THE CHANGING LANDSCAPE OF "FOREVER CHEMICALS": AN UPDATE ON GLOBAL PFAS REGULATIONS AND MANAGEMENT STRATEGIES

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ABSTRACT

The past 12 months have seen a flurry of new regulations, research, occurrence data, and management strategies around per- and polyfluoroalkyl substances (PFAS), both in New Zealand and abroad. These ubiquitous so-called "forever chemicals" pose concerns for management across the water industry and beyond, and regulators have wrestled with the most appropriate way to address production, use, disposal, and public exposure to PFAS. This challenge is made more complex by the existence of thousands of different PFAS, and the numerous associated health impacts, spanning cancer, liver, kidney, fertility, and developmental impacts, asthma, thyroid disease, and reduced vaccine response.

While recent research and monitoring efforts are providing an expanding evidence base, regulators are confronted with the need to act in the short-term and face significant challenges in obtaining and assessing scientific information to support the development of suitable regulations. Regulatory approaches have therefore differed widely, with recent developments across Canada, the United States, and England highlighting the variability.

In February 2023, Health Canada issued draft drinking water guidance limiting the sum of 18 or more PFAS to 30 ng/L. In contrast, the following month the United States Environmental Protection Agency (USEPA)'s proposed drinking water regulations encompassed six PFAS, with four compounds proposed to be regulated via a grouped "hazard index," combining the risk posed by compounds with different health endpoints. This also proposes maximum contaminant levels (MCLs) of 4 ng/L each for PFOS and PFOA, levels dramatically lower than current values issued by USEPA or by individual states. Additional 2023 draft PFAS regulations for the management of PFAS-containing media and treatment plant residuals (under US CERCLA legislation) could impact all facets of water production and wastewater management.

New Zealand's Drinking Water Standards (2022) include a combined maximum allowable value (MAV) for perfluorohexane sulfonate (PFHxS) and PFOS at 70 ng/L, and a separate MAV of 560 ng/L for PFOA. While there is no PFAS

manufacturing in New Zealand, recent studies have corroborated the presence of PFAS in New Zealand's urban waters (Lenka et al, 2022).

In England, although there is limited PFAS manufacturing, monitoring indicates widespread presence of PFAS in the English environment, including "intermediates" (e.g., 6:2 fluorotelomer sulfonate). The publication of the Health and Safety Executive Risk Management Options Analysis (RMOA) for PFAS has been described as a "step change" for the UK, with proposals for future management of PFAS, including restrictions on use. The RMOA further marks the divergence of UK regulation from the European Union – where progress is being made towards restrictions on the use of all PFAS, alongside proposals for new surface water and groundwater environmental quality standards, as well as new drinking water standards.

2023 has been a landmark year, moving the deliberations around PFAS regulations in both the drinking water and environmental contexts. Amidst the shifting of the global regulatory landscape, this paper will provide an overview of the state-of-the-science surrounding PFAS and a roundup of worldwide approaches to compliance, with a focus on their potential implications for water utilities in New Zealand.

KEYWORDS

PFAS, emerging contaminants, global trends, regulation, waste management

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1. INTRODUCTION

A class of more than 10,000 anthropogenic chemicals, per- and polyfluoroalkyl substances (PFAS) are ubiquitous in household and industrial use (European Chemicals Agency – ECHA, 2023). Their use in textiles, fire suppression foams, food and other packaging, lubricants, cosmetics and personal care products, refrigerants and electronics, as well as construction materials has led to extensive manufacturing, while their persistence and mobility have led to global proliferation in surface, ground, and coastal waters (Lenka et al. 2022).

Referred to as "forever chemicals," PFAS are defined by the incredibly stable carbon-fluorine bond, with each compound having at least one hydrophobic fluoroalkyl moiety. Depending on the number of carbon atoms included in the molecule backbone, they are often described as "long-chain" (> 7 carbons), "short chain" (4 to 6 carbons), or "ultrashort-chain" (< 4 carbons).

Perfluorooctanesulfonic acid (PFOS) and perfluorooctanoic acid (PFOA), both 8-carbon long-chain compounds, have been among the most prolifically used and studied PFAS compounds. Given health concerns, manufacturing of these compounds in the western hemisphere has ceased, and replacement PFAS chemicals have taken their place. However, concerns regarding the toxicity, human health, and environmental impacts of PFAS, including the replacements, have prompted increasing global regulation on the manufacturing, sale, and use of PFAS-containing products, as well as on allowable concentrations in drinking water and any potential waste discharge streams.

Since 2009, PFOS has been included in the Stockholm Convention on persistent organic pollutants, restricting their use in the European Union (EU), with additional exemptions removed in 2020, while PFOA was added to the Stockholm Convention in 2019, and banned in the EU in 2020. Addition of a third PFAS compound to the Stockholm Convention, perfluorohexane sulfonic acid (PFHxS) took place in 2022 and formal EU restriction is planned in 2023. Restrictions of these long-chain compounds have led to increased production and use of alternative shorter-chain PFAS compounds, with research into their occurrence, mobility, and fate ongoing.

Regulators have wrestled with the most appropriate way to address the risks posed by PFAS, a challenge made more complex by the existence of thousands of different PFAS, and the numerous associated health impacts, spanning cancer, liver, kidney, fertility, and developmental impacts, asthma, thyroid disease, and reduced vaccine response (USEPA, 2023). PFAS pose significant challenges for drinking water and wastewater utilities, who must monitor and potentially treat water contaminated with PFAS, as well as manage the potential for PFAS accumulation in sludge or residuals waste streams. To further complicate the challenge of PFAS, they are generally extremely recalcitrant to oxidation and other traditional water and wastewater treatment approaches to treatment of chemical contamination.

The challenge to water and wastewater regulators is similarly complex: the decision of what compounds to regulate and to what extent is informed by a range of factors including:

- The existence of a scientific basis on which to establish human health and environmental impacts and from which to estimate exposure limits
- An understanding of the available analytical and monitoring methods and the ability to measure or detect the compounds to be regulated
- A review of the available treatment technologies to allow water and wastewater utilities to meet the regulations

Recent research and monitoring efforts are providing an expanding evidence base, with peer reviewed literature of PFAS rapidly expanding, as shown in Figure 1. However, regulators confronted with the need to act in the short-term face significant challenges in obtaining and assessing scientific information to support the development of suitable regulations. Regulatory approaches have therefore differed widely, with recent developments across Canada, the United States, and England highlighting the variability.

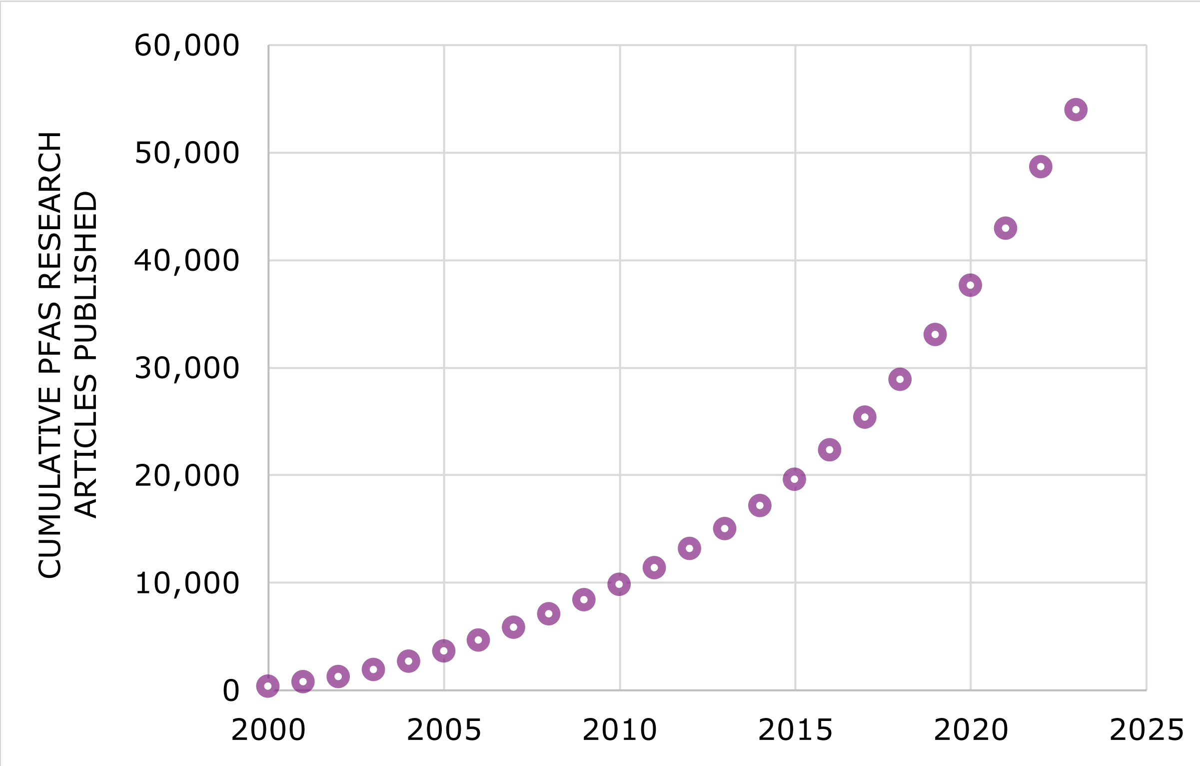

Figure 1: Cumulative research articles published since 2000, per the Science Direct repository of scientific, technical, and medical research (keyword: PFAS)

2. GLOBAL REGULATORY UPDATES

UNITED STATES

Several States have promulgated numerical limits, published non-enforceable guidance values, or proposed regulations for PFAS in drinking water, consumer products, residuals disposal, and waste discharges.

For example, the State of Maine has a combined limit of 20 ng/L for six PFAS in drinking water:

- PFOS
- PFOA
- Perfluorononanoic acid (PFNA, C9, long-chain)
- Perfluorohexanesulfonic acid (PFHxS, C6, short-chain)
- Perfluoroheptanoic acid (PFHpA, C7, long-chain)
- Perfluorodecanoic acid (PFDA, C10, long-chain)

Maine further requires sludge to be tested for PFAS, and as a result of PFAS contamination found in sludge previously used as a fertilizer, in 2022 Maine banned the land application of sludge and sludge-derived product. The State made history in 2021, becoming the first to ban PFAS in all products sold in Maine by 2030. As of January 2023, the State of Maine has also prohibited the sale of carpets, rugs, or fabric treatments, that contain intentionally added PFAS.

In parallel to State-based regulations, several Federal actions to manage the risks of PFAS contamination are also in place in the United States, under a range of legislation, including:

- The Safe Drinking Water Act (SDWA)
- The Toxic Substances Control Act (TSCA)
- The Emergency Planning and Community Right-to-Know Act (EPCRA)
- The Clean Water Act (CWA)
- The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, also referred to as "Superfund")

These Federal actions and associated legislation are outlined in Figure 2.

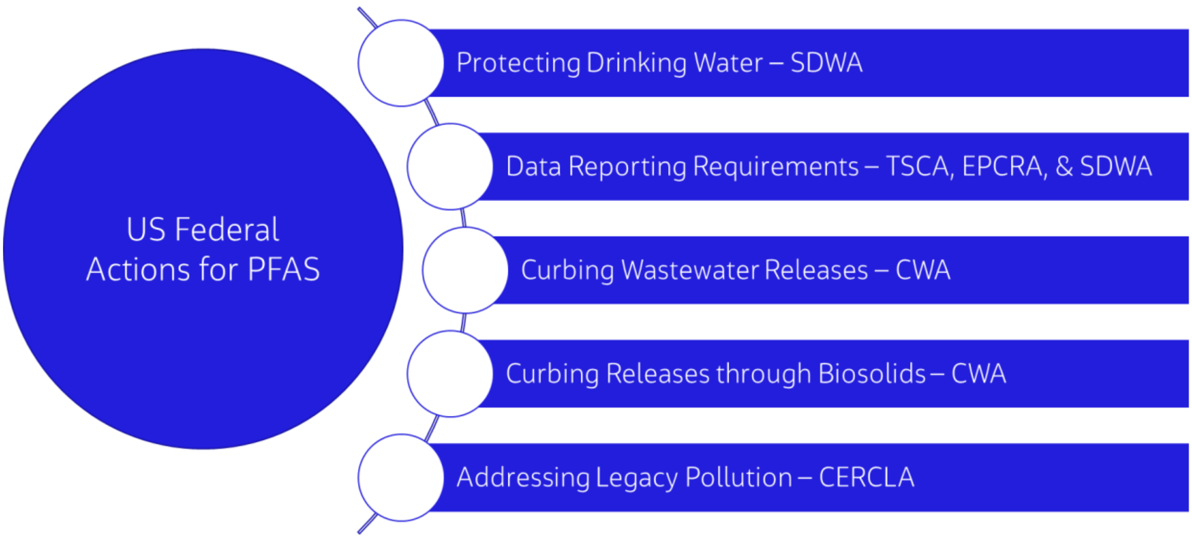

Figure 2: Overview of US Federal Actions for PFAS (Courtesy of Chris Moody, American Water Works Association)

PROPOSED PFAS NATIONAL PRIMARY DRINKING WATER REGULATION

March 2023 saw the release of the United States Environmental Protection Agency (USEPA)'s proposed federal drinking water regulations, which set out proposed drinking water standards, as well as outlining what is currently best available treatment, initial monitoring requirements, compliance monitoring and "right to know" requirements.

The proposed standards encompass six PFAS:

- PFOS
- PFOA
- PFNA
- PFHxS
- Perfluorobutane sulfonate (PFBS, C4, short-chain)
- Hexafluoropropylene oxide-dimer acid (HFPO-DA, a short-chain perfluoroalkyl ether carboxylic acid, commonly referred to as GenX)

Notably, these are not the same six chemicals included in the Maine standard noted above. Table 1 outlines the proposed regulatory limits, which are markedly lower than previous State-set limits throughout the US, or the current USEPA Health Advisory levels.

Table 1: USEPA Proposed PFAS National Primary Drinking Water Regulation and Associated Health Effects of PFAS Compounds

COMPOUND	***PROPOSED NON-ENFORCEABLE MAXIMUM CONTAMINANT LEVEL GOALS (MCLG)***	***PROPOSED ENFORCEABLE MAXIMUM CONTAMINANT LEVELS (MCL)***	***HEALTH EFFECT EVALUATED***
PFOA	Zero	4.0 ng/L	Cancer
PFOS	Zero	4.0 ng/L	Cancer
PFNA	1.0 (unitless) Hazard Index	1.0 (unitless) Hazard Index	Thyroid effects
PFHxS			Developmental effects
PFBS			Liver effects
HFPO-DA (GenX)			Thyroid effects

Four compounds are proposed to be regulated via a grouped "hazard index" (HI), as follows:

$$Hazard\ Index\ (HI) = \frac{[PFHxS]}{9\ ng/L} + \frac{[PFNA]}{10\ ng/L} + \frac{[GenX]}{10\ ng/L} + \frac{[PFBS]}{2{,}000\ ng/L}$$

The HI calculation is based on each compound's individual Health Based Water Concentration, defined as the levels of contaminant at which no adverse health effects are expected to occur for sensitive populations over a lifetime of exposure, with a margin of safety. Faced with the challenge of regulating compounds with different health endpoints which may occur as mixtures, the USEPA has proposed the use of the HI as a tool to evaluate the risks of simultaneous exposure, and is considering feedback on this approach as part of the public consultation phase.

The proposed maximum contaminant levels (MCLs) represent a significant departure from previous Federal guidance. The 2016 USEPA drinking water Health Advisory level was set at 70 ng/L for the combined concentrations of PFOS and PFOA, while new Health Advisory levels announced in 2022 set interim levels of 0.020 ng/L and 0.004 ng/L for PFOS and PFOA, as well as establishing Heath Advisory levels of 10 ng/L and 2,000 ng/L for GenX and PFBS, respectively.

The comment period for the proposed regulation saw significant engagement from the drinking water industry and other interested parties, with comments both in support and in criticism. Approximately 120,000 comments were received, including a 54-page detailed letter from the American Water Works Association, and comments from the Attorneys General of 17 States. Publication of the final regulation is targeted in 2024, with a statutory deadline to publish the final regulation by September 2024, and an estimated compliance date of October 2027 (three years after final rule publication. There are also provisions for an additional two-year extension to be requested).

UNREGULATED CONTAMINANT MONITORING RULE 5

EPA initiated UCMR5 in 2022, which includes requiring water utilities to sample finished water for PFAS using both USEPA Methods 537.1 and 533. The sampling program will continue through 2026 with results published thereafter.

Given that the previous PFAS data collected under UCMR3 contained a more limited number of analytes and the associated detected limits were elevated compared to today's standards, entities like AWWA have requested that USEPA hold off on final MCL rulemaking until the UCMR5 data are complete.

PROPOSED PFAS HAZARDOUS SUBSTANCES CLASSIFICATION

The US EPA has proposed to classify seven PFAS and their related salts as hazardous substances under CERCLA. This approach would allow the EPA to hold parties responsible for the cleanup (or cleanup costs) associated with remediation of a contaminated site. However, there is currently a proposed bill in the US Congress that would provide “CERCLA” exemption for water and wastewater utilities with respect to PFAS, if they are meeting all applicable laws and standards for treatment and residuals management.

CANADA

Individual Provinces within Canada set their own enforceable regulatory levels for both drinking water and wastewater discharge.

In February 2023, Health Canada issued draft drinking water guidance limiting the sum of total PFAS concentrations to 30 ng/L, based on a method that considers a minimum of 18 PFAS compounds.

One or both of two US EPA Methods (Method 533 or Method 537.1) may be used to measure the total PFAS concentration, or a separate method with a minimum of 18 analytes may be developed to comply with the guideline. The potential methods noted in the proposed guideline are outlined in in Table 2, with further detail provided in Section 4, as part of the Regulatory Overview. Interestingly, while these methods have 13 analytes in common, they do not have complete overlap; the use of both methods would screen concentrations of 30 different compounds. Different analytical approaches could therefore lead to the same sample being reported as within the guidelines, or exceeding them.

Table 2: Overview of USEPA Methods 533 and 537.1, as referenced in the Health Canada draft drinking water guidance

	USEPA METHOD 537.1	***USEPA METHOD 533***
METHOD OVERVIEW	Solid phase extraction and liquid chromatography/ tandem mass spectrometry	Isotope dilution anion exchange solid phase extraction and liquid chromatography/ tandem mass spectrometry
LOWEST CONCENTRATION MINIMUM REPORTING LIMITS (LCMRL) (ng/L)	Dependent on the laboratory. Single-laboratory results range from 0.53 – 6.3 ng/L dependent on the analyte	Dependent on the laboratory. Single-laboratory results range from 1.4 – 16 ng/L dependent on the analyte
ANALYTES	18 PFAS compounds	25 PFAS compounds

The draft guideline level would replace the existing 2018 guidelines for PFOS and PFOA currently set at 600 and 200 ng/L, respectively, and the 2019 screening values for 9 additional PFAS: PFHxA, PFNA, PFBS, perfluorobutanoate (PFBA), perfluoropentanoate (PFPeA), perfluorohexanoate (PFHxA), perfluoroheptanoate (PFHpA), 6:2 fluorotelomer sulfonate (6:2 FTS) and 8:2 fluorotelomer sulfonate (8:2 FTS), which ranged from 20 ng/L for PFNA to 30,000 ng/L for PFBA.

As in the United States, the proposed guidelines represent a significant reduction from the previous guidance. The comment period for the proposed guidance saw significant engagement and is now closed as of April 2023, with the finalised guideline under development.

EUROPE

In Europe, chemicals including PFAS are regulated under REACH (Registration, Evaluation, Authorisation and Restriction of Chemicals). Producer companies have to demonstrate to the European Chemicals Agency (ECHA) that substances can be safely used, and if the risks cannot be managed, authorities can restrict or ban their use. Over the years, various assessments have been undertaken and restrictions introduced for certain PFAS or groups of PFAS, however these restrictions have not been effective at limiting substitution with other PFAS which may also be hazardous. ECHA are currently considering two proposals for universal restriction of PFAS – firstly a restriction on all PFAS in firefighting foams, and secondly a universal restriction on all PFAS use. Without the universal restriction, it is estimated that around 4.4 million tonnes of PFASs would end up in the environment over the next 30 years. The proposal is currently under consultation, and adoption of the universal restriction proposal is anticipated in 2025.

PFAS in drinking water is regulated under the European Union Drinking Water Directive which was recast in 2019 and includes a 500 ng/L limit for "Total PFAS" and a 100 ng/l limit for "Sum of PFAS" which encompasses a subset of 20 PFAS (details provided in Section 4). Article 13(7) of the Directive notes that by January 2024, the Commission will establish technical guidelines on monitoring and analysis for "Total PFAS" including detection limits and frequency of sampling. The revised Directive was adopted by the European Parliament and entered into force in early 2021 and is being implemented by member states through national regulation.

The EU Water Framework Directive sets environmental quality standards (EQS) for surface water quality, which must be met in order to achieve 'good' chemical status. Currently there is only an EQS for PFOS, with an annual average (AA) EQS for inland surface waters set at 0.65 ng/l. In October 2022, the European Commission published a proposal amending Water Directives including proposed new EQS for PFAS. This includes new quality standards harmonised for groundwater quality and for surface water. The proposed new standard is 4.4 ng/l 'sum of PFOA equivalents' for 24 PFAS, using relative potency factors to facilitate the risk assessment of the mixture. The 24 PFAS included in the standard include PFCAs, PFSAs, 6:2 FTOH, 8:2 FTOH, ADONA, GEN-X and C604. Relative potency factors range from 10 (for PFNA) to 0.001 (for PFBS). It is interesting to note that this PFAS list includes some PFAS not included in the drinking water regulations summarized in Section 4.

UNITED KINGDOM

The approach to PFAS regulation and management is developing along several fronts in the United Kingdom having diverged from Europe with departure from the EU.

In England and Wales, PFAS in the water supply is currently being addressed through guidance to the water companies, while in Scotland the devolved government have set drinking water standards. Meanwhile work is underway by the UK government to examine the risks posed by PFAS including the development of a 'Regulatory Management Options Analysis' (RMOA), setting out further options for managing the risks of PFAS chemicals, under the UK REACH program, published in April 2023.

The 2023 RMOA collected and analysed information on the intrinsic hazards, uses and routes of exposure to PFAS, as well as considering relevant domestic legislation and international approaches to the management of PFAS. The RMOA recognises that toxicological data-gaps exist for all PFAS groups, with uncertainty on the human health hazards of the majority of PFAS due to a lack of available data and limited understanding of long-term exposure. It identifies a clear primary concern to the environment, driven by the extreme persistence of PFAS, and concludes that, considering the precautionary principle, it would be appropriate to initiate certain risk management measures. This includes actions to support the restriction of PFAS under UK REACH including the use and disposal of fire-fighting foams where non-PFAS alternatives are available, restriction on wide dispersive uses, and the placing on the market of consumer articles from which PFAS are likely to be released. Other recommendations include the development of statutory standards for PFAS in drinking water in England and Wales. The document marks the clear divergence of UK regulation from the European Union.

While there are no current statutory standards for PFAS in drinking water in England, the Drinking Water Inspectorate (DWI) has produced guidance to water companies for PFAS risk assessment and monitoring, with risk-based escalating tiers and actions which should be taken if monitoring results exceed specified concentrations. This approach provides a framework for action to be taken to mitigate against unwholesome water supply, while allowing the development of an evidence base for PFAS occurrence in drinking water supply, prior to development of legal drinking water standards in England and Wales. Water suppliers are required to undertake risk assessments and undertake regular monitoring of the raw water supply. They are advised to consult with local health professionals if concentrations of any PFAS are above 10 ng/L; if the concentrations of any PFAS in the raw water supply are above 100 ng/l they are required to take action to reduce the concentrations in the treated water supply to below that threshold, for example by blending. The thresholds apply to any PFAS, with a minimum required monitoring suite of 47 PFAS (details are provided in Section 4).

The DWI has published summary results for the first year of monitoring under this guidance (DWI, 2023). During 2022, the water industry in England submitted around 310,700 test results (including multiple parameters per sampling point, multiple locations along a supply, and repeat monitoring). PFAS were detected in 11,853 or 3.8% of the test results. Of the 47 substances which required testing, 35 were detected, and 14 were detected at least once in the raw water above 100 ng/l. PFAS detected above 100 ng/l included PFCAs, PFSAs, 6:2 FTS and sulfonamides. PFAS above 100 ng/l were reported from seven individual water supply sites.

In Scotland, the Drinking Water Quality Regulator (DWQR) has taken a grouped approach to PFAS regulation, with a 100 ng/L limit for the sum of 20 PFAS (details are provided in Section 4, as part of the Regulatory Overview).

3. NEW ZEALAND CONTEXT

New Zealand has no history of PFAS manufacturing; however the lack of onshore manufacturing has not arrested their environmental proliferation. PFAS are ubiquitous in household and industrial products. Wastewater effluent, septic systems, "peripheral industries," and airports or users of aqueous film forming foams (AFFF) are all potential historical or ongoing sources of PFAS. Long-chain PFAS were present in AFFF used for several years in New Zealand and it's been noted that complete management of AFFFs containing alternate PFAS is yet to be accomplished (Lenka et al., 2022).

Use of PFOS in firefighting foams was banned in 2006, and the use of PFOS was subsequently banned entirely in 2011 per the ratified Stockholm Convention restrictions. Considerations of further restrictions appear to be ongoing, with a New Zealand's Environmental Protection Authority (NZEPA) proposal to restrict PFHxS as a persistent organic pollutant released in February 2023, and a proposed ban on PFAS in cosmetics proposed in the March 2023 update of the Cosmetic Products Group Standard.

Lenka et al. (2022) investigated the occurrence of 38 PFAS and precursor compounds in New Zealand, and found that, of those they investigated, 20 different PFAS are in circulation in the urban water system. PFAS were detected in both wastewater effluent (up to 13 ng/L, long-, short-, and ultrashort-chain, and the 'intermediate' fluorotelomer 6:2 FTS) and drinking water sources, though concentrations of regulated PFOS + PFHxS and PFOA were well below the 2022 Taumata Arowai Drinking Water Standards (70 and 560 ng/L) and recreational water quality guidelines (2,000 and 10,000 ng/L) (ESR, 2021).

4. DRINKING WATER REGULATORY OVERVIEW

Appendix A provides an overview of the current and proposed drinking water PFAS regulations and guidelines discussed in this paper.

5. REGULATORY TRENDS AND CONCLUSIONS

While numerous regulatory updates have been proposed recently, 2023 has been a landmark year, moving the deliberations around PFAS regulations in the manufacturing, environmental and drinking water contexts. Amidst the shifting of the global regulatory landscape, trends are emerging towards restricted manufacturing, sale and use of PFAS products, as in the European Union, United States and United Kingdom.

An expanding body of research is being developed, with more information needed to understand the impacts of different PFAS compounds on humans and the environment. Increased tracking and monitoring of PFAS sources, and increased environmental and drinking water sampling is underway across the different jurisdictions discussed, to establish a better understanding of current PFAS proliferation. A trend towards a grouped approach to PFAS risk management is visible in recent drinking water regulations, transcending different potential health impacts and toxicological study endpoints, and in some cases referencing the precautionary principle to consider PFAS as a grouped class rather than focusing on individual compounds.

Existing and potential new restrictions on the disposal of sludge and residual streams containing PFAS raise questions about our ability to interrupt the cycle of PFAS proliferation. These questions can impact wastewater nutrient recovery and water reuse prospects, challenging our circular economy and one-water industry goals.

Overall, engagement on the topic of PFAS is high, with abundant media coverage and significant commentary provided from both public and private sectors on newly proposed regulations. While 2023 has seen many proposals put forward, we eagerly await to see the outcomes of the feedback and review period, with 2024 slated to provide yet more developments in the world of PFAS.

APPENDIX A - OVERVIEW OF SELECTED CURRENT AND PROPOSED GLOBAL DRINKING WATER PFAS REGULATIONS AND GUIDELINES

Table A-1: Overview of Selected Current and Proposed Global Drinking Water PFAS Regulations and Guidelines

	Regulator / Advisory Body	***Taumata Arowai***	***England Drinking Water Inspectorate***	***Scotland Drinking Water Quality Regulator***	***European Drinking Water Directive***	***US EPA***			***Health Canada***				
	Year	***2022***	***2021***	***2022***	***2021***	***2023***		***2022***	***2023***			***2018 - 2019***	
	Overview	*3 PFAS regulations, 1 individual at 560 ng/L and 2 combined at 70 ng/L*	*47 individual PFAS guidelines, all at 100 ng/L*	*100 ng/L limit for the sum of 20 PFAS*	*100 ng/L limit for the sum of 20 PFAS*	*6 PFAS regulations (proposed), 2 individually at 4 ng/L and 4 combined based on a Health Index with contributions from 9 to 2,000 ng/L*		*4 individual PFAS guidelines, ranging from 4 to 2,000 ng/L*	*30 ng/L guideline for the sum of 18 - 30 PFAS (depending on the method selected)*			*11 individual PFAS guidelines or screening values, ranging from 20 to 30,000 ng/L*	
PFAS Compound	***Acronym***	***Current Drinking Water Standards (ng/L)***	***Current Drinking Water Guideline (ng/L)***	***Current Drinking Water Standards (ng/L)***	***Current Drinking Water Standards (ng/L)***	***Proposed Maximum Contaminant Level (ng/L)***	***Health Index Calculation***	***Current Health Advisory level (ng/L)***	***Proposed Guideline***	***USEPA method 537.1***	***USEPA Method 533***	***Current Guideline or screening value (ng/L) GV - Guideline Value SV - Screening Value***	
Perfluorooctanoic acid	PFOA	560	100	sum of 20 PFAS < 100 ng/L	sum of 20 PFAS < 100 ng/L	4		0.004 "0" As MCL goal	sum of all PFAS included in USEPA Method 537.1, Method 533, or both, <30 ng/L	x	x	200	GV
Perfluorooctanesulfonic acid	PFOS	combined total [PFOS] + [PFHxS] < 70	100	sum of 20 PFAS < 100 ng/L	sum of 20 PFAS < 100 ng/L	4		0.020 "0" As MCL goal	sum of all PFAS included in USEPA Method 537.1, Method 533, or both, <30 ng/L	x	x	600	GV
Perfluorohexanesulfonate	PFHxS	combined total [PFOS] + [PFHxS] < 70	100	sum of 20 PFAS < 100 ng/L	sum of 20 PFAS < 100 ng/L	Health Index combined score <1	[PFHxS] / 9 ng/L		sum of all PFAS included in USEPA Method 537.1, Method 533, or both, <30 ng/L	x	x	600	SV
Perfluorononanoate	PFNA		100	sum of 20 PFAS < 100 ng/L	sum of 20 PFAS < 100 ng/L	Health Index combined score <1	[PFNA] / 10 ng/L		sum of all PFAS included in USEPA Method 537.1, Method 533, or both, <30 ng/L	x	x	20	SV
Perfluorobutanesulfonate	PFBS		100	sum of 20 PFAS < 100 ng/L	sum of 20 PFAS < 100 ng/L	Health Index combined score <1	[PFBS] / 2,000 ng/L	2000	sum of all PFAS included in USEPA Method 537.1, Method 533, or both, <30 ng/L	x	x	15,000	SV

	Regulator / Advisory Body	Taumata Arowai	England Drinking Water Inspectorate	Scotland Drinking Water Quality Regulator	European Drinking Water Directive	US EPA			Health Canada				
	Year	**2022**	**2021**	**2022**	**2021**	**2023**		**2022**	**2023**			**2018 - 2019**	
	Overview	*3 PFAS regulations, 1 individual at 560 ng/L and 2 combined at 70 ng/L*	*47 individual PFAS guidelines, all at 100 ng/L*	*100 ng/L limit for the sum of 20 PFAS*	*100 ng/L limit for the sum of 20 PFAS*	*6 PFAS regulations (proposed), 2 individually at 4 ng/L and 4 combined based on a Health Index with contributions from 9 to 2,000 ng/L*		*4 individual PFAS guidelines, ranging from 4 to 2,000 ng/L*	*30 ng/L guideline for the sum of 18 - 30 PFAS (depending on the method selected)*			*11 individual PFAS guidelines or screening values, ranging from 20 to 30,000 ng/L*	
PFAS Compound	**Acronym**	**Current Drinking Water Standards (ng/L)**	**Current Drinking Water Guideline (ng/L)**	**Current Drinking Water Standards (ng/L)**	**Current Drinking Water Standards (ng/L)**	**Proposed Maximum Contaminant Level (ng/L)**	**Health Index Calculation**	**Current Health Advisory level (ng/L)**	**Proposed Guideline**	**USEPA method 537.1**	**USEPA Method 533**	**Current Guideline or screening value (ng/L) GV - Guideline Value SV - Screening Value**	
Hexafluoropropylene oxide-dimer acid	HFPO-DA GenX		100			Health Index combined score <1	[GenX] / 10 ng/L	10	sum of all PFAS included in USEPA Method 537.1, Method 533, or both, <30 ng/L	x	x		
Perfluoroheptanoate	PFHpA		100	sum of 20 PFAS < 100 ng/L	sum of 20 PFAS < 100 ng/L				sum of all PFAS included in USEPA Method 537.1, Method 533, or both, <30 ng/L	x	x	200	SV
Perfluorohexanoic acid	PFHxA		100	sum of 20 PFAS < 100 ng/L	sum of 20 PFAS < 100 ng/L				sum of all PFAS included in USEPA Method 537.1, Method 533, or both, <30 ng/L	x	x	200	SV
Perfluorodecanoic acid	PFDA		100	sum of 20 PFAS < 100 ng/L	sum of 20 PFAS < 100 ng/L				sum of all PFAS included in USEPA Method 537.1, Method 533, or both, <30 ng/L	x	x		
4,8-Dioxa-3H-perfluorononanoic acid	ADONA		100						sum of all PFAS included in USEPA Method 537.1, Method 533, or both, <30 ng/L	x	x		
Perfluorododecanoic acid	PFDoA		100	sum of 20 PFAS < 100 ng/L	sum of 20 PFAS < 100 ng/L				sum of all PFAS included in USEPA Method 537.1, Method 533, or both, <30 ng/L	x	x		

	Regulator / Advisory Body	***Taumata Arowai***	***England Drinking Water Inspectorate***	***Scotland Drinking Water Quality Regulator***	***European Drinking Water Directive***	***US EPA***			***Health Canada***				
	Year	***2022***	***2021***	***2022***	***2021***	***2023***		***2022***	***2023***			***2018 - 2019***	
	Overview	*3 PFAS regulations, 1 individual at 560 ng/L and 2 combined at 70 ng/L*	*47 individual PFAS guidelines, all at 100 ng/L*	*100 ng/L limit for the sum of 20 PFAS*	*100 ng/L limit for the sum of 20 PFAS*	*6 PFAS regulations (proposed), 2 individually at 4 ng/L and 4 combined based on a Health Index with contributions from 9 to 2,000 ng/L*		*4 individual PFAS guidelines, ranging from 4 to 2,000 ng/L*	*30 ng/L guideline for the sum of 18 - 30 PFAS (depending on the method selected)*			*11 individual PFAS guidelines or screening values, ranging from 20 to 30,000 ng/L*	
PFAS Compound	***Acronym***	***Current Drinking Water Standards (ng/L)***	***Current Drinking Water Guideline (ng/L)***	***Current Drinking Water Standards (ng/L)***	***Current Drinking Water Standards (ng/L)***	***Proposed Maximum Contaminant Level (ng/L)***	***Health Index Calculation***	***Current Health Advisory level (ng/L)***	***Proposed Guideline***	***USEPA method 537.1***	***USEPA Method 533***	***Current Guideline or screening value (ng/L) GV - Guideline Value SV - Screening Value***	
11-Chloroeicosafluoro-3-oxaundecane-1-sulfonic acid	11Cl-PF3OUdS		100						sum of all PFAS included in USEPA Method 537.1, Method 533, or both, <30 ng/L	x	x		
9-Chlorohexadecafluoro-3-oxanonane-1-sulfonic acid	9Cl-PF3ONS		100						sum of all PFAS included in USEPA Method 537.1, Method 533, or both, <30 ng/L	x	x		
1H,1H, 2H, 2H-Perfluorooctane sulfonic acid	6:2FTS		100						sum of all PFAS included in USEPA Method 537.1, Method 533, or both, <30 ng/L		x	200	SV
Perfluoropentanoic acid	PFPeA		100	sum of 20 PFAS < 100 ng/L	sum of 20 PFAS < 100 ng/L				sum of all PFAS included in USEPA Method 537.1, Method 533, or both, <30 ng/L		x	200	SV
Perfluorobutanoic acid	PFBA		100	sum of 20 PFAS < 100 ng/L	sum of 20 PFAS < 100 ng/L				sum of all PFAS included in USEPA Method 537.1, Method 533, or both, <30 ng/L		x	30000	SV
1H,1H, 2H, 2H-Perfluorodecane sulfonic acid	8:2FTS		100						sum of all PFAS included in USEPA Method 537.1, Method 533, or both, <30 ng/L		x	200	SV

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	Overview	*3 PFAS regulations, 1 individual at 560 ng/L and 2 combined at 70 ng/L*	*47 individual PFAS guidelines, all at 100 ng/L*	*100 ng/L limit for the sum of 20 PFAS*	*100 ng/L limit for the sum of 20 PFAS*	*6 PFAS regulations (proposed), 2 individually at 4 ng/L and 4 combined based on a Health Index with contributions from 9 to 2,000 ng/L*		*4 individual PFAS guidelines, ranging from 4 to 2,000 ng/L*	*30 ng/L guideline for the sum of 18 - 30 PFAS (depending on the method selected)*			*11 individual PFAS guidelines or screening values, ranging from 20 to 30,000 ng/L*	
PFAS Compound	***Acronym***	***Current Drinking Water Standards (ng/L)***	***Current Drinking Water Guideline (ng/L)***	***Current Drinking Water Standards (ng/L)***	***Current Drinking Water Standards (ng/L)***	***Proposed Maximum Contaminant Level (ng/L)***	***Health Index Calculation***	***Current Health Advisory level (ng/L)***	***Proposed Guideline***	***USEPA method 537.1***	***USEPA Method 533***	***Current Guideline or screening value (ng/L) GV - Guideline Value SV - Screening Value***	
Nonafluoro-3,6-dioxaheptanoic acid	NFDHA		100						sum of all PFAS included in USEPA Method 537.1, Method 533, or both, <30 ng/L		x		
Perfluoro(2-ethoxyethane)sulfonic acid	PFEESA		100						sum of all PFAS included in USEPA Method 537.1, Method 533, or both, <30 ng/L		x		
Perfluoroheptanesulfonic acid	PFHpS		100	sum of 20 PFAS < 100 ng/L	sum of 20 PFAS < 100 ng/L				sum of all PFAS included in USEPA Method 537.1, Method 533, or both, <30 ng/L		x		
1H,1H, 2H, 2H-Perfluorohexane sulfonic acid	4:2FTS		100						sum of all PFAS included in USEPA Method 537.1, Method 533, or both, <30 ng/L		x		
Perfluoro-3-methoxypropanoic acid	PFMPA								sum of all PFAS included in USEPA Method 537.1, Method 533, or both, <30 ng/L		x		
Perfluoro-4-methoxybutanoic acid	PFMBA								sum of all PFAS included in USEPA Method 537.1, Method 533, or both, <30 ng/L		x		

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	Overview	*3 PFAS regulations, 1 individual at 560 ng/L and 2 combined at 70 ng/L*	*47 individual PFAS guidelines, all at 100 ng/L*	*100 ng/L limit for the sum of 20 PFAS*	*100 ng/L limit for the sum of 20 PFAS*	*6 PFAS regulations (proposed), 2 individually at 4 ng/L and 4 combined based on a Health Index with contributions from 9 to 2,000 ng/L*		*4 individual PFAS guidelines, ranging from 4 to 2,000 ng/L*	*30 ng/L guideline for the sum of 18 - 30 PFAS (depending on the method selected)*			*11 individual PFAS guidelines or screening values, ranging from 20 to 30,000 ng/L*	
PFAS Compound	***Acronym***	***Current Drinking Water Standards (ng/L)***	***Current Drinking Water Guideline (ng/L)***	***Current Drinking Water Standards (ng/L)***	***Current Drinking Water Standards (ng/L)***	***Proposed Maximum Contaminant Level (ng/L)***	***Health Index Calculation***	***Current Health Advisory level (ng/L)***	***Proposed Guideline***	***USEPA method 537.1***	***USEPA Method 533***	***Current Guideline or screening value (ng/L) GV - Guideline Value SV - Screening Value***	
Perfluoropentanesulfonic acid	PFPeS		100	sum of 20 PFAS < 100 ng/L	sum of 20 PFAS < 100 ng/L				sum of all PFAS included in USEPA Method 537.1, Method 533, or both, <30 ng/L		x		
Perfluoroundecanoic acid	PFUnA		100	sum of 20 PFAS < 100 ng/L	sum of 20 PFAS < 100 ng/L				sum of all PFAS included in USEPA Method 537.1, Method 533, or both, <30 ng/L		x		
N-ethyl perfluorooctane-sulfonamidoacetic acid	NEtFOSAA		100						sum of all PFAS included in USEPA Method 537.1, Method 533, or both, <30 ng/L	x			
N-methyl perfluorooctane-sulfonamidoacetic acid	NMeFOSAA		100						sum of all PFAS included in USEPA Method 537.1, Method 533, or both, <30 ng/L	x			
Perfluorotetradecanoic acid	PFTA								sum of all PFAS included in USEPA Method 537.1, Method 533, or both, <30 ng/L	x			
Perfluorotridecanoic acid	PFTrDA			sum of 20 PFAS < 100 ng/L	sum of 20 PFAS < 100 ng/L				sum of all PFAS included in USEPA Method 537.1, Method 533, or both, <30 ng/L	x			
Perfluorotetradecanoic acid	PFTeA		100										

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	Overview	3 PFAS regulations, 1 individual at 560 ng/L and 2 combined at 70 ng/L	47 individual PFAS guidelines, all at 100 ng/L	100 ng/L limit for the sum of 20 PFAS	100 ng/L limit for the sum of 20 PFAS	6 PFAS regulations (proposed), 2 individually at 4 ng/L and 4 combined based on a Health Index with contributions from 9 to 2,000 ng/L		4 individual PFAS guidelines, ranging from 4 to 2,000 ng/L	30 ng/L guideline for the sum of 18 - 30 PFAS (depending on the method selected)			11 individual PFAS guidelines or screening values, ranging from 20 to 30,000 ng/L	
PFAS Compound	**Acronym**	**Current Drinking Water Standards (ng/L)**	**Current Drinking Water Guideline (ng/L)**	**Current Drinking Water Standards (ng/L)**	**Current Drinking Water Standards (ng/L)**	**Proposed Maximum Contaminant Level (ng/L)**	**Health Index Calculation**	**Current Health Advisory level (ng/L)**	**Proposed Guideline**	**USEPA method 537.1**	**USEPA Method 533**	**Current Guideline or screening value (ng/L) GV - Guideline Value SV - Screening Value**	
Perfluorohexadecanoic acid	PFHxDA		100										
Perfluorooctadecanoic acid	PFODA		100										
Perfluorononanesulfonic acid	PFNS		100	sum of 20 PFAS < 100 ng/L	sum of 20 PFAS < 100 ng/L								
Perfluorodecanesulfonic Acid	PFDS		100	sum of 20 PFAS < 100 ng/L	sum of 20 PFAS < 100 ng/L								
Perfluoroundecane sulfonate	PFUnDS		100	sum of 20 PFAS < 100 ng/L	sum of 20 PFAS < 100 ng/L								
Perfluorododecane Sulfonic Acid	PFDoS		100	sum of 20 PFAS < 100 ng/L	sum of 20 PFAS < 100 ng/L								
Hexafluoropropylene oxide trimer acid	HFPO-TA		100										
Perfluoro-4-methoxybutanic acid	PFMOBA		100										
Perfluoroethylcyclo-hexane Sulfonate	PFecHS		100										
3-Perfluoropropyl propanoic acid	3:3FTCA		100										
2H,2H,3H,3H-Perfluorooctanoicacid	5:3FTCA		100										
3-Perfluoroheptyl propanoic acid	7:3FTCA		100										
Perfluorobutane sulfonamide	FBSA		100										
Perfluorohexane-sulfonamide	FHxSA		100										

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	Overview	3 PFAS regulations, 1 individual at 560 ng/L and 2 combined at 70 ng/L	47 individual PFAS guidelines, all at 100 ng/L	100 ng/L limit for the sum of 20 PFAS	100 ng/L limit for the sum of 20 PFAS	6 PFAS regulations (proposed), 2 individually at 4 ng/L and 4 combined based on a Health Index with contributions from 9 to 2,000 ng/L		4 individual PFAS guidelines, ranging from 4 to 2,000 ng/L	30 ng/L guideline for the sum of 18 - 30 PFAS (depending on the method selected)			11 individual PFAS guidelines or screening values, ranging from 20 to 30,000 ng/L	
PFAS Compound	**Acronym**	**Current Drinking Water Standards (ng/L)**	**Current Drinking Water Guideline (ng/L)**	**Current Drinking Water Standards (ng/L)**	**Current Drinking Water Standards (ng/L)**	**Proposed Maximum Contaminant Level (ng/L)**	**Health Index Calculation**	**Current Health Advisory level (ng/L)**	**Proposed Guideline**	**USEPA method 537.1**	**USEPA Method 533**	**Current Guideline or screening value (ng/L) GV - Guideline Value SV - Screening Value**	
Perfluorooctane-sulfonamide	FOSA		100										
N-methyl perfluorooctane sulfonamide	MeFOSA		100										
Sulfluramid	EtFOSA		100										
N-Methylperfluorooctane-sulfonamidoethanol	MeFOSE		100										
N-Ethyl Perfluorooctane Sulfonamido Ethanol	EtFOSE		100										
Perfluorotridecane sulfonic acid	PFTrDS			sum of 20 PFAS < 100 ng/L	sum of 20 PFAS < 100 ng/L								

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