

PFactS 2 | PFAS in Drinking Water



This is the second in a series of factsheets on per- and polyfluoroalkyl substances (PFAS) and their occurrence in catchments, waste streams, drinking water treatment and wastewater treatment and reuse. These factsheets have been designed to assist Australian and global water utilities navigate the risks, regulations, treatment options and monitoring recommendations specifically relating to PFAS. *PFactS 2* introduces the ways in which PFAS can impact drinking water production and provides water treatment plant personnel with information to assist in risk analysis and mitigation exercises concerning both human and environmental health effects.

Table 1 – Commonly studied PFAS compounds, groups and acronyms

Compound/Subset	Acronym	Notes
Compound/Subset	Acronym	Notes
Perfluoroalkyl Acids	PFAAs	Covers all of PFHxS, PFOA, PFOS and others
Perfluorinated Carboxylic Acids	PFCAs	PFOA is included in this subset
Perfluorohexanesulfonic Acid	PFHxS	
Perfluorooctanoic Acid	PFOA	
Perfluorooctanesulfonic Acid	PFOS	
Perfluoroalkylsulfonic Acids	PFASAs	PFHxS and PFOS included in this subset
PFHxS/PFOA/PFOS	PFAS3	Refers to three most commonly studied compounds

What are PFAS?

PFAS refers to Per- and polyfluoroalkyl Substances that represent a large range of chemicals that historically have been used in applications such as non-stick coatings, textiles, paper products and firefighting foams. Sharing a common structural element of a partial (poly-) or fully (per-) fluorinated carbon chain, these compounds are highly resistant to biological, thermal and chemical degradation, allowing them to persist in the environment and resist removal by the majority of water and wastewater treatment processes.

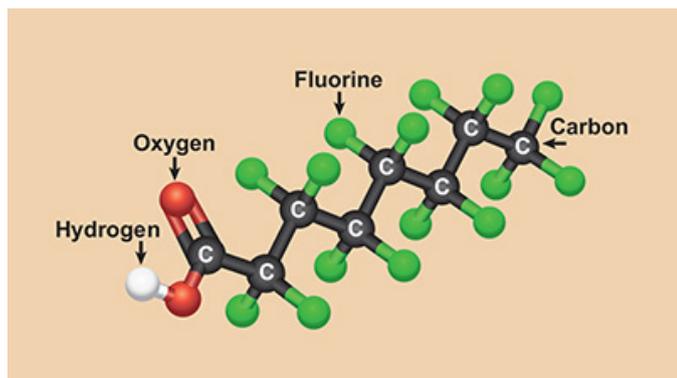


Figure 1 - Perfluorooctanoic acid (PFOA). Image credit: <https://www.niehs.nih.gov/health/topics/agents/pfc/index.cfm>

In general, the vast majority of studies into PFAS substances which have informed global advisory and regulatory limits of PFAS in drinking water, environmental waters and recycled waters are generally focussed on either specific subsets of PFAS chemicals or individual compounds. The most common are listed in Table 1:

It is important to note that advances in analytical chemistry and PFAS research over the past decade have led to the majority of large commercial environmental and analytical laboratories offering PFAS analyses as part of their services. These analyses can quantitatively identify a broad range of PFAS from small volumes (usually 500 mL or less) and can further identify PFAS precursor molecules.

PFAS in raw water sources

General information on primary sources of PFAS and their fate in the natural environment are covered in *PFactS 1*; more detailed information relevant to drinking water production are collated in Table 2, which gives indicative levels in surface and ground waters used for drinking water, in addition to drinking waters globally. The majority of studies of this nature find elevated levels of PFAS in catchments associated with primary PFAS sources (industrial areas); furthermore many researchers have found that as “legacy” PFAS chemicals (PFOS and PFOA) are phased out and replaced with novel compounds, the concentrations of these compounds (such as PFHxS) are beginning to increase.

PFActS 2 | PFAS in Drinking Water



Table 2 – Global maximum levels of PFAS in surface, ground and drinking (tap) waters

Surface Waters	Max PFAS (ng/L)	Max PFAS3 (ng/L)
Eastern China ^[1]	713	
New Jersey ^[2]	160	
India ^[3]	28	
Groundwaters		
New Jersey ^[2]		55
India ^[3]	12	
Drinking (Tap) Waters		
Australian ^[4]		20
South Korea ^[5]	224	
Germany ^[6]		23

PFAS regulatory limits and advisory guidelines for drinking water

Due to the constantly evolving nature of PFAS research and uncertainty around long term health effects, it can be difficult for utilities considering regulatory guidelines and advisory targets. The US in particular has advisory limits that vary from state to state, and it can be difficult to assess whether limits are regulatory, advisory (or screening) values, or trigger levels for response. For instance, the US EPA recommendations on PFAS in drinking water are not passed into law at a federal level; however legal limits exist at state level for many states^[7].

The Interstate Technology Regulatory Council (ITRC) have compiled a database of PFAS regulatory guidelines in both the US and globally with all relevant information included; it is recommended that this database is used as the primary resource for water utilities when conducting risk assessments^[7]. Summary data is provided in Table 3. It is important to note that outside of certain US states, only Canada has legislated PFAS limits (for maximum allowable concentrations); all other countries have screening and health based advisory limits only.

Table 3 – Advisory and regulatory limits for PFAS in drinking water globally * Legislated limits

Country	Agency	Standard/Guidance	PFOA Limit (ng/L)	PFOS Limit (ng/L)	PFHxS Limit (ng/L)	Notes
USA	US EPA	Lifetime Health Advisory	70	70	None	ΣPFOA+PFOS < 70 ng/L
Australia	Department of Health ^[6]	Health Based Target	560	70	70	ΣPFOS+PFHxS < 70 ng/L
Canada	Health Canada	Advisory/Maximum Acceptable Limit (MAL)*	200*	600*	600	Screening values exist for other PFAS
Denmark	EPA	Health Based	100	100	100	Σ PFAS < 100
Germany	Ministry of Health	Health based (h) Administrative (a)	300 (h) 100 (a)	300 (h) 100 (a)	None	Administrative value for long term exposure
Italy		Health Based	500	30	None	
UK	Drinking Water Inspectorate	Health Based	10,000	300	None	

In addition to the advisory PFAS limits for drinking water given above, many countries have similar environmentally focused values for surface and ground waters that in many cases are similar to those for drinking water. Utilities should seek out such guidelines where they exist, as a knowledge of PFAS levels in source waters for WTPs is integral for risk assessment exercises and can assist in locating primary PFAS sources and limiting PFAS contamination of raw waters. Should a raw water source have higher PFAS levels than those given in local guidelines, this could indicate a PFAS contamination point somewhere in the catchment.

PFActS 2 | PFAS in Drinking Water



PFAS removal in water treatment processes

PFAS in drinking water is problematic in that most conventional water treatment plants comprising coagulation/sedimentation/filtration/disinfection are incapable of removing more than 10% of PFAS from raw waters^[9]. Due to this, advanced treatment using either adsorptive technologies (anion exchange resins, AIX); powdered and granular activated carbon (PAC/GAC) dosing/filtration or membrane filtration (nanofiltration (NF) and reverse osmosis (RO)) is required in most

instances). A summary of the performance of water treatment processes for the removal of specific PFAS compounds is given in Table 4^[9]. As seen in Table 4, treatment performance varies with PFAS of varying molecular weight/size, with smaller molecules being harder to remove than larger. Furthermore, raw water characteristics, in particular dissolved organic carbon (DOC), can heavily affect process performance; laboratory and pilot scale validation of any treatment technology is required for confidence in PFAS removal performance at full scale.

Table 4 – Removal of individual PFAS molecules by various treatment technologies^[9]

		Removal <10%	Removal 10-90%	Removal >90%						
Compound		M.W. (g/mol)	AER	COAG/DAF	COAG/FLOC/SED/G- or M-FIL	AIX	GAC	NF	RO	MnO ₄ , O ₃ , ClO ₂ , Cl ₂ , CLM, UV
		PFBA	214	assumed	assumed					
	PFPeA	264								
	PFHxA	314								
	PFHpA	364								
	PFOA	414								
	PFNA	464		unknown		assumed	assumed			
	PFDA	514		unknown		assumed	assumed			
	PFBS	300								
	PFHxS	400								
	PFOS	500								
	FOSA	499	unknown	unknown		unknown	assumed	unknown	assumed	unknown
	N-MeFOSAA	571	assumed	unknown		assumed	assumed	assumed		unknown
	N-EtFOSAA	585		unknown		assumed	assumed	assumed		unknown ^a

a - <10% removal by Cl₂ and KMnO₄; “assumed”: treatment performance is assumed based on the PFAA size/charge and/or known removal data of shorter or longer chain homologues

AER: Aeration, AIX: Anion Exchange, CLM: Chloramination, Cl₂: Hypochlorous/Hypochlorite, ClO₂: Chlorine Dioxide, COAG: Coagulation, DAF: Dissolved Air Flotation, O₃: Ozone, FLOC: Flocculation, GAC: Granular Activated Carbon Filtration, G-FIL: Granular Filtration, M-FIL: Microfiltration, MnO₄: Permanganate, RO: Reverse Osmosis, SED: Sedimentation, UV: UV Photolysis, UV-AOP: UV Photolysis with Advanced Oxidation (Hydrogen Peroxide)



PFActS 2 | PFAS in Drinking Water



A novel approach to PFAS removal that minimises sampling and analysis requirements and hence ongoing costs is to apply a critical control point (CCP) approach to PFAS across each process, as is commonly the current practice for pathogen removal^[10]. Applying a similar approach to PFAS may allow WTPs to formulate overall log reduction values (LRVs) for a range of PFAS, increase operational certainty and reduce analytical costs.

An example of the above is operation of ozonation and reverse osmosis (RO) processes, where operational parameters that could be continually monitored and hence used as CCP limits include minimum ozone residual and RO filtrate conductivity. Both of these were shown to correlate with a percentage removal of a given class of chemicals when processes were operated within CCP limits. Applying a similar approach to PFAS may allow WTPs to formulate overall log reduction values (LRVs) for a range of PFAS, increase operational certainty and reduce analytical costs.

Like most of the science surrounding PFAS, treatment options, technologies and case studies are constantly evolving, and utilities are encouraged to conduct further investigation to ensure that they have all relevant information.

Practical guide for water utilities

The extent of PFAS risk assessment exercises conducted by a given water utility will be heavily dependent on the PFAS risks in the local area. For instance, if a utility does not detect PFAS in finished water, or if the levels are an order of magnitude below the relevant local regulatory guidelines, extensive monitoring is not required. However, given the ability of PFAS

to bioaccumulate it would be prudent for utilities to consider longer term monitoring of raw waters to identify any gradual increases in PFAS over time.

In general, a PFAS risk assessment for a WTP involves:

1. Collate all relevant local regulatory and advisory guidelines and limits concerning PFAS.
2. Conduct sampling and PFAS analysis on raw water source(s) and finished waters.
3. Use results as input into risk analysis exercises to estimate the likelihood of producing finished water with PFAS levels close to or exceeding relevant guideline limits.
4. If action is required to lower PFAS risks, it would be preferable to investigate primary PFAS sources (industry/military/fire training sites/landfill) within the catchment and assess measures to minimise PFAS contamination of raw waters.
5. If additional treatment barriers are required for ongoing management of PFAS risks, conduct laboratory and pilot scale studies to identify optimum treatment technologies.
6. If possible, apply Hazard Analysis and Critical Control Point (HACCP) philosophy to new treatment processes such that they can be run within set operational parameters and deliver a verified and validated PFAS removal, minimising ongoing sampling and analysis costs.

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