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Editorial

Relevance of PFAS (per- and polyfluoroalkyl substances) contamination to the environment and sustainable development

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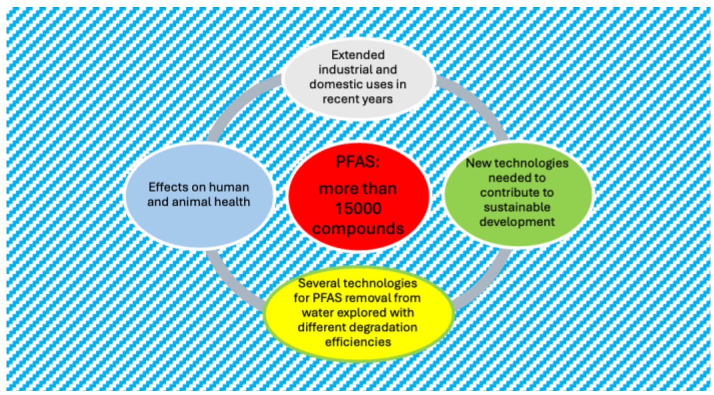

Highlights

- *Per- and polyfluoroalkyl substances (PFAS) are priority pollutants.*
- *PFAS have a chain of strongly linked carbon and fluorine atoms.*
- *PFAS are "forever chemicals" causing multiple health effects.*
- *Several remediation technologies for PFAS in water are possible.*

Abstract

Following the objective of the *Journal of Environmental Science, Health & Sustainability* to provide a dedicated platform to report important environmental problems, this editorial aims to motivate the readers to stay aware of the dramatic situation represented by per- and polyfluoroalkyl substances (PFAS) and how they are related to sustainable development. PFAS are a large and complex class of synthetic chemicals that have been extensively used in consumer products globally since the 1950s. These molecules have a chain of linked carbon and fluorine atoms, and, due to the high strength of the C-F bonds, they do not degrade and are environmentally persistent. For these reasons, humans and animals are exposed to these compounds, causing multiple health effects, and these "forever chemicals" have been declared priority pollutants. PFAS interfere with Sustainable Development Goals because they undermine goals related to clean water, good health, and sustainable ecosystems. They contaminate water and soil, harming wildlife and human health by potentially causing reproductive and developmental issues, increased cancer risk, and immune system suppression. Addressing this requires phasing out non-essential uses and developing solutions for decontamination and sustainable water management. In this sense, several technologies have been attempted to degrade these persistent and toxic pollutants from water, achieving different efficiencies. The PFAS chemical structure, applications, effects on human health, and some remediation solutions are mentioned in this editorial with the objective of relating these aspects to sustainable development.

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1 Introduction

Per- and polyfluoroalkyl substances (PFAS) are a complex group of synthetic chemicals which have been incorporated into consumer products since the 1950s. The molecules belong to a group of nearly 15,000 synthetic chemicals having a chain of linked carbon and fluorine atoms (National Institute of Environmental Health Science, 2025). These C-F bonds are extremely strong and resistant to several treatments for degradation.

There are different types of PFAS, the most important classes being perfluoroalkyl carboxylic acids (PFCAs), perfluoroalkyl sulfonic acids (PFSAs), and perfluoroether carboxylic acids (PFECA) (Ohoro et al., 2024). **Figure 1** shows the chemical structures of some PFAS (Blake and Fenton, 2020).

The strong carbon-fluorine bonds make PFAS stable and resistant to the attack of various chemicals and processes. The compounds are chemically inert, thermally stable, heat resistant, and present low molecular polarity, and hydro- and oleo/lipophobicity (Yadav et al., 2024). Perfluorooctane sulfonic acid (PFOS, $C_8F_{17}SO_3H$) and perfluorooctanoic acid (PFOA, $C_7F_{15}COOH$) are the most popularly used PFAS (**Fig. 1**). A substitute of PFOA, GenX, a hexafluoropropylene oxide dimer acid (HFPO−DA), is now an important alternative to PFOA (Guo et al., 2025). Similarly, perfluoroalkane sulfonamides and their derivatives (FASAs, $C_nF_{2n+1}SO_2NH_2$) are increasingly used as replacements for legacy PFAS (Ma and Olivares, 2025).

2 Application of PFAS

Due to their properties, PFAS are appropriate for multiple consumer and industrial applications (Ohoro et al., 2024). Among them, the most relevant use is in the food industry, e.g., as fast-food wrappers, in bags for microwave popcorn, tableware, boxes for takeaway, baking paper, coffee cups, and others. They are extensively employed by families, including children and young people, due to the popularity of fast-food consumption. Additionally, PFAS have multiple applications such as firefighting foams, household cleaners, cosmetics, explosives, medicine, oil and gas, plastics, refrigerants, transportation, ink production, paints, and surfactants.

3 Concerns about PFAS application and effect on health

Widespread use of these chemicals causes an increasing occurrence of PFAS in soils, ground- and surface water, wastewater, drinking water and sediments (Racz and Kempisty, 2021), and there is an augmentation of the exposure of people and animals to these pollutants through contaminated water, food, or air (National Institute of Environmental Health Science, 2025). Although PFAS levels in surface and groundwater are low (ng L^{-1} to μg L^{-1}), their widespread presence in aquatic environment highlights the strong link between the water cycle and the human environment. The highest PFAS concentrations in surface waters (68,500 ng L^{-1}) were found in China, those in sediments (2,800 ng g^{-1}) were reported in Finland and those in biota (4,600 ng g^{-1}), in Sweden. China and the USA accounted for 28% and 19% of the studies about the distribution of PFAS concentrations in the world, while studies from Africa and Australia are only 5%, South America having the least (2%, with data only from Brazil) (Ohoro et al., 2024).

PFAS are hardly (bio)degradable, toxic to humans and animals, highly persistent and possibly bioaccumulative, being called "poisons of the century" or "forever chemicals" (Fang et al., 2024). They have been linked to several health problems, such as reduced immune response, cancer, steroid hormone disturbances, infertility, lipid and insulin dysregulation, liver or kidney disease, altered immunological and thyroid function, cardiovascular effects, and developmental effects (Ohoro et al., 2024). The USEPA qualified these substances as pollutants of emerging concern (USEPA, 2006). PFAS are categorized into two main families according to their molar mass: i) low molar mass products (<1,000 Da), which are toxic, mobile, bioaccumulable, and cross the human membranes, and ii) those of much higher molar masses (macromolecules), which are safe and reliable, and do not cross the cellular membranes (Ameduri, 2025). There are several global advisory guidelines with the aim of reducing the prevalence of PFOS and PFOA in aquatic ecosystems (Ohoro et al., 2024). Additionally, the presence and accumulation of GenX in natural waters and biological species causes alarm, as it is considered potentially more toxic than legacy PFAS (Wen et al., 2023).

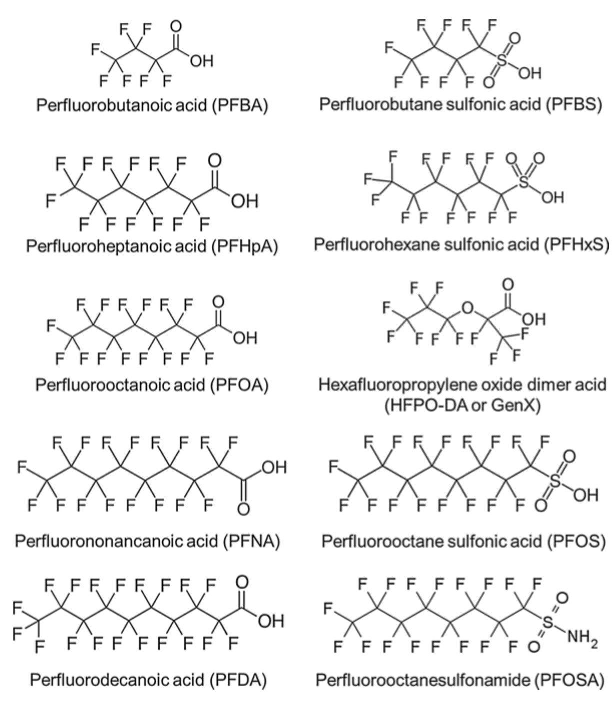

Figure 1. *Structures of some PFAS (Blake and Fenton, 2020). Reproduced with permission.*

So far, only three PFAS have been included under the Stockholm Convention, which seeks to eliminate or restrict persistent organic pollutants: PFOS, whose use is limited to a few exceptions, and PFOA and perfluorohexanesulfonic acid (PFHxS), both banned globally (Häubi and Turuban, 2025). In 2024, EPA announced the final National Drinking Water Standards for six PFAS with individual maximum contaminant levels (MCLs) values of 4.0 ng L^{-1} for PFOA and PFOS, 10 ng L^{-1} for PFNA, PFHxS, and GenX, and a HI value of 1 for a mixture of PFNA, PFHxS, GenX and PFBS (EPA, 2025), where the HI (Hazard Index) of 1, as used in environmental risk assessments, indicates that exposure to a substance is at the level where non-cancer health effects are considered possible. In 2020, the European Food Safety Authority decreased the tolerable daily intake to 0.63 ng kg^{-1} of body weight for the sum of four PFAS, i.e., PFOA, PFOS, PFNA, and PFHxS (Schrenk et al., 2020; Moghadasi et al., 2023).

4 Possible treatments of PFAS

Effective PFAS treatment technologies are mandatory for the most toxic forms. Treatment of PFAS-contaminated water includes conventional technologies such as adsorption, ion exchange, coagulation, sand filtration, biological treatment, and most advanced technologies such as nanofiltration, reverse osmosis, catalytic oxidative or reductive degradation, or electrocatalysis (e.g., Verma et al., 2021; Leung et al., 2022; Gomri et al., 2024). From them, adsorption on activated carbon and membrane filtration are the most used. In the last decades, several advanced oxidation/reduction processes (AOPs/ARPs), such as sonolysis, persulfate oxidation, electrochemical treatment, ultraviolet (UV) photolysis, UV-Fenton process ($UV/Fe^{2+}/H_2O_2$), UV+sulfite, photocatalysis, cavitation, etc. (which produce strong oxidative species like hydroxyl radicals (HO•) have been developed for PFAS degradation (Alalm and Bofitto, 2022; Esfahani et al., 2024; Wang et al., 2025; Tshangana et al., 2025). In recent years, nanotechnology has gained prominence as an effective tool for the removal of pollutants from wastewater. Nanoparticles, small atomic clusters in the 1–100 nm range with size-dependent properties (Litter, 2018), have been studied for PFAS removal from water (Birch et al., 2022; Yin and Villagrán, 2022). Particularly, zerovalent iron nanoparticles (nZVI), low-cost materials with high reactivity and good adsorption activity, have been recently tested (Pasinszki and Krebsz, 2020).

The degradation pathways of PFCAs and PFSAs have been investigated more than those of any other PFAS. Especially, one of these compounds, PFOA, is resistant to most conventional reduction and oxidation processes, and it also does not readily break down through biological processes (Qian et al., 2020). Analysis of the use of zerovalent iron nanoparticles has been reported recently (Litter, 2025, submitted).

5 Conclusion

This editorial underline the importance of PFAS regarding the environment and the need to provide solutions to this problem due to the dramatic effect of these "forever" pollutants on humans and animals health. PFAS interfere with Sustainable Development Goals (SDGs) (United Nations, 2025), especially SDGs 3 (Good Health and Well-being), 6 (Clean Water and Sanitation), and 12 (Responsible Consumption and Production) because they are persistent environmental pollutants that undermine goals related to clean water, good health, and sustainable ecosystems. They contaminate water and soil, harming wildlife and human health by potentially causing, among others, reproductive and developmental issues, increased cancer risk, and immune system suppression. Addressing this requires phasing out non-essential uses and developing solutions for decontamination and sustainable water management.

6 Data availability statement

Not applicable.

7 Ethical statements

Not applicable.

8 Conflict of interest

The author declares no conflict of interest.

9 Author contributions

Marta I. Litter conceptualized the study and wrote the manuscript. The author approved the final version of the manuscript.

10 Copyright statement

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