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Editorial: Occurrence, Fate, and Treatment of Perfluoroalkyl and Polyfluoroalkyl Substances in the Environment and Engineered Systems

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Editorial on the Research Topic

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Per- and polyfluoroalkyl substances (PFAS) are fabricated chemicals comprising over 4,700 species. They have been applied in a wide range of products to achieve different purposes for more than 5 decades. PFAS have been extensively formulated in consumer products such as food packaging, paper industry, cosmetics, petroleum products, clothing materials, and aqueous film-forming foams (AFFFs). The complex structures of PFAS derive from the diversity in functional groups, interchangeable ionization state, chain length, and degree of branching. Despite their high versatility in physiochemistry, the per/poly-fluoroalkyl moiety generally leads to high thermal stability, great hydrophobicity and oleophobicity. In addition, ionizable and polar headgroups in their structures often result in the properties of surfactants.

PFAS emissions occur unintentionally during fluoropolymer processing, decomposition, and discarding of PFAS-containing products. Transformation through biochemical processes is generally initiated from their labile non-fluorinated groups. The perfluoroalkyl groups are highly resistant to different treatment processes. The current of surface water or groundwater governs their occurrence at the regional scale, while the oceanic and atmospheric transport make them ubiquitous contaminants. PFAS are nowadays commonly found in wastewater influents. However, their removal efficiency in conventional biological and chemical treatment processes including advanced oxidation processes is not sufficient to remove PFAS residuals from the wastewater, resulting in their accumulation in natural water bodies. Recent advances in tracing PFAS using deuterated nitrogen indicated a clear link between release of PFAS and biomagnification in human food as presented in "Kaboré et al.".

Even though most studies suggest that water is the primary carrier of PFAS, leading to their widespread presence in the environment, recent studies concluded that the atmospheric deposition of PFAS is also an important contamination route of the environment. As documented, the distribution radius of PFAS atmospheric deposition may exceed 45 km from the source of release. However, the maximum PFAS concentration may be found within 20 km of the wind direction from the manufacturing source.

In the early 2000s, the presence of perfluoroalkyl acids (PFAAs) in serum of human blood and detection of perfluorooctane sulfonate (PFOS) in remote habitats and polar bears raised public concerns about their potential toxicity and environmental impacts. In 2015, the public health concerns ended the production line of long-chain PFAS in several countries and prompted the production of short-chain species instead.

While many studies have reported PFAS accumulation in shallow water bodies and soils, their impacts on fisheries and aquaculture have not been well discussed. For example, bullfrog (*Rana catesbiana*), an ecosystem health indicator species, is highly prone to bioaccumulation of PFAS. This health threat has been highlighted in "Sun et al.". The PFAS accumulation in such species and appropriate risk assessment should be a priority in evaluating the impact of PFAS on the nexus of Food-Water-Energy.

While low levels of PFAS are broadly detected in the environment, finding hotspots and source control of PFAS might be a more effective approach to limit their negative effects. However, it still requires sampling from soil or water, which is often costly. Efforts in tracking their source have usually centered around linking specific PFAS components to a particular formulation, using statistical methods (i.e., Principal Component Analysis), or machine learning techniques. However, new tools to be used on-site have high interest as they provide real-time data. Design and development of polar organic chemical integrative samplers (POCIS) in "Hale et al." have been suggested for PFAS detection in environments due to easy management and cost benefits. POCIS can significantly enhance the control and management of PFAS emissions from multiple point/non-point sources. The time-averaged concentration and low detection limits of POCIS allow characterizing PFAS in water bodies, troposphere, and wastewater.

The published articles are a resourceful collection for scientists and engineers who are interested in understanding the issues of PFAS and in developing environmental strategies and actions to mitigate their effects. Explicitly, the articles included in this Research Topic conclude innovative source tracking, validation, and analysis strategies for PFAS assessments in environmental matrices and living tissues. We believe that this Research Topic highlights the present state of PFAS concerns and showcases innovative directions that expand our understanding of the toxicity, persistence, and fate of PFAS, and horizons for developing strategies to remediate PFAS polluted water and soil.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct, and intellectual contribution to the work, and approved it for publication.

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