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1 Introduction

A PFAS introduction Video is available.

Per- and polyfluoroalkyl substances (PFAS) constitute a large family of fluorinated chemicals, exceeding several thousand that might be in commercial use or the environment, that vary widely in their chemical and physical properties. The number of PFAS and their uses have expanded over the years. It has been estimated that the PFAS family may include more than 12,000 chemical substances (USEPA 2020). A recent inventory of PFAS identified more than 4,700 PFAS with Chemical Abstracts Service (CAS) Registry Numbers that could have been, or may be, on the global market (OECD 2021), although the uses of each of these PFAS may not be known (KEMI 2015). More information is included in Section 2.

The persistence and mobility of some PFAS, combined with decades of widespread use in industrial processes, certain types of firefighting foams, and consumer products, have resulted in their being present in environmental media at trace levels across the globe. PFAS have relatively recently come to the attention of investigators and the public in large part due to the fact that until the early 2000s analytical methods to detect low levels of PFAS in the environment were available only in a few select research institutions. It was not until the early 2010s that these methods to detect a limited number of PFAS became widely available and had detection limits in water low enough to be commensurate with levels of potential human health effects. Toxicological studies have raised concerns regarding the bioaccumulative nature and potential health concerns of some PFAS (Section 7). As a result, our understanding of PFAS and the risks they may pose is rapidly evolving.

Broadly speaking, PFAS are characterized as having carbon atoms linked to each other and bonded to fluorine atoms, by which the fluorination imparts properties to the molecule. The carbons may be partially fluorinated (polyfluorinated) or fully fluorinated (perfluorinated). Modifying characteristics, such as addition of a functional group, other substitutions (for example, chlorine), and partial fluorination, are described in Section 2.2 along with evolving definitions of PFAS.

This guidance document is designed specifically to support state and federal environmental staff, as well as others (including stakeholders, project managers, and decision makers), to gain a working knowledge of the current state of PFAS science and practice. Developed by a team of over 500 environmental practitioners drawn from state and federal government, academia, industry, environmental consulting, and public interest groups, it also provides a summary of the current understanding of all aspects of PFAS from a broad perspective. While every effort was made to keep the information accessible to a wide audience, it is assumed the reader has some basic technical background in chemistry, environmental sciences, and risk assessment. The document addresses the following questions:

Questions	Document Sections
What are PFAS?	• Naming Conventions and Use • Chemistry, Terminology, and Acronyms • PFAS Uses and Products • PFAS Releases to the Environment • Firefighting foams (AFFF)
How do they behave in the environment?	• Physical and Chemical Properties • Environmental Fate and Transport Processes • Media-Specific Occurrence
Why are we concerned about PFAS?	• Human and Ecological Health Effects • Basis of Regulations • Site Risk Assessment • Surface Water Quality
How do we evaluate PFAS in the environment?	• Site Characterization • Sampling and Analysis • Case Studies

Questions	Document Sections
How do we remediate PFAS?	• Treatment Technologies
What are the major concerns of communities and Tribes and how do we share what we know about PFAS?	• Stakeholder Perspectives • Risk Communication

The thousands of chemicals that make up the large family known as PFAS can be divided into two major classes: nonpolymers and polymers. This document focuses primarily on those nonpolymer PFAS that, to date, are most commonly detected in the environment, particularly the highly persistent perfluoroalkyl acids (PFAAs), some of the better-known replacements for phased-out long-chain PFAAs, and some of the precursor chemicals—PFAS that can break down to form PFAAs. These precursors include *poly*fluorinated alkyl substances and a subset of polymer PFAS known as side-chain fluorinated polymers (Washington et al. 2018). Many polymer PFAS, especially certain high–molecular weight fluoropolymers, are insoluble in the environment and not bioavailable, and therefore less of a concern to human and ecological health (Henry et al. 2018), so are not discussed in detail in this document. As this paragraph illustrates, it is important to be clear about which PFAS is being discussed and what its particular physical and chemical properties are.

The physical and chemical properties that make some PFAS persistent and mobile in the environment also make them particularly challenging to analyze and remediate. Analytical methods sensitive enough to detect environmentally relevant concentrations became widely available in the early 2010s. Although analyte lists continue to expand, and methods continue to be developed, currently available methods still only allow identification of a small fraction of the thousands of PFAS that have reportedly been created and used since the 1950s. As existing analytical methods improve and new, nontargeted analyses become commercially available, it is likely that additional PFAS and new release sites will be identified.

Concerns have been raised regarding human health and ecological risks associated with certain PFAS. These are based on widespread detections of some PFAS in humans and wildlife, evidence that certain PFAS bioaccumulate in individuals and bioconcentrate in the food chain, and studies reporting multiple toxicological effects in animals and potential health effects in humans. However, risk assessment of PFAS is hampered by the unique physical and chemical properties of many PFAS, which result in uncertainty in identifying sources and quantifying source area mass, complex fate and transport in the environment, poorly understood biological and chemical transformation pathways, and unique bioaccumulation processes. Moreover, the widespread presence of some PFAS in environmental media and the many potential PFAS sources also complicate interpretation of site data. Data evaluation methods to help distinguish between site-specific anthropogenic “background” PFAS, PFAS that are site-related, and PFAS from another nearby source are still being developed.

As with other emerging contaminants, our evolving understanding of PFAS and the volume of scientific studies makes it difficult for most environmental practitioners to stay current with the critical information about these chemicals. Meanwhile, public concern about PFAS has created pressure on state and federal agencies to take action, resulting in evolving regulatory approaches and regulatory standards, screening values, and guidance values. Our understanding of PFAS will continue to improve as more scientific research is completed and published.

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