Global Water Research Coalition

Water Research AUSTRALIA

PFActS 1 | PFAS in the Environment

This is the first 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 1* is an introduction to the issue and discusses what PFAS are, where they come from, where and how they accumulate, and how this affects the operations of water utilities.

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.

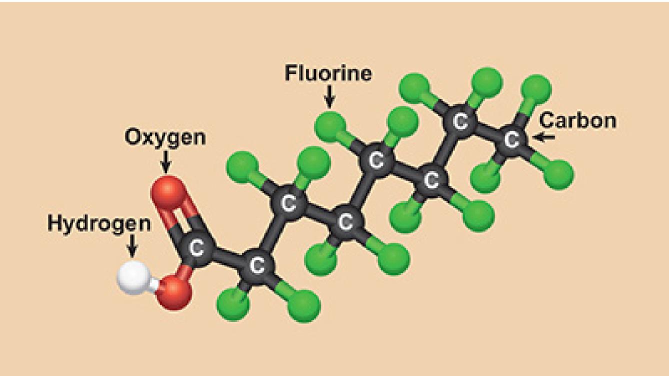

Figure 1 - Perfluorooctanoic acid (PFOA). Image credit: https://www.niehs.nih.gov/health/topics/agents/pfc/index.cfm

PFAS were first developed in the 1940s by 3M in the US, however in the early 21st century concerns over possible health and environmental effects resulted in progressive restrictions on use. Under a voluntary agreement with the US EPA, 3M had ceased production of perfluorooctanesulfonic acid (PFOS) by 2002. In 2006, under another voluntary agreement, the US EPA asked eight PFAS manufacturers to phase out perfluorooctanoic acid (PFOA) production by 2015, however manufacturers outside of the US continued to make PFOA. While production and use of PFAS in Japan, Western Europe and the US has fallen sharply since 2000, there has been a rapid increase in production in China, India, Poland and Russia. This continued production of PFAS, combined with the lack of degradation within the environment, has led to concerns about levels of PFAS in recycled water.

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:

Table 1 – Commonly studied PFAS compounds, groups and acronyms

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	PFSAs	PFHxS and PFOS included in this subset
PFHxS/PFOA/PFOS	PFAS3	Refers to three most commonly studied compounds

Sources and exposure pathways of PFAS

PFAS may be introduced into waters either via primary sources, where PFAS compounds are directly applied at the source; or via secondary sources, where PFAS is an additive to products/processes which then leach into the environment. For instance, due to the historical prevalence of PFAS in manufacturing processes, the majority of households and commercial workplaces will likely include products which contain PFAS and hence represent a minor secondary point source of PFAS entry into waste streams.

The four major sources of PFAS [(1)] are:

- Fire training/fire response sites (primary source)
- Industrial sites (primary source)
- Landfills (secondary source)
- Wastewater treatment plants/biosolids (WWTPs) (secondary source)

These are shown graphically in Figure 2. It must be noted that when considering sources of PFAS, it is beneficial to gather as much information as possible on the manufacturing processes, both historical and

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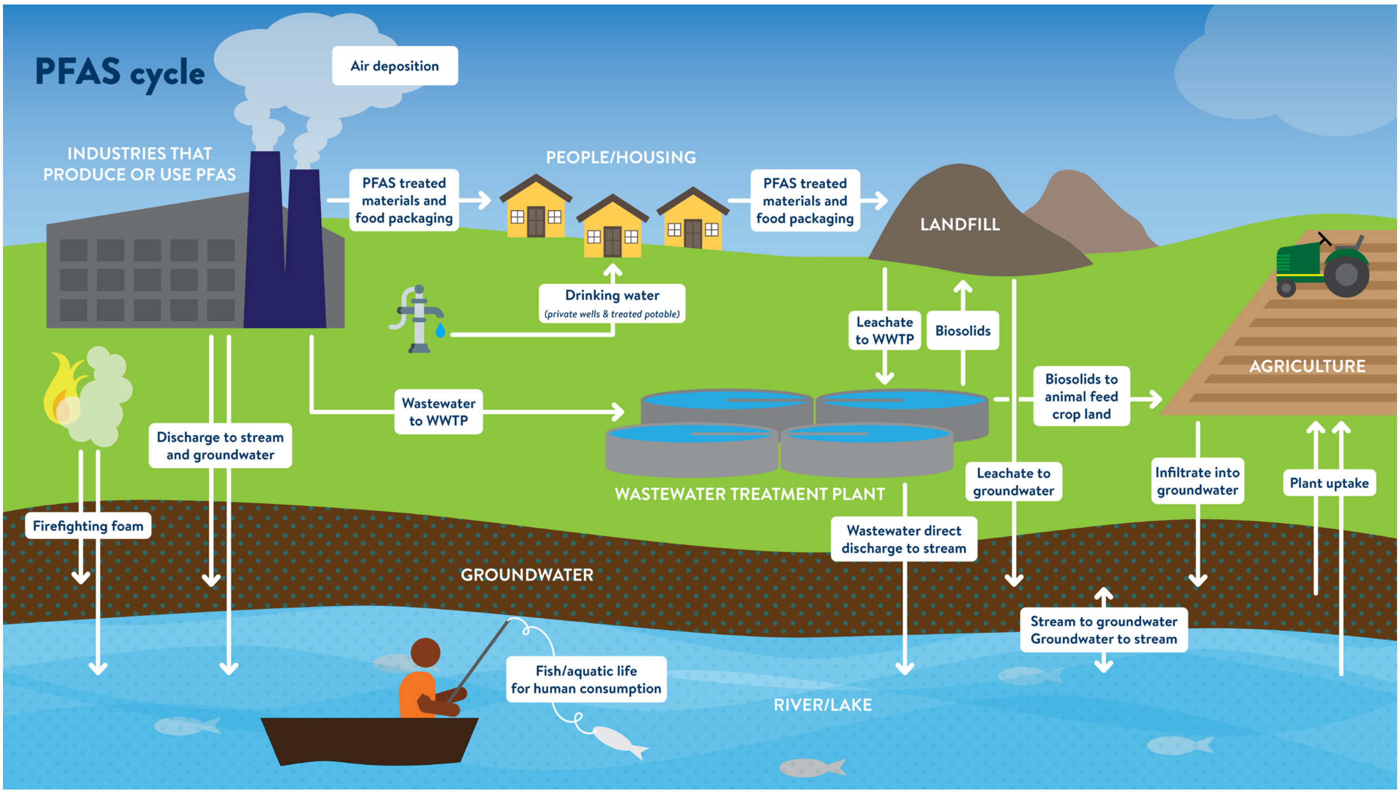

Figure 2 - PFAS sources and transport in the environment. Image: Minnesota Pollution Control Agency, re-printed with permission.

current, by which PFAS have been produced and utilised, as changes in manufacturing processes produce waste streams with varying PFAS compositions [1].

Other point and diffuse sources of PFAS exist, and may be significant locally, but generally are expected to be small by comparison to these main four sources. The proliferation of PFAS throughout the natural environment is further complicated by the presence of polyfluorinated precursor compounds which can be broken down in the environment by either physical or biological processes to form more persistent PFAS, meaning that any environmental investigations will need to include not only those PFAS compounds of immediate concern (as listed in Table 1) but also a precursor assay to provide a comprehensive indication of PFAS risks in a given area.

Water utilities not exposed to the primary sources of PFAS shown in Figure 2 may nonetheless find themselves exposed to PFAS risks due to the extensive ability of PFAS to persist in and travel across the natural environment.

Global background levels of PFAS

From the primary sources shown in Figure 2, PFAS spread throughout the environment via both solid (particulate) and liquid (aqueous chemical) transport methods, and eventually accumulate in soils, marine and freshwater environments globally [1]. Indicative global levels of PFAS in soils and waters are given in Table 2 [1].

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Table 2 – Global background levels of PFAS in air, soils and sediments, groundwater and surface waters

PFAS in Soil and Sediment		
Location	PFOS (µg/kg)	PFOA (µg/kg)
Global Median	0.47	0.12
Fire training/response	2,400	21
Industrial areas	5	24
Municipal Biosolids	80 to > 2000	8 – 68
PFAS in Groundwater		
Location	PFOS (µg/L)	PFOA (µg/L)
PFAS Release Sites (non-fire training)	4.2	0.42
Fire Training Sites	Up to 2300	Up to 6570
PFAS in Surface Waters		
Location	PFOS (µg/L)	PFOA (µg/L)
Japan and USA	< 0.14	< 67
Fire Training/Response	< 9	< 4
Municipal WWTP Outfalls	0.024	0.025
Stormwaters	< 0.6	< 1.2

Based on this data, the range of PFAS present varies globally and is strongly dependent on the presence of local primary PFAS sources, which implies that water utilities in such areas are at the highest risk of PFAS levels exceeding local guidelines for production of both potable and recycled water. However, the wide range of PFAS concentrations observed in other locations highlights the need for all water utilities to conduct, at minimum, a rudimentary environmental survey including sampling and analysis for PFAS and precursor molecules to obtain baseline data for use in longer term risk management planning exercises. This is discussed in greater detail in the other factsheets in this series.

Environmental and human health effects

Research into the effects of PFAS in both the environment and humans is ongoing; although it is widely agreed that both chronic and carcinogenic effects have been observed in animal studies, a recent (2018) Australian Expert Health Panel [(2)] agreed with various European agencies that the evidence did not warrant specific health interventions and decisions to regulate or cease production of specific PFAS chemicals should continue to be based on evidence of persistence and accumulation.

Regardless of the findings on the effects of PFAS on environmental and human health, of most concern to water utilities is that they are adhering to relevant local guidelines or observing best international practice should no such guidelines be available. An indication of advisory limits of various PFAS in various countries is given in Table 3 [(3)].

Table 3 – Advisory limits for PFAS compounds in Australia, US, Europe and UK

	Drinking Water (µg/L)		Recreational Water (µg/L)		Human Consumption (µg/ kg bw/day)	
Country	PFOS + PFHxS	PFOA	PFOS + PFHxS	PFOA	PFOS + PFHxS	PFOA
Australia [(4)]	0.07	0.56	2.0	10.0	0.02	0.16
US	0.07 in total (ex PFHxS)				0.02 in total (ex. PFHxS)	
Europe	0.09 – 0.53	0.090 – 0.5			0.03 (PFOS)	0.1
UK	1	5			0.15 (PFOS)	1.5

From an environmental health perspective, Australia, the US and the EU have published environmental guidelines such as Australia's PFAS National Environmental Management Plan (NEMP) [(4)], which outlines the guiding principles, roles and responsibilities of stakeholders, PFAS guideline values, and recommendations for PFAS monitoring and treatment.

In the US, the Interstate Technology Regulatory Council (ITRC) provides detailed examples of site risk assessments, with environmental guideline values based on protection of 95% of a given group of organisms from both acute and chronic effects of PFAS [(5)]. Similar guidelines may be found in Australia's NEMP, and vary depending on the conservation value of the environment as seen in Table 4.

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Table 4 – NEMP guideline limits for PFOS and PFOA in freshwater and marine systems

Scenario	Freshwater Systems	Marine Systems
High conservation value PFOS Guideline (µg/L)	0.00023	0.00023
High conservation value PFOA Guideline (µg/L)	19	19
Slight to moderate disturbance PFOS Guideline (µg/L)	0.13	0.13
Slight to moderate disturbance PFOA Guideline (µg/L)	220	220

Practical guidance for water utilities

The information presented here in *PFActS 1* is intended to be useful background reading for all water utilities, as it shows that, regardless of the size and location of a water, wastewater or recycled water treatment process:

- PFAS compounds are now prevalent throughout the natural environment and present in most surface, ground and receiving waters and soils; and,
- As a result, many regulatory bodies are either imposing limits or providing advisory guidelines for safe PFAS levels, particularly PFAS3 compounds.

It is strongly recommended that all water utilities conduct preliminary local environmental risk assessments to ensure that baseline data on background levels of PFAS in source waters and receiving environments are established as early as possible and databases updated with periodic sampling events to monitor and assess PFAS risks, allowing for early detection and mitigation. Of most relevance to water utilities is:

- Establishing what type of risk assessment exercise is required;
- Establishing the frequency and extent of sampling and analysis required;
- Identifying and implementing risk management strategies;
- Ensuring ongoing monitoring of PFAS risks and performance of risk management strategies; and,
- Staying abreast of developments in local regulations, guidelines, and technological advances that may improve risk management strategies or provide additional treatment options.

To assist water utilities in achieving these goals, further information is provided in *PFActS 2 – PFAS in Drinking Water,* and *PFActS 3 – PFAS in Recycled Water.*

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