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Unstoppable? Ultrashort PFAS in the Environment and Water Sources

Ultrashort chain per- and polyfluoroalkyl substances (USC-PFAS), defined as those with three or fewer carbon atoms, are characterised by their significant mobility within the environment, high water solubility, and low affinity for organic matter. These properties contribute to their widespread presence in environmental waters and wastewaters, as well as drinking waters. The environmental concerns associated with USC-PFAS include their persistence, potential for groundwater contamination, and challenges in remediation due to their resistance to conventional treatment methods.

Figure 1: Illustrative picture

Occurrence, uses and sources

Ultrashort chain PFAS have been poorly characterised compared with their longer chain counterparts, and understanding of their intended and unintended transformation processes is limited. Sources of USC-PFAS include degradation of precursor compounds, atmospheric degradation of hydrofluorocarbons and hydrochlorofluorocarbons used as refrigerants, and intentional direct use in products like batteries. Crucially, TFA, a major ultrashort-chain PFAS, is also formed through the environmental breakdown of fluorinated pesticides and pharmaceuticals. They are also byproducts from historical electrochemical fluorination (ECF) manufacture of longer chain PFAS. USC-PFAS are also found in urban and industrial waste, as well as aqueous film-forming foams (AFFFs) used in firefighting.

Fate and transport

Carbon chain length plays a key role in determining the physicochemical characteristics of different PFAS chemicals. Long chain PFAS for instance are more hydrophobic, a property that has been leveraged by removal techniques using carbonaceous materials like granular activated carbon (GAC). By contrast, short and ultrashort chain PFAS are hydrophilic, with characteristically low pKa values (i.e. more acidic), high water solubilities and decreased log Koc values (i.e. less adsorptive to organic carbon). These attributes mean that USC-PFAS dissociate freely in aqueous environments and are less prone to sorption onto natural solids. The outcome is that USC-PFAS are highly mobile in the aquatic environment and can travel far from contamination source areas.

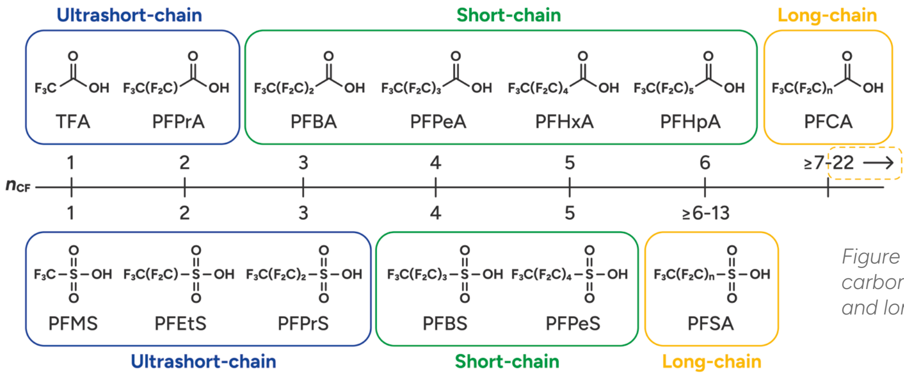

Figure 2: PFSA and PFCA categorization based on carbon chain length – ultrashort-chain, short-chain and long-chain.

The global regulatory landscape

Awareness about the persistence and bioaccumulative nature of C8-C14 PFAS began to attract widespread concern near the turn of the millennium, and inclusion of PFOS, PFOA and PFHxS on the persistent organic pollutants (POPs) list of the Stockholm Convention soon ensued. Consequentially, manufacturers began adopting short and ultrashort chain alternatives.

However, with the change from C8 to C4 and shorter fluorinated carbon chains came the sacrifice to lower technical performance, and greater quantities were needed for equivalent performance. Hence, while it is generally accepted that short and ultrashort chain PFAS have lower toxicological profiles, environmental risks are not necessarily obviated since USC-PFAS presence, and continuous, cumulative, release suggests that adverse risks may lie ahead.

Global regulations of USC-PFAS vary by region and are often included under broader PFAS regulations. For example, the European Union has specific guidelines and limits for the total concentration of PFAS compounds in drinking water (as set out in EU Directive 2020/2184). The EU's Drinking Water Directive established a limit of 0.5 µg/L for 'PFAS Total,' although ongoing discussions concern the specific methodology for incorporating trifluoroacetic acid (TFA). Furthermore, TFA was recently added to the priority list for the initial proposed sum of 24 PFAS in surface water. LINK

PFAS Sampling Containers

Only tested and verified sampling containers are recommended to ensure reliable results in PFAS analysis; these containers are available upon request from ALS laboratories.

Targeted analytical services are becoming more accessible

Testing for USC-PFAS is challenging due to several analytical factors. Background contamination and matrix noise can interfere with the detection of these compounds, particularly trifluoroacetic acid (TFA). Furthermore, sample preparation presents a significant challenge because of the constant risk of cross-contamination. To mitigate this risk, the sample preparation procedure was specifically designed to be as simple and straightforward as possible. Other USC-PFAS compounds generally have lower ambient background concentrations, which makes achieving lower Limits of Reporting (LOR) more readily achievable. ALS has successfully developed a testing method that includes USC-PFAS compounds in environmental water matrices, achieving a total LOR of 50 ng/L for TFA and even lower LORs for other USC compounds. The full list of analyzed USC-PFAS is summarized in table 1.

Table 1 – Scope of target analytes

USC-PFAS Compounds	CAS No.
Trifluoroacetic acid (TFA), Perfluoroethanoic acid (PFEtA)	76-05-1
Trifluoromethane sulfonic acid (TFMS), Perfluoromethane sulfonic acid (PFMeS)	1493-13-6
Perfluoroethane sulfonic acid (PFEtS)	354-88-1
Perfluoropropanoic acid (PFPrA)	422-64-0
Perfluoropropane sulfonic acid (PFPrS)	423-41-6
Trifluoromethane sulfinic acid	34642-42-7
Lithium bis(trifluoromethanesulfonyl) imide (LiTFSI)	90076-65-6

References

LINK Directive (EU) 2020/2184 of the European Parliament and of the Council of 16 December 2020 on the quality of water intended for human

LINK Council of the EU, 23 September 2025: Water pollution: Council and Parliament reach provisional deal to update priority substances in surface and ground waters