

PFAS SOURCE CONTROL: ESSENTIAL TO FACILITATING A CIRCULAR ECONOMY FOR THE URBAN WATER SECTOR

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ABSTRACT

Wastewater treatment plants are increasingly expected to manage PFAS despite having no control over their sources and limited capacity to remove them. Analysis of 499 biosolids samples from Queensland shows PFAS are ubiquitous, with PFOS and PFDA dominating concentrations and landfill leachate and consumer products contributing significant loads. Current regulatory approaches place the burden on utilities rather than controlling chemicals at their origin. Evidence from other contaminant bans demonstrates that meaningful reductions occur only through decisive upstream restrictions. Without stronger national source control, PFAS contamination will continue to undermine beneficial biosolids reuse and threaten the circular economy ambitions of the urban water sector.

INTRODUCTION

The Australian urban water sector faces increasing scrutiny as emerging contaminants, especially per- and polyfluoroalkyl substances (PFAS), are detected in biosolids and treated wastewater. Wastewater treatment plants (WWTPs) are passive receivers of contaminants from households, trade waste, and landfill leachate. They are not designed to remove persistent pollutants yet bear regulatory and cost burdens when contaminants pass into effluent and biosolids. With circular economy goals emphasising beneficial reuse of both biosolids and recycled water, particularly in agriculture, poorly controlled contaminants create uncertainty and risks for these pathways.

The Australian Government's Industrial Chemicals Environmental Management Standard (IChEMS) represents a recent attempt at upstream regulation of PFAS but remains inadequate. IChEMS covers three compounds, PFOA, PFOS, PFHxS and some associated precursor chemicals, permits

“unintentional trace contamination” at levels (25 µg/kg) well above PFAS limits in guidelines for finished compost (e.g. 1 µg/kg, QG 2024) and for unrestricted use of biosolids (1.1 µg/kg, HEPA 2025) and leaves major gaps in consumer product regulation. These bans in Australia are not supported by regulation of ingredient labelling in consumer or industrial chemicals. Meanwhile, state-level reviews of biosolids guidelines and resulting tightening contaminant thresholds (NSW EPA 2025) highlight the disproportionate burden on utilities.

While industrial and trade waste discharges remain important contributors, studies from Australian biosolids (Moodie et al. 2021) and empirical analysis of domestic and industrial wastewaters (Hester 2024) suggests that community-derived PFAS remain a significant input to WWTP influent.

STUDY CONTEXT

Importance of Source Control

Evidence shows that source control works, but only with strong and comprehensive measures. For example, chlorofluorocarbons (Velders et al. 2007) and brominated flame retardants (Ma et al. 2024), which had complete bans and were backed by strong enforcement have been effective.

The phase-out of PFAS-based firefighting foams in Australia that commenced 2003 produced measurable declines in PFAS levels in human serum, but this success has taken two decades to materialise (Taucare et al. 2024), and the complete phase out of stocks of these products has yet to occur (Australian Senate 2025).

Meanwhile, the European Union is moving towards a near-total ban on all PFAS under its REACH regulation (ECHA 2026) and New Zealand is banning intentionally added PFAS in cosmetic products, with regulations prohibiting manufacture

and importation, and a total sales ban by the end of 2027 (EPA NZ, 2024).

Research has demonstrated that PFAS precursor compounds especially fluorotelomer phosphate diesters (diPAPs) dominate the mass load of PFAS from WWTP products (Moodie et al. 2021, Thompson et al. 2023a). The diPAP class of PFAS compounds are commonly found in paper and paper-based products, where their use is part of the manufacturing process. These products include toilet paper, has been shown to constitute a major contributor to the total load of diPAPs to wastewater in some systems (Thompson et al. 2023b).

The presence of these (and other) precursor compounds contributes directly to the formation of perfluoroalkyl acids (PFAAs) (Thompson et al. 2023a), which include the most persistent terminal PFAS (and regulated) compounds like PFOS, PFOA and PFHxS. While some transformation reduces precursor load, WWTPs generally act as “converters” rather than destroyers, leading to PFAS release via effluent and biosolids. Accordingly, the urban water sector has long been seen as the easiest point of regulation owing to its role as the receiver and manager of wastewater on behalf of the community.

Biosolids in the circular economy

Biosolids play an important role in the circular economy by returning valuable nutrients, organic carbon and trace minerals from urban wastewater back to productive soils. When beneficially reused in agriculture, biosolids improve soil structure, support crop productivity and reduce reliance on synthetic fertilisers which are subject to significant price fluctuations on the international market. This reuse pathway also diverts large volumes of organic material away from landfill, avoiding the loss of recoverable resources and reducing the environmental impacts associated with disposal.

In Queensland the reuse of biosolids in agriculture is regulated through the End of Waste (EOW) Code Biosolids, which was enacted in 2019 and previously by a Beneficial Use Approval. The code establishes conditions under which treated sewage sludge can cease to be regulated as waste and instead be used as a beneficial product. It sets quality standards, treatment requirements, and management conditions to ensure biosolids can be safely applied to land (e.g. agriculture or rehabilitation) without posing unacceptable risks to human health or the environment. Compliance with the code allows generators and users to manage biosolids under a

product-style framework rather than waste regulation.

Compliance with the EOW Code requires characterising biosolids through monitoring (e.g. metals, nutrients, and contaminants such as PFAS) and confirming treatment and stabilisation criteria are met.

Before land application, soil testing and site assessments establish baseline soil conditions, nutrient status, and contaminant levels. Application rates must then be calculated based on agronomic nutrient requirements and contaminant limits to avoid excessive nutrient loading or contaminant accumulation.

ANALYSIS

PFAS in Queensland biosolids

Data collected for compliance with the EOW Code provide the context for PFAS presence in biosolids. The dataset includes 499 analyses of biosolids from Queensland’s wastewater treatment plants, directed for land application on arable land that is principally used for growing cotton, sugar cane or cattle pasture. The dataset incorporates biosolids derived from a range of sources that include large urban WWTPs as well as those in smaller regional centres.

The dataset (Figure 1) shows that mass of PFAS in biosolids are dominated by five PFAS congeners: the long chain perfluoroalkane sulfonic acid (PFSA) congener PFOS, followed in order of median concentration by the perfluoroalkane carboxylic acids (PFCAs) PFDA, PFHxA, PFOA, and PFNA. Of these PFOS and PFDA also showed the greatest range of concentrations (Figure 2) in addition to having the greatest concentrations overall.

This data is consistent with previous studies from Australian biosolids, with Gallen et al. (2016) reporting that PFDA was present in biosolids in the highest concentrations after PFOS, and Moodie et al. (2021) where PFDA was the most abundant of the PFCAs present.

Sources of PFAS in industrial wastewater

Recently published research from Queensland has provided valuable insights into the sources of PFAS in industrial discharges into wastewater. The study (Keane et al. 2026) aimed to identify and characterise chemical contaminants in industrial wastewater (including PFAS) across multiple industry types to detect industry-specific contaminant signatures and improve source control within sewer catchments. By analysing 132 samples

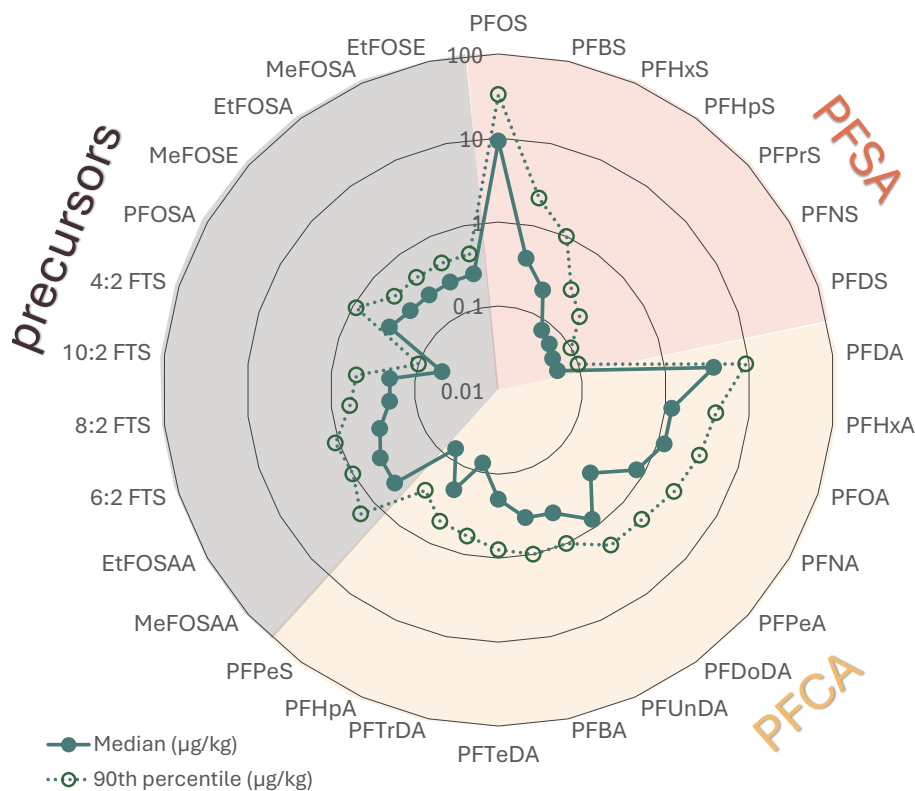


Figure 1. PFAS detected in 499 analyses of biosolids collected under the Queensland EOW code. Data is ranked by the 90th percentile concentration within the PFAS groups. Median concentration is shown for reference.

for conventional wastewater parameters and a wide suite of emerging contaminants, the researchers developed a data-driven model linking particular contaminants with specific industries. The dominant trade waste contributors and concentration of PFAS congeners above background levels are shown in Table 1 as categorised by Keane et al. (2026) into industries as follows: Food = food product manufacturing, Beverage = beverage manufacturing, Chemical = chemical and chemical product manufacturing, Laundry = laundry and dry cleaning services and Waste = waste collection, treatment and disposal services. In this case the waste category included landfills (liquid waste, hardfill, general waste), waste treatment facilities (hazardous and clinical) and recycling facilities (paper, plastic, cardboard, glass, aluminium and municipal wastewater).

Comparison of the dominant trade waste contributors and concentration of PFAS congeners above background levels (Table 1) with the biosolids data shows a disproportionate contribution from the “Waste” category for several for PFAS congeners. In particular, PFDA, which is the second-most concentrated PFAS congener in biosolids was identified at levels in industrial waste that were greater than 200 times baseline levels. Keane et al. (2026) determined that landfill facilities released the

highest concentrations of PFDA, PFOA of all industrial wastewaters. An earlier study (Gallen et al. 2017) found that PFDA was ubiquitously detected in landfill leachate from each of 27 Australian landfill sites.

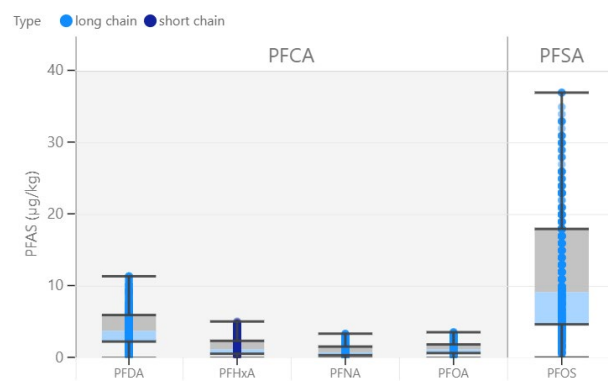


Figure 2. Box and whisker plot of the five most abundant PFAS congeners in Queensland biosolids

PFDA is widely used in a range of consumer products including stain and grease-proof coatings on food packaging, furniture, upholstery, and carpet (USEPA 2024). It has also been identified in flame retardant-treated textiles in conjunction with PFOA (Zhu et al. 2020) and in textile finishing agents available on the Chinese market (Mumtaz et al. 2019). Australia is a significant importer of Chinese manufactured textiles and consumer goods.

PFAS class	PFAS type	Congener	Food	Waste	Beverage	Chemical	Laundry
PFSA	long chain	PFOS		1-10			
		PFHxS		1-10			
		PFDS	1-10			1-10	
	short chain	PFBS	1-10	10-100		1-10	1-10
PFCA	long chain	PFDA		>200		1-10	
		PFOA		1-10			
	short chain	PFHxA		10-100		10-100	
		PFBA	1-10	10-100	1-10	1-10	1-10
		PFPeA	1-10	1-10			
		PFHpA	1-10	1-10			
		PFPeS		1-10			
FASA	precursor	MeFOSE					10-100
FTSA	precursor	6:2 FTS		1-10		1-10	
		8:2 FTS				1-10	
Percentage of total flows			48%	8%	15%	2%	8%
Percentage of total sites surveyed			39%	11%	8%	8%	6%

Table 1. Sources of PFAS for the top five mass flow industries from Keane et al. (2026) with associated concentrations above wastewater baselines.

PFDA is not currently listed on Schedule 7 of the IChEMS register, which means that this chemical and articles containing this chemical are not currently restricted from importation and use in Australia. Without proper enforcement of existing Schedule 7 listed chemicals (PFOS, PFOA and PFHxS and some associated precursor chemicals) it seems likely that the flux of Schedule 7-listed PFAS chemicals into both domestic and industrial wastewater will continue.

Moreover, it is extremely difficult to identify if products contain PFAS in Australia, Material Safety Data Sheets often omit PFAS due to “proprietary ingredient” protections, making compliance impractical. Sector experience has shown that businesses that discharge industrial wastewater are prepared to switch to PFAS-free alternative formulations once identified.

DISCUSSION

Findings of the PFAS senate select committee

The Australian Senate established the Senate Select Committee on PFAS in August 2024 to examine the extent of PFAS contamination in Australia and assess the adequacy of existing regulatory, health, and environmental management

frameworks. The inquiry received extensive evidence from government, industry, researchers, and affected communities, producing an interim report in March 2025 and a final report in November 2025 (Australian Senate, 2025).

Based on the committee’s final report, the Senate Select Committee consistently emphasised that effective management of PFAS must prioritise source control rather than relying on downstream containment or treatment by passive receivers such as water utilities and waste managers.

Overall, the report frames source control as the only scalable, cost-effective and equitable long-term strategy to reduce human and environmental exposure, noting that without decisive upstream action, investments in treatment, monitoring and disposal will continue to escalate while contamination persists across multiple environmental pathways.

Six key recommendations of the Committee can be summarised as follows:

- Fast-track the phase out of legacy PFAS firefighting foams
- Fast-track removal of PFAS from food contact materials

- Resource chemical assessment of PFAS through the AICIS
- Monitoring and enforcement of IChEMS Schedule 7 listing
- PFAS ban in cosmetics and personal care products
- Introduce mandatory PFAS product labelling.

These measures, if properly implemented and funded at a national level will provide a solid foundation to reduce ongoing diffuse loading into wastewater, biosolids, landfill leachate and recycled organics streams.

Outcomes

Partial or inconsistent bans of PFAS and other contaminants of concern are insufficient. Thousands of consumer chemicals and pharmaceuticals enter households daily and cannot be managed downstream. Effective control requires upstream bans before products reach consumers, supported by comprehensive labelling.

The key outcomes from sector analysis and consultation are clear:

- Landfill leachate represents a major opportunity for source management of PFAS and other contaminants.
- Trade waste regulation remains essential, but many diffuse industrial contributions bypass effective controls. Better product labelling and traceability would strengthen trade waste management.
- Community-derived inputs are the greatest challenge. Without broad bans on PFAS in consumer goods, WWTPs cannot prevent environmental entry.
- Sector capacity is being stretched by compliance costs and inconsistent regulation. Investment should shift from end-of-pipe solutions to upstream restrictions for greater long-term benefits.

CONCLUSION

Source control is the only pathway to align biosolids and treated wastewater management with circular economy ambitions. Strengthening IChEMS to include the full PFAS class, lowering allowable trace thresholds, and mandating labelling of PFAS-containing products are immediate priorities. Shifting focus upstream, toward landfills, trade waste, and consumer products, would relieve WWTPs of

inequitable burdens and keep biosolids viable for reuse. Without decisive action, the sector risks escalating costs, regulatory paralysis, and the loss of public confidence in sustainable wastewater management.

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