinking Water Parameter Cooperation Project: Support to the revision of Annex I Council Directive 98/83/EC on the Quality of Water Intended for Human Consumption (Drinking Water Directive) – Recommendations*, 2017.

[204] Explanatory Memorandum, *Proposal for a directive of the European Parliament and of the Council on the quality of water intended for human consumption (recast)*, COM/2017/0753 final - 2017/0332 (COD), 2017, p 17.

[205] The comparator values cited were the drinking water limits recommended by the Swedish National Food Agency for the sum of 11 PFAS (90 ng/L), the health advisory levels then in use by the US EPA (70 ng/L for PFOS or PFOA) and an EU inland surface water environmental quality standard (0.65 ng/L for PFOS), Explanatory Memorandum, *Proposal for a directive of the European Parliament and of the Council on the quality of water intended for human consumption (recast),* COM/2017/0753 final - 2017/0332 (COD), 2017, p 17.

[206] J Reinikainen, *Inconsistencies in the EU regulatory risk assessment of PFAS call for readjustment*, *Environment International*, 2024, 186: 108614, doi: 10.1016/j.envint.2024.108614.

[207] *Decreto legislativo 23 febbraio 2023, n. 18, Attuazione della direttiva (UE) 2020/2184 del Parlamento europeo e del Consiglio, del 16 dicembre 2020, concernente la qualita' delle acque destinate al consumo umano* [Legislative Decree no. 18 of 23 February 2023, Implementation of Directive (EU) 2020/2184 of the European Parliament and of 16 December 2020 on the quality of water intended for human consumption.] (Italy); C Hogue and C Bettenhausen, A tale of PFAS, pollution, and patent claims, *Chemical & Engineering News*, 27 March 2021, accessed 30 January 2025.

[208] Livsmedelsverket, *Riskhantering - PFAS i dricksvatten och fisk*, [Risk management - PFAS in drinking water and fish], updated 3 July 2016, archived 11 February 2017.

[209] *Bekendtgørelse om vandkvalitet og tilsyn med vandforsyningsanlæg* [Executive Order on Water Quality and Supervision of Water Supply Facilities] BEK no. 1023 of 29 June 2023 (Denmark); *Trinkwasserverordnung vom 20. Juni 2023* [Drinking Water Ordinance of 20 June 2023] BGBl. 2023 I no. 159 of 23 June 2023 (Germany); *Livsmedelsverkets föreskrifter om dricksvatten* [The National Food Agency's regulations on drinking water] LIVSFS 2022: 12 of 30 November 2022 (Sweden).

PFAS 4 in 2020 by the European Food Safety Authority (EFSA).[210] The reasons given by EFSA for selecting those particular PFAS were that they made the largest contribution to total PFAS levels in human blood and that they had similar effects in animal tests and similar bioaccumulation properties in humans.[211]

Alongside its statutory EU sum of PFAS parameter, the Netherlands has developed a non-statutory sum of PFAS drinking water guideline value that attempts to take into account differences in the potency of each PFAS–that is, differences in what dose of each PFAS is expected to result in harmful health effects. For this relative potency guideline value, the concentration of each specified PFAS is converted to 'PFOA equivalents' based on how potent it is at inducing liver effects in animal tests.[212] The PFAS covered by the guideline are any PFAS for which the government has derived a relative potency factor. As of February 2025, 24 PFAS have a relative potency factor for drinking water (Table 8).[213]

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[210] EFSA Panel on Contaminants in the Food Chain (EFSA CONTAM Panel), D Schrenk et al., 2020. Risk to human health related to the presence of perfluoroalkyl substances in food, *EFSA Journal,* 2020, 18(9): e06223, doi: 10.2903/j.efsa.2020.6223.

[211] EFSA CONTAM Panel, D Schrenk et al., 2020. Risk to human health related to the presence of perfluoroalkyl substances in food, *EFSA Journal,* 2020, 18(9): e06223, doi: 10.2903/j.efsa.2020.6223, p 157.

[212] *Besluit van 23 mei 2011, houdende bepalingen inzake de productie en distributie van drinkwater en de organisatie van de openbare drinkwatervoorziening (Drinkwaterbesluit)* [Decree of 23 May 2011, containing provisions on the production and distribution of drinking water and the organisation of the public drinking water supply (Drinking Water Decree)], annex A (Netherlands); RIVM, *PFAS in Drinkwater* [PFAS in Drinking Water] n.d., accessed 16 January 2025.

[213] RIVM, *Relative potency factors PFAS*, updated 12 December 2023, acccessed 16 January 2025; additional PFAS types have relative potency factors, but these generally do not apply to treated drinking water, RIVM, *Method of testing PFAS in drinking water samples,* Netherlands Government, 11 December 2023.

Table 8. EU: Sum of PFAS drinking water guideline values from selected EU jurisdictions

Sum of PFAS value (type)	Long-chain PFCA/PFSAs	Short-chain PFCA/PFSAs	Ether PFAS	Fluorotelomers
EU				
100 ng/L	PFDA PFDoDA PFDoDS PFDS PFHpS PFHxS PFNA PFNS PFOA PFOS PFTrDA PFTrDS PFUnDA PFUnDS	PFBA PFBS PFHpA PFHxA PFPeA PFPeS	–	–
Italy				
100 ng/L	Same as the EU	Same as the EU	ADONA HFPO-DA (GenX) C6O4	6:2 FTS
Netherlands				
100 ng/L	Same as the EU	Same as the EU	–	–
4.4 ng/L PFOA equivalents (based on relative potency factors, see section 4.2.5)	PFDA PFDoDA PFDS PFHpS PFHxDA PFHxS PFNA PFOA PFODA PFOS PFTeDA PFTrDA PFUnDA	PFBA PFBS PFHpA PFHxA PFPeA PFPeS TFA	ADONA HFPO-DA (GenX)	6:2 FTOH 8:2 FTOH
Sweden				
100 ng/L	Same as the EU	Same as the EU	–	6:2 FTS
4 ng/L (PFAS-4)	PFHxS PFOS PFOA PFNA	–	–	–

Source: EU; Italy; Netherlands – RIVM guideline values; Netherlands – Drinking Water Decree; Sweden

4.2.6 United Kingdom

In the United Kingdom, regulation of drinking water quality is devolved to national governments.[214] The statutory water quality standards in each jurisdiction were originally derived from the EU standards that preceded introduction of the sum of PFAS and PFAS total parameters.[215] Scotland is the only UK government that has subsequently incorporated the EU's PFAS parameters into its own national law.[216]

4.2.6.1 Regulations in England and Wales

In England and Wales, there is no statutory PFAS limit, but water companies are subject to additional PFAS monitoring, reporting and risk assessment requirements specified in guidance from the Drinking Water Inspectorate.[217] Since 2021 water companies have been required to test and report on levels of 47 specified PFAS and undertake certain risk assessment actions based on the concentration of individual PFAS.[218] In 2024 the inspectorate indicated that from 2025 risk assessment actions would be evaluated against the sum of PFAS levels, rather than against individual PFAS levels (Table 9).[219] The 2024 guidance also specified an additional PFAS for reporting, 6:2 FTAB, which is an ingredient of certain firefighting foams.[220]

The guidance sets out a tiered approach to the actions required of water companies at different sum of PFAS levels. If a water company finds the sum of the levels of the 48 specified PFAS exceeds 100 ng/L (known as tier 3 levels) they are expected to implement emergency contingency measures to prevent consumers receiving the water exceeding the guidelines, along with a variety of other risk management measures.[221] For sum of PFAS levels between 10 ng/L and 100 ng/L (tier 2) water companies are also required to undertake various risk assessment and risk reduction measures,

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214 *The Public Water Supplies (Scotland) Regulations 2014* (Scot) SI 2014/364; *The Water Supply (Water Quality) Regulations (Northern Ireland) 2017* (NI) SR 2017/212; *The Water Supply (Water Quality) Regulations 2016* (UK) SI 32016/614; *The Water Supply (Water Quality) Regulations 2018* (Wales) SI 2018/647 (W. 121).

215 *Council Directive 98/83/EC of 3 November 1998 on the quality of water intended for human consumption* [1998] OJ L 330/32 (EU).

216 *The Public Water Supplies (Scotland) Amendment Regulations 2022* (Scot) SI 2022/387.

217 Drinking Water Inspectorate (DWI), *Guidance on the Water Supply (Water Quality) Regulations 2016 (as amended) for England and Water Supply (Water Quality) Regulations 2018 for Wales specific to PFAS (per- and polyfluoroalkyl substances) in drinking water*, version 1.1, UK Government, 2025.

218 DWI, *Information letter 05/20/21: Requirements for Poly and Perfluorinated Alkyl Substances (PFAS) monitoring by water companies in England and Wales*, 1 October 2021, archived 3 November 2021, accessed 7 April 2025; DWI, *Information Letter 03/2022: Risk assessments under regulation 27 and associated reports under regulation 28 of the Water Supply (Water Quality) Regulations 2016 (2018 in Wales) for Poly and Perfluorinated Alkyl Substances (PFAS)*, 7 July 2022, archived 31 May 2024, accessed 11 February 2025, p 6.

219 DWI, *Guidance on the Water Supply (Water Quality) Regulations 2016 (as amended) for England and Water Supply (Water Quality) Regulations 2018 for Wales specific to PFAS (per- and polyfluoroalkyl substances) in drinking water*, version 1.0, UK Government, 2024, archived 16 January 2025, accessed 4 April 2025.

220 6:2 FTAB has been reported in drinking water in the UK and Canada, T Teymoorian et al., PFAS contamination in tap water: Target and suspect screening of zwitterionic, cationic, and anionic species across Canada and beyond, *Environment International,* 2025, 195:109250, doi: 10.1016/j.envint.2025.109250; 6:2 FTAB has also been detected in a creek (not drinking water) near a waste management site in Melbourne, W Alghamdi et al., Release of per- and polyfluoroalkyl substances (PFAS) from a waste management facility fire to an urban creek, *Journal of Hazardous Materials Advances,* 2022, 8:100167, doi: 10.1016/j.hazadv.2022.100167.

221 DWI, *Guidance on the Water Supply (Water Quality) Regulations 2016 (as amended) for England and Water Supply (Water Quality) Regulations 2018 for Wales specific to PFAS (per- and polyfluoroalkyl substances) in drinking water*, version 1.1, UK Government, 2025, p 7.

including increased monitoring frequency.[222] At the lowest risk level (tier 1 – below 10 ng/L) water companies are still required to monitor quarterly to establish a baseline for risk assessment, and then may decrease their testing frequency to yearly.[223]

The inspectorate states that to establish its guidance on PFAS concentrations it considered the advice of the UK Health Security Agency and information available from various other nations and organisations.[224] However, no further details are provided on the basis on which the concentrations used to specify the tiers were chosen. The tier 3 value is described by the inspectorate as 'reasonably practicable to achieve'.[225]

Since October 2021 water companies have carried out over 1 million PFAS tests on water samples, providing a significant dataset for understanding local risks. In 2023, only one sample from over 47,000 tests of treated drinking water was found to exceed 100 ng/L.[226] However, 410 samples of treated drinking water were classified as tier 2. Graphs published by the inspectorate suggest the most common PFAS in tier 2 water samples were PFOS, PFHxS, PFecHS, PFPeA, PFHxA, PFOA and PFBA.[227]

4.2.6.2 Selection of PFAS for regulation

The inspectorate states that the original 47 PFAS for monitoring were chosen based on their known prevalence of use in England and Wales and were identical to the UK Environment Agency's monitoring program list.[228] The agency's list seems to have slightly changed since then and the inspectorate now describes its list as 'largely aligned' to the agency's.[229] 6:2 FTAB was added to the inspectorate's list after monitoring by water companies highlighted the chemical as of potential concern.[230]

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[222] DWI, *Guidance on the Water Supply (Water Quality) Regulations 2016 (as amended) for England and Water Supply (Water Quality) Regulations 2018 for Wales specific to PFAS (per- and polyfluoroalkyl substances) in drinking water*, version 1.1, UK Government, 2025, p 8.
[223] DWI, *Guidance on the Water Supply (Water Quality) Regulations 2016 (as amended) for England and Water Supply (Water Quality) Regulations 2018 for Wales specific to PFAS (per- and polyfluoroalkyl substances) in drinking water*, version 1.1, UK Government, 2025, p 8.
[224] DWI, *Guidance on the Water Supply (Water Quality) Regulations 2016 (as amended) for England and Water Supply (Water Quality) Regulations 2018 for Wales specific to PFAS (per- and polyfluoroalkyl substances) in drinking water*, version 1.1, UK Government, 2025, p 5.
[225] DWI, *Guidance on the Water Supply (Water Quality) Regulations 2016 (as amended) for England and Water Supply (Water Quality) Regulations 2018 for Wales specific to PFAS (per- and polyfluoroalkyl substances) in drinking water*, version 1.1, UK Government, 2025, p 5.
[226] DWI, *Drinking Water 2023 – Public supplies England*, UK Government, 2024, p 47–50.
[227] DWI, *Drinking Water 2023 – Public supplies England*, UK Government, 2024, p 49.
[228] DWI, Information letter 05/20/21: Requirements for Poly and Perfluorinated Alkyl Substances (PFAS) monitoring by water companies in England and Wales, 1 October 2021, archived 3 November 2021, accessed 7 April 2025.
[229] Drinking Water Inspectorate (DWI), *Guidance on the Water Supply (Water Quality) Regulations 2016 (as amended) for England and Water Supply (Water Quality) Regulations 2018 for Wales specific to PFAS (per- and polyfluoroalkyl substances) in drinking water*, version 1.1, UK Government, 2025, p 13; Environment Agency, *Poly- and perfluoroalkyl substances (PFAS): sources, pathways and environmental data*, 2021, UK Government, p 92-94.
[230] DWI, *Guidance on the Water Supply (Water Quality) Regulations 2016 (as amended) for England and Water Supply (Water Quality) Regulations 2018 for Wales specific to PFAS (per- and polyfluoroalkyl substances) in drinking water*, version 1.1, UK Government, 2025, p 13; the DWI has also stated that many water companies already test for 6:2 FTAB, DWI, *Drinking Water 2023 – Public supplies England*, UK Government, 2024, p 49.

Table 9. England and Wales: PFAS subject to the sum of PFAS risk assessment values

Value	Long-chain PFCA/PFSAs	Short-chain PFCA/PFSAs	Ether PFAS	Fluoro-telomers	Others
100 ng/L (tier 3)	PFDA PFDoDA PFDoDS PFDS PFECHS PFHpS PFHxDA PFHxS PFNA PFNS PFOA PFODA PFOS PFTeDA PFTrDA PFUnDA PFUnDS	PFBA PFBS PFHpA PFHxA PFPeA PFPeS	6:2 Cl-PFESA (F-53B) 8:2 Cl-PFESA (F-53B) ADONA HFPO-DA (GenX) HFPO-TA NFDHA PFEESA PFMBA PFMPA	3:3 FTCA 4:2 FTS 5:3 FTCA 6:2 FTS 6:2 FTAB 7:3 FTCA 8:2 FTS	FBSA NEtFOSAA NEtFOSE NMeFOSA NMeFOSAA NMeFOSE PFHxSA PFOSA Sulfluramid (NEtFOSA)

Source: Drinking Water Inspectorate

5. Case studies: Regulation of PFAS as a class

This section considers some of the attempts by overseas jurisdictions to regulate all PFAS as a class, via restrictions on their manufacture and use or via regulation of their concentration in drinking water.

5.1 Some jurisdictions are implementing restrictions on all PFAS as a class

A small number of jurisdictions have proposed or implemented bans on all PFAS as a class in the form of restrictions on either manufacture, import, use, sale, or placing on the market of PFAS or products containing intentionally added PFAS. These bans all include exemptions for certain applications.

5.1.1 PFAS restrictions in US states

Several US states have now banned or will ban all types of PFAS in certain applications. For example, California has banned the use of all PFAS in food packaging, juvenile products, cosmetics and textiles.[231] Washington, Vermont and Colorado have also implemented or will implement bans on PFAS in certain consumer products.[232]

Rather than banning PFAS in specific product classes, Maine and Minnesota have designed more general bans that apply to all products, with a wide variety of exemptions. For example, in Maine the sale of all products containing intentionally added PFAS will be prohibited from 2032, unless the use is designated a currently unavoidable use by the Maine Department of Environmental Protection.[233] Currently unavoidable uses have not yet been determined. Restrictions come into effect earlier than 2032 for certain products, such as carpets and fabric treatments (2023), cleaning, cookware and cosmetic products (2026) and artificial turf (2029). Refrigerants, foams and aerosol propellants would not be restricted until 2040. Certain categories of product are exempt, including firefighting foam, medical products, veterinary products, packaging, used products, motor vehicles, watercraft

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[231] Cal. Health & Safety Code § § 108946, 108981.5, 109000, 108971 (California); SA Bălan, Regulating PFAS as a Chemical Class under the California Safer Consumer Products Program, *Environmental Health Perspectives,* 2021, 129(2): CID: 025001, doi: 10.1289/EHP7431.

[232] Washington has prohibited or will prohibit PFAS in aftermarket stain and water resistant treatments, carpets and rugs, and leather and textile furniture and furnishings, WAC ch 173-337 (2023) (Washington); Washington Department of Ecology, *Chapter 173-337 WAC – Safer Products Restrictions and Reporting*, n.d., accessed 24 January 2025; Vermont will prohibit PFAS in cosmetic and menstrual products, 9 VSA §§ 2494a-2494c, aftermarket stain and water resistant treatments, artificial turf, cookware, incontinency protection products, juvenile products, rugs and carpets, ski wax, textiles, 9 VSA §§ 2494e-2494o, firefighting agents and equipment, 9 VSA §§ 2494p-2494v, and food packaging §§ 2494w-2494z, Vermont Department of Health, *PFAS Guidance for Manufacturers, Suppliers, and Distributors*, 2023; Colorado has prohibited PFAS in carpets and rugs, fabric treatments, food packaging, juvenile products, oil and gas products, cosmetics, indoor textile furnishings and upholstered furniture and will prohibit PFAS in cleaning products, cookware, dental floss, menstrual products, ski wax, outdoor furnishings and furniture, textile articles, outdoor apparel for severe wet conditions and food equipment in commercial settings, CRS §§ 25-16-601–25-15-605 (Colorado), Colorado Department of Public Health & Environment, *Colorado laws and policies related to chemicals from firefighting foam and other sources*, n.d. accessed 4 April 2025.

[233] Restrictions come into effect earlier for certain products, such as carpets and fabric treatments (2023), cleaning, cookware cosmetic products, dental floss, juvenile products, menstrual products, certain textile articles, ski wax, upholstered furniture (2026) and artificial turf (2029). Refrigerants, foams, aerosol propellants, heating, ventilation, air conditioning or refrigeration equipment would not be restricted until 2040. Certain categories of product are exempt, including firefighting foam, medical products, veterinary products, packaging, used products, motor vehicles, watercraft and semi-conductors, 38 MRSA §1614 (Maine); Maine Department of Environmental Protection, *PFAS in Products*, updated 14 February 2025, accessed 4 April 2025.

and semi-conductors. The ban was first enacted in 2021, but was amended in 2024 to extend timelines, provide exemptions and reduce reporting requirements.[234] Similar restrictions have been implemented in Minnesota, with some bans in effect in 2025 and the remainder to come into effect in 2032.[235]

The US states enacting these PFAS prohibitions have defined PFAS as all substances containing at least one fully fluorinated carbon atom.[236] This definition covers more pesticides and medicines than other definitions in regulatory use, including the OECD 2021 definition; for instance it covers almost all fluorinated drugs, including the high-cholesterol drug atorvastatin (Lipitor) and the antibiotic ciprofloxacin (Cipro).[237] Both Maine and Minnesota have legislated exemptions from the PFAS ban for products that are regulated by the US Food and Drug Administration, which would include fluorinated medicines.[238]

It is not yet known whether fluorinated pesticides will be designated as currently unavoidable uses in these jurisdictions and therefore exempted from the ban. In Minnesota, 95 pesticide active ingredients meet the state's definition of PFAS, but these only represent approximately 2% of pesticide active ingredient sales by weight.[239] A report by the Minnesota Department of Agriculture noted that, in contrast to most PFAS, approved pesticides have readily available data on toxicity, human exposure and product formulation due to the requirements of the US EPA's pesticide registration process.[240]

5.1.2 Proposed PFAS restriction in the EU

In 2023, Denmark, Germany, the Netherlands, Norway and Sweden submitted a proposal to the European Chemicals Agency (ECHA) to restrict all PFAS in the EU.[241] ECHA's scientific committees are currently evaluating the proposal, a process that will take until at least the second half of 2025.[242] The committees will then develop, consult on and adopt opinions for consideration by the European Commission.[243]

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[234] *An Act to Amend the Laws Relating to the Prevention of Perfluoroalkyl and Polyfluoroalkyl Substances Pollution*, Pub L 2023, 630 (Maine); K Cough, Maine's new PFAS law draws international objections, *The Maine Monitor,* 15 October 2023, accessed 17 January 2025; V Leigh, Maine lawmakers weigh consequences of new PFAs law, *News Center Maine,* 7 March 2024, accessed 17 January 2025; M Schauffler, Maine's law to reduce PFAS in products is off to a slow start, *The Maine Monitor,* 27 November 2022, accessed 17 January 2025; P Overton, Businesses seek changes in Maine's first-in-the-nation PFAS ban, *Portland Press Herald,* 29 January 2024, accessed 17 January 2025.

[235] *Amara's Law,* Minn Stat § 116.943 (Minnesota); MPCA, *PFAS use prohibitions*, n.d., accessed 17 January 2025.

[236] CRS § 25-5-1302 (Colorado); Cal. Health & Safety Code § 108945 (California); 38 MRSA § 1614.1 (Maine); Minn Stat § 116.943.1 (Minnesota); 9 VSA § 2494a (Vermont); WAC § 173-337-025 (Washington).

[237] E Hammel et al., Implications of PFAS definitions using fluorinated pharmaceuticals, *iScience*, 2022, 25(4):104020, doi: 10.1016/j.isci.2022.104020.

[238] 38 MRSA § 1614.4.E (Maine); Minn Stat § 116.943.8 (Minnesota)

[239] Minnesota Department of Agriculture, *PFAS in Pesticides: Interim Report to the Legislature*, 2024, p 1.

[240] Minnesota Department of Agriculture, *PFAS in Pesticides: Interim Report to the Legislature*, 2024, p 34.

[241] PFAS restriction dossier submitters, *Annex XV Restriction Report – Per- and polyfluoroalkyl substances*, version 2, 2023.

[242] ECHA, *Per- and polyfluoroalkyl substances (PFAS)* , n.d. accessed 24 March 2025; ECHA, *Progress update on the per- and polyfluoroalkyl substances - 20 November 2024*, 2024 p 1.

[243] ECHA, *Progress update on the per- and polyfluoroalkyl substances - 20 November 2024*, 2024 p 1; ECHA, *Scientific evaluation of the proposal to restrict per- and - polyfluoroalkyl substances (PFAS) – Current status March 2025*, 2025, p 1-2.

The proposal is to prohibit the manufacture, placing on the market and use of all PFAS, with temporary exemptions for a wide variety of largely industrial and professional uses, such as hydraulic systems for aircraft and textiles used in personal protective equipment. Firefighting foam is the subject of a separate PFAS restriction proposal.[244]

The consultation process for the initial restriction proposal prompted more than 5,000 submissions, many of them from fluoropolymer producers and users arguing for a fluoropolymer exemption.[245] ECHA subsequently announced that for some industries and applications it would be considering alternative options to a ban (such as conditions on use). It also noted that fluoropolymers were of 'high interest for stakeholders' and indicated alternative restriction options may be considered for this group.[246]

Because the OECD 2021 PFAS definition was the starting point of the definition used in the PFAS restriction proposal, some pesticides and pharmaceuticals would be considered PFAS under the plan.[247] The restriction proposal recommends a general exemption from the PFAS restrictions for active substances in certain otherwise regulated products, including pesticides and medicines. The proposal noted that the use of these substances is already regulated in the EU under extensive evaluation processes, but proposed these products should be subject to additional PFAS reporting requirements.[248]

5.1.3 Regulation of PFAS as a class in Canada

In 2021 the Canadian Government stated its intention to address PFAS as a class.[249] In 2023 and 2024 it consulted on a State of PFAS Report that concluded that the class of PFAS meets the criteria to be considered toxic under the *Canadian Environmental Protection Act 1999* (CEP Act), which would allow regulation of the entire class.[250] In March 2025 public consultation commenced on a proposed regulatory order that would add all PFAS except for fluoropolymers to the list of toxic substances under the CEP Act.[251] Consultation also started on a risk management approach that proposes 3 phases of restrictions:

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[244] ECHA, *Annex XV Restriction Report – Per- and polyfluoroalkyl substances in firefighting foams*, version 1, 2022; in 2023 ECHA's Risk Assessment Committee and Socio-economic Analysis Committee adopted opinions supporting the PFAS in firefighting foam restriction proposal, ECHA, *ECHA's committees: EU-wide PFAS ban in firefighting foams warranted*, 22 June 2023, accessed 4 April 2025.

[245] ECHA, *ECHA receives more than 5,600 comments on PFAS restriction proposal*, 26 September 2023, accessed 4 April 2025; ECHA, *Progress document*, 20 November 2024; Plastics Europe Fluoropolymer Product Group, *EU PFAS restriction*, n.d., accessed 7 January 2025; A Scott, The battle over PFAS in Europe, *Chemical & Engineering News*, 18 September 2023.

[246] ECHA, *Progress document*, 20 November 2024, p 2.

[247] PFAS restriction dossier submitters, *Annex XV Restriction Report – Per- and polyfluoroalkyl substances*, version 2, 2023, p 2; PFAS Restriction Proposal Dossier Submitters, *Annex A to the Annex XV Restriction Report - Per- and polyfluoroalkyl substances*, version 2, 2023, p 152–153.

[248] PFAS restriction dossier submitters, *Annex XV Restriction Report – Per- and polyfluoroalkyl substances*, version 2, 2023, p 4, 72-74.

[249] Notice of intent to address the broad class of per- and polyfluoroalkyl substances, *Canada Gazette,* pt 1, vol 155, no 17, 24 April 2021.

[250] Environment and Climate Change Canada, Health Canada, *Updated draft state of per- and polyfluoroalkyl substances (PFAS) report*, Government of Canada, 2024.

[251] Order Adding a Toxic Substance to Part 2 of Schedule 1 to the Canadian Environmental Protection Act, 1999, *Canada Gazette,* pt 1, vol 159, no 10, 8 March 2025; Environment and Climate Change Canada, Health Canada, *Risk management approach for per- and polyfluoroalkyl substances (PFAS), excluding fluoropolymers*, Government of Canada, 2025.

- Phase 1: Currently unregulated uses of PFAS in firefighting foams (2027)
- Phase 2: Uses of PFAS not needed for the protection of health, safety or the environment, such as cosmetics, non-prescription drugs, food packaging, paints, cleaning products, textiles and ski waxes (consultation to start following phase 1)
- Phase 3: Uses for which there may not currently be feasible alternatives and requiring further evaluation of the role of PFAS, such as fluorinated gases, prescription drugs, medical devices, industrial food contact materials, industrial sectors, transport and military applications (date to be determined).[252]

The PFAS definition used in the proposed order is the OECD's 2021 definition, with the exclusion of fluoropolymers.[253]

Fluoropolymers were excluded from the proposal after public consultation on the initial draft of the State of PFAS Report and are expected to be considered in a separate assessment.[254]

5.2 Regulating all PFAS in drinking water is not yet feasible

Attempting to regulate all PFAS in drinking water presents additional logistical complications compared to limiting emissions of PFAS through restrictions on use. As outlined in section 4.1, these challenges include the inability to measure environmental concentrations of all PFAS and a lack of data from which to derive a health-based limit that could cover all types of PFAS.

In addition, the cost of treating drinking water to remove PFAS can be high, and current treatment methods are not equally effective for all PFAS types.[255] Even the proponents of restricting all PFAS as a class have noted that precautionary regulatory decisions for drinking water guidelines can have profound impacts on costs, stating 'it may therefore be necessary, in resource-constrained settings, to more strictly prioritize cleanup levels on the basis of established toxicological risk.'[256]

The sections below introduce 2 examples of jurisdictions that have attempted or are attempting to set drinking water limits for PFAS as a class.

5.2.1 Vermont's consideration of deriving drinking water limits for PFAS as a class

In 2019 the Vermont General Assembly directed the Agency of Natural Resources to assess the feasibility of regulating PFAS as a class in public water systems.[257] In 2020, the agency concluded it

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[252] Environment and Climate Change Canada, Health Canada, *Risk management approach for per- and polyfluoroalkyl substances (PFAS), excluding fluoropolymers*, Government of Canada, 2025, p 27.
[253] Order Adding a Toxic Substance to Part 2 of Schedule 1 to the Canadian Environmental Protection Act, 1999, *Canada Gazette,* pt 1, vol 159, no 10, 8 March 2025.
[254] Environment and Climate Change Canada (ECCC), Health Canada, *Updated draft state of per- and polyfluoroalkyl substances (PFAS) report*, Government of Canada, 2024, p 14–15; ECCC, Health Canada, *Draft state of per- and polyfluoroalkyl substances (PFAS) report*, Government of Canada, 2024, p 81.
[255] M Scheurer et al., Small, mobile, persistent: Trifluoroacetate in the water cycle – Overlooked sources, pathways, and consequences for drinking water supply, *Water Research,* 2017, 126: 460–471, doi: 10.1016/j.watres.2017.09.045; F Li et al. Short-chain per- and polyfluoroalkyl substances in aquatic systems: Occurrence, impacts and treatment, *Chemical Engineering Journal,* 2020, 380: 122506, doi: 10.1016/j.cej.2019.122506.
[256] IT Cousins et al. Strategies for grouping per- and polyfluoroalkyl substances (PFAS) to protect human and environmental health, *Environmental Science: Processes & Impacts*, 2020, 22:1444-1460, doi:10.1039/D0EM00147C.
[257] *An act relating to the regulation of polyfluoroalkyl substances in drinking and surface waters,* Act 21, 2019 (Vermont).

was not currently feasible to derive a drinking water maximum contaminant level for PFAS as a class.[258] Challenges identified included a lack of toxicological information for different PFAS and insufficient analytical methods.[259]

5.2.2 EU's PFAS total parameter for drinking water

The EU's PFAS total drinking water parameter is intended to regulate the levels of all PFAS in drinking water. However, target PFAS analysis, which uses reference standards, cannot measure the levels of all PFAS types in a sample, so it is not clear how compliance with the parameter would be enforced. Options under consideration include certain PFAS analysis methods that are sometimes referred to as 'total PFAS methods'.

Total PFAS methods generally aim to measure PFAS not detected by target analysis methods.[260] They are usually used as screening methods or as complements to quantitative analytical methods.[261] For example, in Queensland a total PFAS method known as the total oxidisable precursor (TOP) assay is used as a method for demonstrating compliance with PFAS policies for firefighting foam, biosolids and composting operations.[262]

In 2024 the European Commission published a statutorily required technical guidance document for member states to use in implementing the sum of PFAS and PFAS total parameters.[263] The guidance recommends 3 proxy methods for estimating PFAS total but cautions that these methods are not standardised, which means there is not a standard procedure that is validated to ensure results will be reliable across different laboratories.[264] The 3 proxy methods are:

- **TOP assay**: The TOP assay is a total PFAS analysis method designed to estimate the amount or types of precursors present in a sample. The assay involves subjecting a sample to a chemical treatment that forces the conversion of otherwise undetectable precursors into PFCAs that can be analysed by target analysis methods. Not all PFAS can be converted to PFCAs, and those that can may not be completely converted, which means there is a high risk that the method will underestimate the true value of PFAS total.
- **EOF-CIC**: This method is a different type of total PFAS analysis that involves extracting compounds containing carbon and fluorine from a sample and then measuring the total

[258] Vermont Agency of Natural Resources, *Advance Notice on the Regulation of Perfluoroalkyl, Polyfluoroalkyl Substances (PFAS) as a Class*, Vermont Government, 2020; Vermont Agency of Natural Resources, *Notice of Decision Not To Adopt a Maximum Contaminant Level Regulating PFAS as a Class in Public Drinking Water Systems*, Vermont Government, 2021.
[259] Vermont Agency of Natural Resources, *State Seeks Additional Science Before Regulating PFAS as a Class in Public Drinking Water*, n.d., accessed 24 January 2025.
[260] HEPA, *PFAS National Environmental Management Plan version 3.0*, Australian, New Zealand and state and territory governments, 2025, p 179.
[261] HEPA, *PFAS National Environmental Management Plan version 3.0*, Australian, New Zealand and state and territory governments, 2025, p 184-188.
[262] Queensland Department of Environment and Science, *Operational Policy: Environmental Management of Firefighting Foam: October 2021*, Queensland Government, 2021; Department of Environment, Science and Innovation, *End of Waste Code for Biosolids*, Queensland Government, 2024; Department of Environment, Science and Innovation, *Monitoring and testing for PFAS in organic material processing (composting)*, Queensland Government, 2024.
[263] European Commission, *Commission Notice – Technical guidelines regarding methods of analysis for monitoring of per- and polyfluoroalkyl substances (PFAS) in water intended for human consumption* [2024] OJ C C/2024/4910.
[264] European Commission, *Commission Notice – Technical guidelines regarding methods of analysis for monitoring of per- and polyfluoroalkyl substances (PFAS) in water intended for human consumption* [2024] OJ C C/2024/4910, p 7–8.

fluorine present. Because this method is not specific to PFAS (other compounds contain carbon and fluorine), non-PFAS chemicals may cause exceedances of the PFAS total value.

- **LC-HRMS**: This non-target analysis method can detect a range of PFAS. Compared to target analysis using reference standards, this method is able to identify many more types of PFAS and is considered much more comprehensive. However, no method is able to identify every possible type of PFAS. LC-HRMS is a semi-quantitative method, which means it may provide general indications of the amount of some PFAS types, but it can't provide accurate quantitative data.

One complicating issue not addressed in the EU Drinking Water Directive is the high levels of TFA that may be present in drinking water. The European Commission's technical guidance document notes that TFA was not considered a PFAS at the time the DWD was adopted and states that the TFA concentration in water sources in Europe may significantly exceed the PFAS total limit for drinking water.[265] It notes that the recommended PFAS total analytical methods have not been fully validated for ultra-short-chain PFAS, and their performance can vary substantially with respect to TFA. The guidance document recommends separately measuring TFA concentrations alongside the PFAS total and then subtracting the TFA value from the PFAS total value.[266]

Instead of using the PFAS total parameter in their national legislation, EU member states can opt to instead use only the sum of PFAS parameter, for which standardised methods are readily available. Some member states, including Germany and the Netherlands, have chosen not to transpose the PFAS total parameter into their national law.[267]

[265] European Commission, *Commission Notice – Technical guidelines regarding methods of analysis for monitoring of per- and polyfluoroalkyl substances (PFAS) in water intended for human consumption* [2024] OJ C C/2024/4910, p 6–8.
[266] European Commission, *Commission Notice – Technical guidelines regarding methods of analysis for monitoring of per- and polyfluoroalkyl substances (PFAS) in water intended for human consumption* [2024] OJ C C/2024/4910, p 8.
[267] *Trinkwasserverordnung vom 20. Juni 2023* [Drinking Water Ordinance of 20 June 2023] BGBl. 2023 I Nr. 159 of 23 June 2023 (Germany); *Besluit van 23 mei 2011, houdende bepalingen inzake de productie en distributie van drinkwater en de organisatie van de openbare drinkwatervoorziening (Drinkwaterbesluit)* [Decree of 23 May 2011, containing provisions on the production and distribution of drinking water and the organisation of the public drinking water supply (Drinking Water Decree)] (Netherlands).

6. Appendix

6.1 Long-chain and short-chain PFCAs and PFSAs

Number of carbons	PFCAs	PFSAs	
12	PFDoDA	PFDoDS	Long-chain
11	PFUnDA	PFUnDS	
10	PFDA	PFDS	
9	PFNA	PFNS	
8	PFOA	PFOS	
7	PFHpA	PFHpS	
6	PFHxA	PFHxS	
5	PFPeA	PFPeS	Short chain
4	PFBA	PFBS	
3	PFPrA	PFPrS	
2	TFA	PFEthS	

6.2 Glossary

Term or abbreviation	Description
6:2 fluorotelomer substances	Fluorotelomer substances with 6 perfluorinated carbons. They can form the short-chain PFHxA during breakdown.
6:2 FTAB	A type of 6:2 fluorotelomer substance
6:2 FTS	A type of 6:2 fluorotelomer substance
8:2 fluorotelomer substances	Fluorotelomer substances with 8 perfluorinated carbons. They can form the long-chain PFOA during breakdown.
Additive toxicity	A type of toxicity in which the health effects of a mixture of chemicals are equial to the sum of the effects of the individual chemicals
ADONA	A type of ether PFAS
Bioaccumulation	Occurs when an organism absorbs a substance faster than it can be eliminated. A bioaccumulative substance will gradually accumulate inside an organism that ingests it.
C6O4	A type of ether PFAS
CEP Act	Canadian Environmental Protection Act 1999
CFCs	A type of refrigerant that is an ozone-depleting substance and regulated under the Montreal Protocol on Substances that Deplete the Ozone Layer
ECHA	European Chemicals Agency
EFSA	European Food Safety Authority
EOF-CIC	Extractable Organofluorine analysis by Combustion Ion Chomatography (a type of total PFAS analysis)

Term or abbreviation	Description
Ether PFAS	A group of PFAS types. Examples include GenX (HFPO-DA) and ADONA. Many ether PFAS have been used as substitutes for PFOA or PFOS.
F53B	A type of ether PFAS
Fluorinated	Contains one or more flourine
Fluorochemical	A fluorinated chemical substance
Fluoropolymers	A type of PFAS polymer. Solid plastics that are not typically considered to be precursors to non-polymeric PFAS.
Fluorotelomer substances	Also referred to as fluorotelomers. A large group of PFAS types manufactured using a process known as telomerisation. Key ingredient of certain firefighting foams and surface treatments. Degradation products can include PFCAs.
FSANZ	Food Standards Australia and New Zealand
GenX	A type of ether PFAS. GenX is the trade name for HFPO-DA in combination with its ammonium salt. A replacement for PFOA developed for use as a processing aid during the manufacture of certain fluoropolymers.
Guideline value	A concentration derived by a regulator to provide guidance on safe levels of a chemical in environmental media such as drinking water
Hazard index	A method for assessing the cumulative health risk from mixtures of chemicals. The hazard index calculated for a particular mixture has no units.
HBVs	Health-based Values. A non-statutory value set by the Minnesota Department of Health that represents the level of a contaminant that can be present in water and pose little or no health risk to humans who drink that water.
HBWC	Health-based water concentration. A statutory value set by the US EPA that is defined as the level below which adverse health effects are not likely to occur. The HBWC is used in the calculation of the hazard index of a mixture, for the purposes of determining compliance with the hazard index MCL.
HRLs	Health Risk Limits. A statutory groundwater value set by the Minnesota Department of Health that represents the level of a contaminant that can be present in water and pose little or no health risk to humans who drink that water
IChEMS	Industrial Chemicals Environmental Managment Standard. A chemicals managment framework established by the Australian Government.
LC-HRMS	Liquid Chromatography-High Resolution Mass Spectrometry (a method for comprehensive identification of PFAS present in a sample)

Term or abbreviation	Description
Long-chain	A description of certain types of PFCAs, PFSAs and their precursors. Long-chain PFCAs have 8 or more carbons and long-chain PFSAs have 6 or more carbons.
MCL	Maximum Contaminant Limit - a US national statutory limit on a particular contaminant in drinking water set by the US EPA
NHMRC	National Health and Medical Research Council
Non-polymers	Non-polymers are discrete molecules generally of a defined molecular weight.
OECD	Organisation for Economic Co-operation and Development
Persistence	The amount of time a chemical is likely to remain in the environment before it is broken down. A persistent chemical remains intact for a long period of time.
PFAS	Per and polyfluoroalkyl substances
PFAS Total	A parameter specified in the EU Drinking Water Directive that is defined as the totality of PFAS
PFBA	A short-chain PFCA with 4 carbons
PFBS	A short-chain PFSA with 4 carbons
PFCAs	A group of PFAS types that is among the most studied. Examples include PFOA, PFHxA, PFNA and PFBA. PFCAs can be long-chain or short-chain.
PFECHS	A long-chain PFSA with 8 carbons
PFHxA	A short-chain PFCA with 6 carbons. Can be formed during degradation of 6:2 fluorotelomer substances.
PFHxS	A long-chain PFSA with 6 carbons. Listed as a persistent organic pollutant under the Stockholm Convention.
PFOA	One of the first PFAS types to attract public and regulator concern about health effects of exposure. A long-chain PFCA with 8 carbons. Listed as a persistent organic pollutant under the Stockholm Convention.
PFOS	One of the first PFAS types to attract public and regulator concern about health effects of exposure. A long-chain PFSA with 8 carbons. Listed as a persistent organic pollutant under the Stockholm Convention.
PFPeA	A short-chain PFCA with 5 carbons
PFNA	A long-chain PFCA with 9 carbons
PFSAs	A group of PFAS types that is among the most studied. Examples include PFOS, PFHxS, and PFBS. PFSAs can be long-chain or short-chain.
Precursors	PFAS that can break down in the environment or within organisms to form other types of PFAS
Polymers	Polymers are large molecules composed of sequences of many repeating units connected together

Term or abbreviation	Description
Reference standard	Known quantity of a high-purity sample of a particular PFAS type, used in analysis of PFAS concentrations
Relative potency factor	Used in the Netherlands to convert concentrations of an individual PFAS into PFOA equivalents for the purposes of determining whether a mixture exceeds the sum of PFAS guideline value. For example, the relative potency factor of PFNA (a 9-carbon PFCA) is 10, which effectively means its concentration would be multiplied by 10 before being added to the total sum of PFAS.
Short-chain	A description applied to certain PFCAs, PFSAs and their precursors. Short-chain PFCAs have 7 or fewer carbons and short-chain PFSAs have 5 or more carbons.
Sulfluramid	An insecticide commonly used against leaf-cutter ants in South America. Degrades to produce PFOS.
Sum of PFAS	A parameter specified in the EU Drinking Water Directive that is the sum of the concentrations of each of 20 specified PFAS
Target analysis	PFAS analysis methods that can quantify the levels of selected PFAS by comparison to reference standards
Terminal degradation product	A PFAS type that does not further degrade
TFA	A short-chain PFCA with 2 carbons
TOP assay	Total oxidisable precursor assay – a type of total PFAS analysis
Total PFAS analysis	Methods that aim to measure PFAS not detected by target analysis
US EPA	United States Environmental Protection Agency

6.3 Chemical abbreviations

Abbreviation	Chemical name	CAS number
3:3 FTCA	3:3 Fluorotelomer carboxylic acid	356-02-5
4:2 FTS	4:2 Fluorotelomer sulfonic acid	757124-72-4
5:3 FTCA	2H,2H,3H,3H-Perfluorooctanoic acid	914637-49-3
6:2 Cl-PFESA (F-53B major)	Perfluoro(2-((6-chlorohexyl)oxy)ethanesulfonic acid)	756426-58-1
6:2 FTAB	6:2 Fluorotelomer sulfonamide betaine	34455-29-3
6:2 FTOH	Fluorotelomer alcohol 6:2	647-42-7
6:2 FTS	6:2 Fluorotelomer sulfonic acid	27619-97-2
7:3 FTCA	3-(Perfluoroheptyl)propanoic acid	812-70-4
8:2 Cl-PFESA (F-53B minor)	11-Chloroperfluoro-3-oxaundecanesulfonic acid	763051-92-9
8:2 FTOH	Fluorotelomer alcohol 8:2	678-39-7
8:2 FTS	8:2 Fluorotelomer sulfonic acid	39108-34-4
ADONA	4,8-Dioxa-3H-perfluorononanoic acid	919005-14-4

Abbreviation	Chemical name	CAS number
C6O4	Perfluoro(2-[5-methoxy-1,3-dioxolan-4-yloxy]acetic acid)	1190931-41-9
CFCs	Chlorofluorocarbons	-
FBSA	Perfluorobutanesulfonamide	30334-69-1
GenX	The trade name for HFPO-DA and its ammonium salt	-
HFPO-DA (GenX)	Perfluoro-2-methyl-3-oxahexanoic acid	13252-13-6
HFPO-TA	Perfluoro-2,5-dimethyl-3,6-dioxanonanoic acid	13252-14-7
NEtFOSAA	2-(N-Ethylperfluorooctanesulfonamido)acetic acid	2991-50-6
NEtFOSE	N-Ethyl-N-(2-hydroxyethyl)perfluorooctane sulfonamide	1691-99-2
NFDHA	Perfluoro-3,6-dioxaheptanoic acid	151772-58-6
NMeFOSA	N-Methylperfluorooctanesulfonamide	31506-32-8
NMeFOSAA	2-(N-Methylperfluorooctanesulfonamido)acetic acid	2355-31-9
NMeFOSE	N-Methyl-N-(2-hydroxyethyl)perfluorooctanesulfonamide	24448-09-7
PFAS	Per and polyfluoroalkyl substances	-
PFBA	Perfluorobutanoic acid	375-22-4
PFBS	Perfluorobutanesulfonic acid	375-73-5
PFCAs	Perfluorocarboxylic acids	-
PFDA	Perfluorodecanoic acid	335-76-2
PFDoDA	Perfluorododecanoic acid	307-55-1
PFDoDS	Perfluorododecanesulfonic acid	79780-39-5
PFDS	Perfluorodecanesulfonic acid	335-77-3
PFECHS	Perfluoro-p-ethylcyclohexylsulfonic acid	646-83-3
PFEESA	Perfluoro-2-ethoxyethanesulfonic acid	113507-82-7
PFHpA	Perfluoroheptanoic acid	375-85-9
PFHpS	Perfluoroheptanesulfonic acid	375-92-8
PFHxA	Perfluorohexanoic acid	307-24-4
PFHxDA	Perfluorohexadecanoic acid	67905-19-5
PFHxS	Perfluorohexanesulfonic acid	355-46-4
PFHxSA	Perfluorohexanesulfonamide	41997-13-1
PFMBA	Perfluoro(4-methoxybutanoic acid)	863090-89-5
PFMPA	Perfluoro-3-methoxypropanoic acid	377-73-1
PFNA	Perfluorononanoic acid	375-95-1
PFNS	Perfluorononanesulfonic acid	68259-12-1

Abbreviation	Chemical name	CAS number
PFOA	Perfluorooctanoic acid	335-67-1
PFODA	Perfluorooctadecanoic acid	16517-11-6
PFOS	Perfluorooctanesulfonic acid	1763-23-1
PFOSA	Perfluorooctanesulfonamide	754-91-6
PFPeA	Perfluoropentanoic acid	2706-90-3
PFPeS	Perfluoropentanesulfonic acid	2706-91-4
PFSAs	Perfluorosulfonic acids	-
PFTeDA	Perfluorotetradecanoic acid	376-06-7
PFTrDA	Perfluorotridecanoic acid	72629-94-8
PFTrDS	Perfluorotridecanesulfonic acid	791563-89-8
PFUnDA	Perfluoroundecanoic acid	2058-94-8
PFUnDS	Perfluoroundecanesulfonic acid	749786-16-1
Sulfluramid (NEtFOSA)	N-Ethylperfluorooctane sulfonamide	4151-50-2
TFA	Trifluoroacetic acid	76-05-1

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The Parliament of New South Wales acknowledges and respects the traditional lands of all Aboriginal people and pays respects to all Elders past and present. We acknowledge the Gadigal people as the traditional custodians of the land on which the Parliament of New South Wales stands.

This image comes from 'Our Colours of Country', which was created for the Parliament of NSW by Wallula Bethell (Munro) a Gumbaynggirr/Gamilaroi artist born and raised in Tamworth who has spent time living on Dunghutti Country and is currently living in Western Sydney on Darug Country with her husband and son.