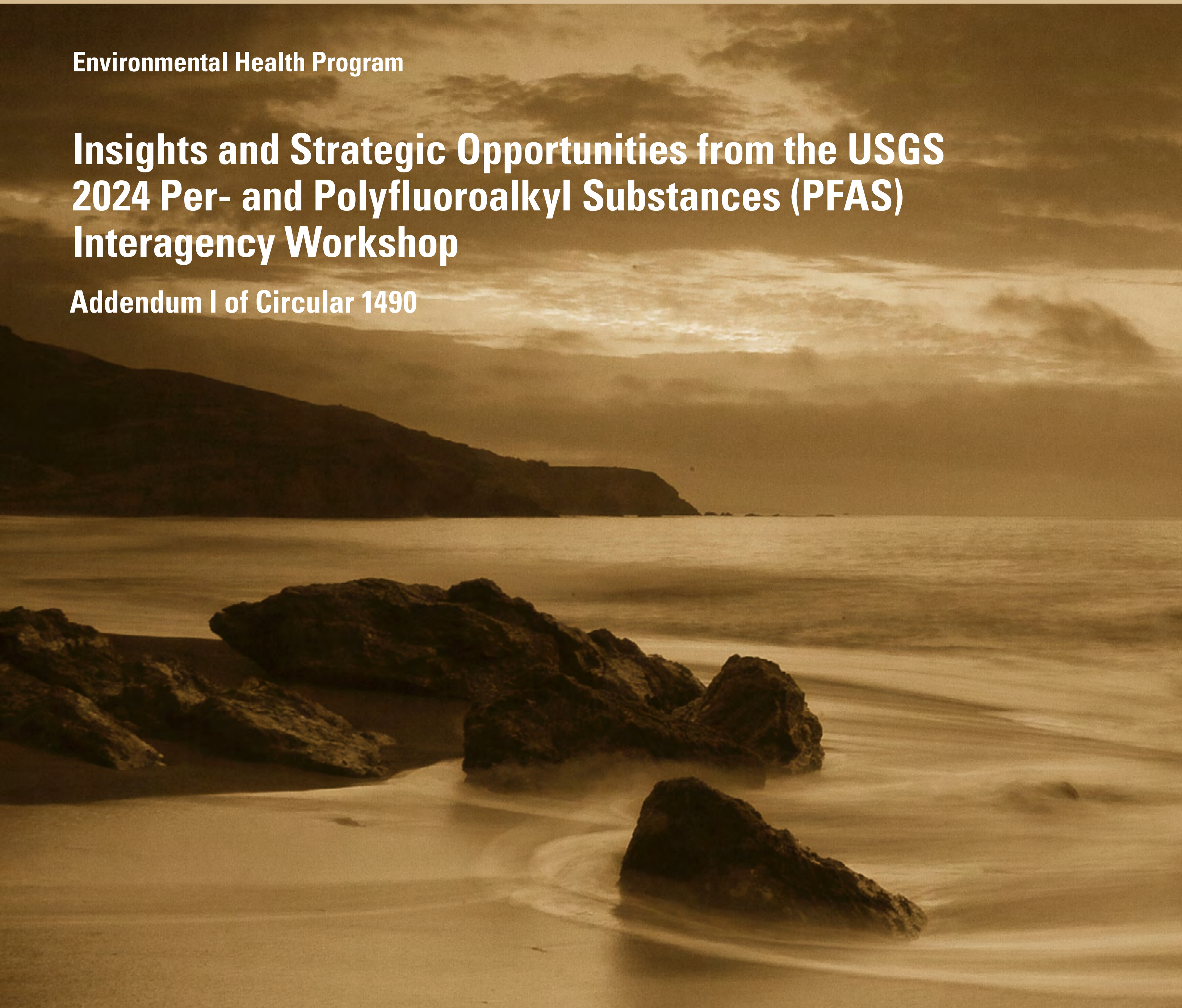
Environmental Health Program

Insights and Strategic Opportunities from the USGS 2024 Per- and Polyfluoroalkyl Substances (PFAS) Interagency Workshop

Addendum I of Circular 1490



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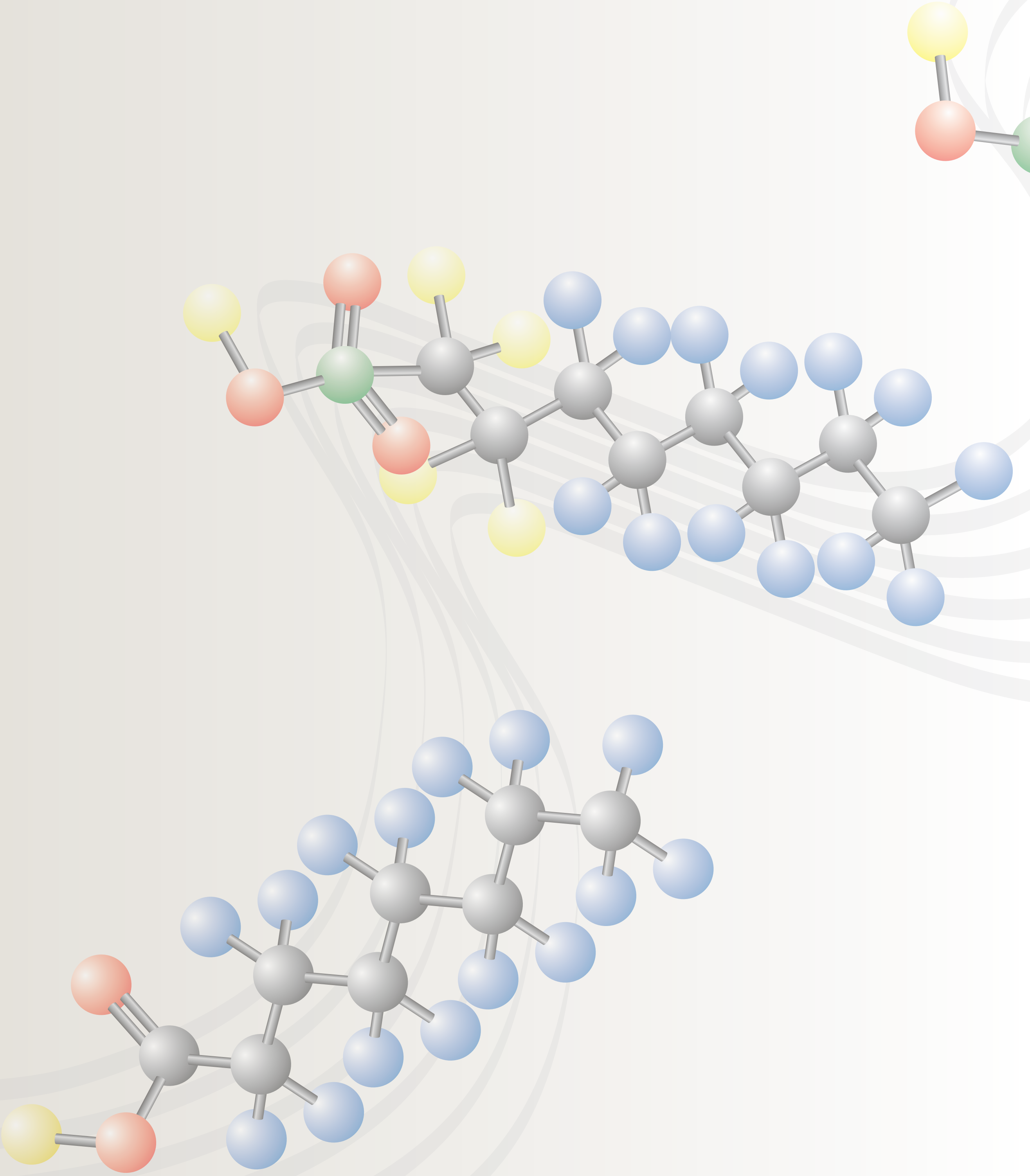

Cover: A storm clears at sunset at Rodeo Cove, California. Photograph by Scott K. Jackson, U.S Geological Survey.

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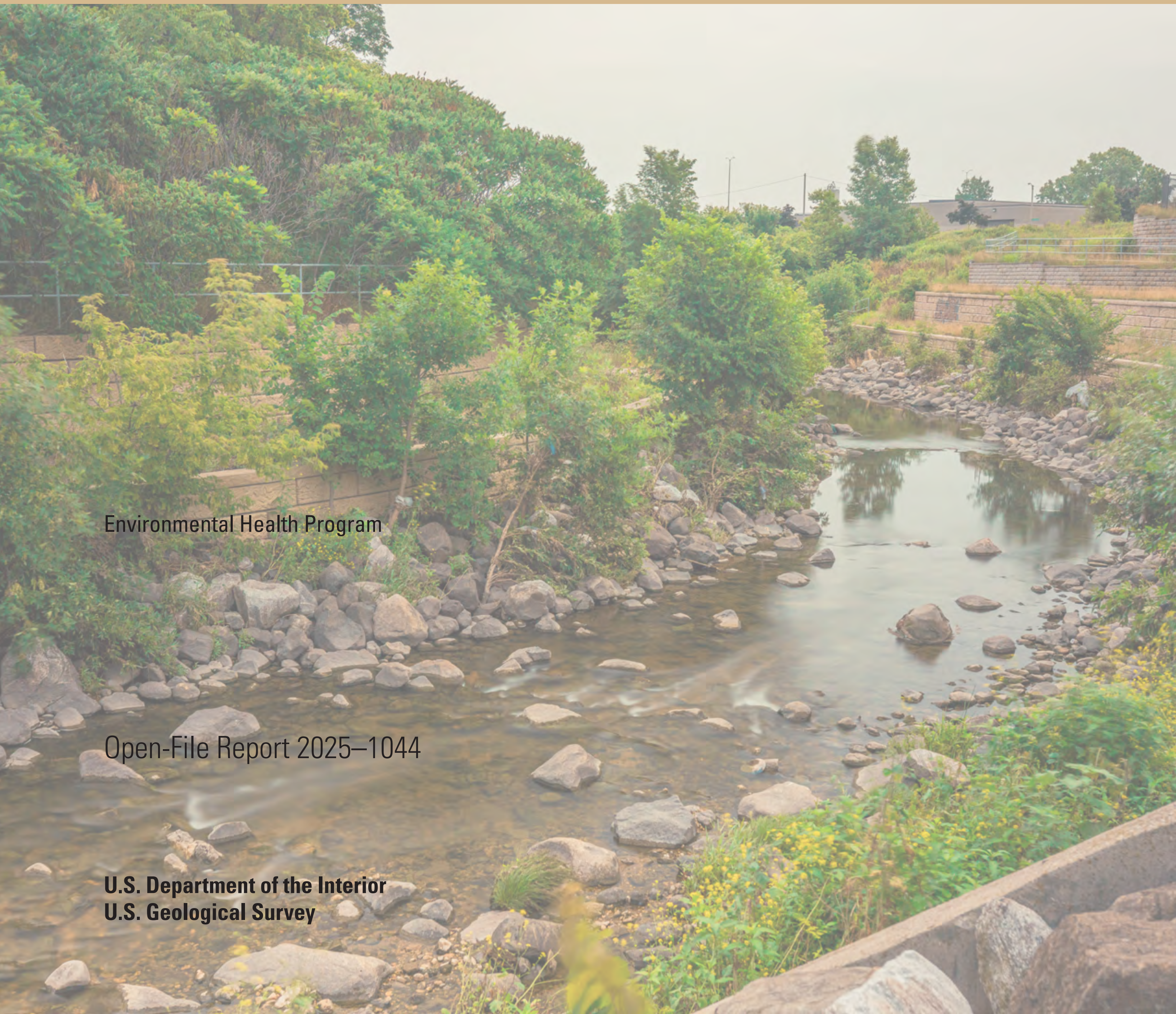

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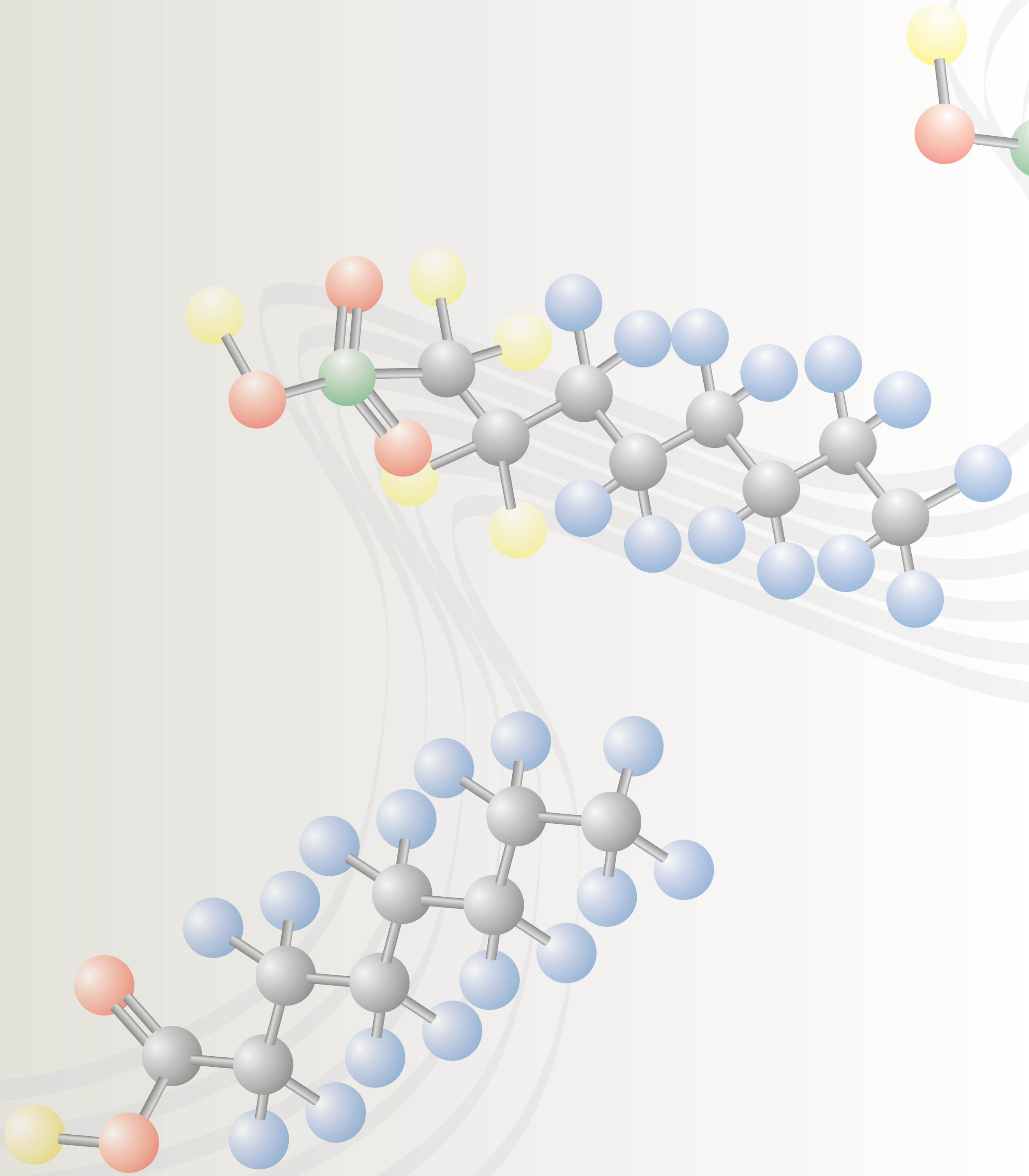
PFAS per- and polyfluoroalkyl substances

USGS U.S. Geological Survey



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Introduction

In 2021, the U.S. Geological Survey (USGS) published Circular 1490 titled, "Integrated Science for the Study of Perfluoroalkyl and Polyfluoroalkyl Substances (PFAS) in the Environment: A Strategic Science Vision for the U.S. Geological Survey" (Tokranov and others, 2021). Circular 1490 was created to be a resource for USGS scientists prioritizing and planning research related to per- and polyfluoroalkyl substances (PFAS) and to be a guide for developing partnerships with other scientists, State and Federal agencies, and stakeholders engaged in PFAS research and management and mitigation of the environmental and human-health effects of PFAS. This USGS PFAS Strategic Science Vision document was intended to be the foundation for a "living strategic vision," periodically providing updates on the state of USGS PFAS research, emerging PFAS data gaps and needs, and progress on interagency and stakeholder PFAS partnerships and priorities. To meet this objective, the USGS planned to host an Interagency and Stakeholder PFAS Workshop every 2–3 years.

During September 10–12, 2024, the USGS hosted the first Interagency and Stakeholder PFAS Workshop in Reston, Virginia. The Workshop brought together experts from other Federal agencies (U.S. Environmental Protection Agency, National Institute of Environmental Health Sciences, Food and Drug Administration, Department of Defense [Air Force, Army]), State agencies (Washington Fish and Wildlife, Virginia Department of Transportation), and academia (Harvard University, University of Maryland) to address key challenges relating to the measurement and modeling of PFAS and the implications for environmental health. Participants engaged in in-depth discussions centered around six pivotal topics related to PFAS: (1) sampling protocols, methods and interpretation; (2) environmental sources, source apportionment, and occurrence; (3) environmental fate and transport; (4) human and wildlife exposure routes and risk; (5) bioconcentration, bioaccumulation, and biomagnification; and (6) ecotoxicology and effects. Each topic had three breakout sessions.

A recurrent theme of workshop discussions was how data on a nationwide scale for PFAS occurrence in various environmental matrices, including air, water, food crops, biota, soil, and streambed sediment could help to advance scientific understanding. Participants noted significant geospatial data gaps, particularly in the midwestern and southern United States and the Pacific Northwest. PFAS data collection tends to be more robust along the eastern seaboard and in California.

Participants stressed how enhancing the integration of large and small datasets across various agencies could help to support national scale understanding of PFAS. To address these gaps, attendees suggested leveraging datasets from Federal entities like the USGS and the U.S. Department of Defense, State agencies, and municipal utility services to develop predictive contaminant detection and transport models. Improved coordination between water quality programs and USGS research could help to facilitate access to valuable data, leading to comprehensive databases that inform PFAS point (wastewater treatment plants and landfills) and nonpoint (runoff from land, atmospheric deposition, food packaging) sources, environmental transport mechanisms, environmental detection and concentrations, potential exposure routes, and health effects on different biota, including humans. A specific request was made to develop a map demarking the depth of modern (1953 or later) groundwater, which is susceptible to surface-derived anthropogenic (that is, human-made) contamination, based on tritium-age dating. Emphasis was placed on incorporation of hydrology, groundwater flow paths, groundwater–surface water interactions, and landscape factors in predictive statistical models as a step to improve contaminant source identification and tracking.

Molecular fingerprinting approaches garnered attention as techniques to link specific PFAS mixtures detected in a sample to environmental sources and levels in biota (Dávila-Santiago and others, 2022). Integrating data from abiotic (that is, water, soil, and air) and biotic (that is, living organisms) systems identified as a research opportunity. For example, understanding the composition of soils and sediments, which include a mixture of mineral, plant, and animal components, could advance understanding of exposure pathways.

The discussions highlighted opportunities to explore and understand the potential redistribution and biotic exposures of PFAS from biosolid and wastewater treatment plant effluent land application practices, in addition to atmospheric releases and discharges from landfill and wastewater treatment plants. Participants identified research gaps surrounding how these sources may contribute to contamination and may affect surrounding ecosystems, including a better definition of anthropogenic background concentrations.

Moving forward, the collection of co-occurrence data was noted as a means to improve understanding of complex mixtures and to leverage companion modeling efforts focused on areas with high and low contamination levels to identify areas of concern and unaffected resources. Participants emphasized how centralized USGS databases and the establishment of sample-metadata archives can help to ensure that samples are preserved and accessible for future research.

In conclusion, the workshop participants identified opportunities to bridge data gaps and improve measurement techniques, modeling frameworks, databases, and communication, to enhance the understanding of PFAS and their effects on environmental and human health. Upon completion of the workshop, participants indicated an interest in developing strategic data collection, modeling, and analytical approaches to address these challenges.

USGS Interagency and Stakeholder PFAS Workshop (2024) Discussion Topics and Recommendations

The organization of the following is based on chapter 2 of “Integrated Science for the Study of Perfluoroalkyl and Polyfluoroalkyl Substances (PFAS) in the Environment: A Strategic Science Vision for the U.S. Geological Survey” (Tokranov and others, 2021, p. 11–31). Topic-specific breakout sessions (table 1) took place over the course of 3 days. Each session lasted a total of 90 minutes and included two moderators, a notetaker, and attendees. Session notes were subsequently organized, edited, and reviewed by notetakers and the PFAS Workshop Committee and compiled into the following list of potential opportunities for future PFAS research.

Table 1. Overview of the 2024 U.S. Geological Survey per- and polyfluoroalkyl substances (PFAS) workshop breakout sessions by topic.

[AFFF, Aqueous Film-Forming Foam, a type of firefighting foam designed to suppress flammable liquid fires, particularly those involving fuels such as gasoline, diesel, and aviation fuel; WWTP, Wastewater Treatment Plant, a facility designed to treat and manage wastewater from a variety of sources (residential, industry and commercial) before the treated water is released back into the environment or reused]

Topic	Breakout Session
1. Sampling Protocols, Methods and Interpretation	A. Sampling Protocols, Analytical Methods and Interpretation
	B. Analytica Capabilities Including Method Development
	C. Total PFAS and Non-Target Analysis
2. Environmental Sources, Source Apportionment, and Environmental Occurrence	A. Point and Nonpoint Sources (AFFF, WWTPs, biosolids, atmospheric deposition)
	B. Source Apportionment Tools and Methods
	C. Occurrence and Predictive Modeling of Water Resources, Soils, Atmospheric Deposition and Biota
3. Environmental Fate and Transport	A. Solid, Water and Air-Water Sorption
	B. Biotransformation rates, Mechanisms and products, fate processes and remediation
	C. Fate and Transport Modeling
4. Human and Wildlife Exposure Routes and Risk	A. Human Exposure Risk—Drinking Water
	B. Human Exposure Risk—Food
	C. Aquatic and Terrestrial Wildlife: Food Web
5. Bioconcentration, Bioaccumulation, and Biomagnification	A. Uptake in Aquatic Systems
	B. Uptake in Terrestrial Systems
	C. Trophic Transfer and Food Web Modeling
6. Ecotoxicology and Effects	A. Effects of Regulatory Concern
	B. Mode of Action
	C. Cross-Species Extrapolation and Identifying Sensitive Bioindicators Across Species

Sampling Protocols Methods and Interpretation

Sampling Protocols

- Conduct more rigorous testing of field sampling equipment to understand sorption and contamination issues and ensure reliable data collection.
- Compare historic sampling methods across different agencies to assess biases and improve understanding of previously collected data.
- Improve and standardize lake-sampling procedures and instrument cleaning methods to ensure consistency in data collection.
- Assess the sorption behavior of stainless-steel churns over time and evaluate how different blank collection methods affect results.
- Facilitate cross-review of protocols and method publications by different groups to provide cohesive sampling strategies and most current information.
- Conduct rigorous blank sampling studies to standardize protocols and address conflicting guidance from multiple agencies regarding sampling materials and practices.

Analytical Capabilities and Method Development

- Enhance knowledge of PFAS sources, molecular fingerprinting capabilities, and analytical capabilities to include a broader range of individual PFAS (target and nontarget analytes) and more comprehensively estimate PFAS contamination. Gather complete exposure data, focusing on human exposures from water, food (including packaging), and atmospheric sources, to support improved cumulative assessments of PFAS-exposure risk.
- Establish lower detection limits for effective source tracking and regulatory compliance to address the fundamental challenges on method consistency, detection limits, and matrix effects.
- Standardize sampling protocols and terminology (for example, method detection and reporting limit) to ensure comparability across methods, improve communication among agencies, and support data aggregation.
- Increase laboratory staffing and instrumentation to increase sample capacity and throughput, reduce backlogs, and improve data delivery times.
- Connect target and nontarget analyses to provide a more complete dataset on PFAS exposure(s).
- Foster collaboration through regular workshops, develop a nontarget database to identify frequently found nontarget compounds, and create methods compatible with existing lab equipment for efficient analyses.

Total PFAS and Nontarget Analysis

- Develop and standardize mass balance and total organic fluorine methods for inclusion in the analytical toolkit.
- Assess the value of redundancy in nontarget analysis, particularly for addressing data gaps in aqueous environments (for example, groundwater, surface water, and aquatic sediments).
- Build, in collaboration with State and other Federal agencies, a comprehensive target, suspect, and nontarget analyte list to identify frequently detected compounds, determine commonly tested compounds that are frequently not found in environmental samples, assess detection frequencies across various media (water, sediment, biota), and support the implementation of relevant toxin assessments.
- Determine lower detection limits for nontarget and total organic fluorine analyses of environmental samples.
- Develop, along with State and other Federal agencies, a quality assurance and quality control database to provide a model for standardizing data and protocols across different analytical methods.
- Communicate changes in protocols and provide guidance for semiquantitative assessments.

Environmental Sources, Source Apportionment, and Environmental Occurrence

Point and Nonpoint Sources (AFFF, WWTPs, Biosolids, Atmospheric Deposition)

- Identify where there is a general absence of data on municipal sludge and fire training locations.
- Standardize field studies concerning point and nonpoint sources to ensure they include concurrent hydrologic measurements (that is, discharge, water levels, and so on), source chemical profiles (atmospheric deposition, role of microbes in biotransformation), and what role, if any, wastewater treatment plants have on the source, fate, and transport of PFAS in the environment.
- Investigate the potential for PFAS sorption and environmental transport on micro- and nano-plastics.
- Conduct a national assessment of Class A (composted biosolids, lime pasteurized biosolids and fertilizer pellets) and B (treated sewage sludge) biosolids for PFAS and other contaminants.
- Develop laboratory techniques and standardized methods to address current data gaps, including the (1) accuracy of passive samplers in simulating environmental conditions, (2) potential for PFAS sorption on micro- and nano-plastics, (3) presence of PFAS in septic drainage, and (4) adoption of specialized medical-grade equipment and fingerprinting techniques.
- Address geographic gaps in sampling, particularly in the Western United States.
- Improve methods of communicating contaminant transformation rates within and between Federal agencies.

Source Apportionment Tools and Methods

- Conduct chemical characterization of PFAS point-source inputs, focusing on under-researched areas, such as industrial effluents, landfill drainage, biosolids, and mining activities in nationwide studies.
- Identify co-occurring constituents and proxy measurements as source indicators, including wastewater compounds, agricultural chemicals, and trace elements.
- Investigate weathering and (bio)transformation processes to assess the transport effects of primary source PFAS signatures and perform source apportionment in non-water matrices.
- Design experiments and sampling methods to maintain hydrologic connectivity, allowing for the evaluation of aggregate effects from multiple potential sources.
- Utilize inverse and forward modeling approaches to identify PFAS sources and predict downgradient transport while addressing aerosolized PFAS concerns from foam, septic or landfill drainage, and wastewater treatment plant emissions.
- Develop a harmonized database for PFAS sources in groundwater and surface water.

Occurrence and Predictive Modeling of Water Resources, Soils, Atmospheric Deposition, and Biota

- Conduct research in the data-poor interior of the conterminous United States to develop a dataset that includes the anthropogenic background in soil, air, and water; use this data to develop a map based on tritium age dating.
- Develop PFAS atmospheric-deposition and soil-concentration maps; leveraging archives and existing datasets (ice cores, soil, air, surface water, museum tissues) for better modeling.
- Compile all published data, including archived and new datasets (ice cores, soil, air, surface water, museum tissues), into a dashboard that can be leveraged with data from State and other Federal agencies for improved national predictive modeling. Include more metadata (that is, hydrology, groundwater flow paths, bioaccumulation, seasonal variability, and so on) to improve dataset accessibility, utility, and longevity.
- Use PFAS fingerprinting techniques to connect and correlate abiotic and biotic datasets and address existing data gaps on the role of atmospheric deposition in contaminant transport and linkages between terrestrial and aquatic models, including food web models.
- Conduct studies to improve the understanding of biosolids, biosolids and wastewater land application, and wastewater effluent migration, particularly with reference to drainage from landfills and wastewater treatment plants.

Environmental Fate and Transport

Solid-Water and Air-Water Sorption

- Determine the effects of anaerobic environments (that is, reducing conditions) on PFAS fate and transport behavior and compare to aerobic environments.
- Examine the role of microbial interactions in PFAS sorption and bioaccumulation, focusing on short- and long-term effects of biosorption as an understudied aspect of PFAS fate and transport.
- Address sampling challenges, including the need for more data on turbidity and non-equilibrium conditions, and propose methods to minimize volatilization losses during sampling.
- Identify the need for improved partitioning data (soil adsorption and organic carbon-water partition values) and isotherms under various biogeochemical conditions, including PFAS partitioning during ice formation.
- Conduct batch and column experiments to better understand the transport mechanisms of PFAS via micro- and nano-plastics.
- Conduct research on PFAS sorption at the air-water interface, including the effects on saturated zone concentrations, and investigate foam formation, its constituents, and its implications for bioaccumulation in organisms, such as fish, feeding on surface algae.

Biotransformation Rates, Mechanisms and Products, Fate Processes, and Remediation

- Evaluate the potential for microbial transformations in PFAS mitigation and remediation, including the comparative benefits of partial transformation and complete degradation in a sequential treatment process.
- Identify options to address current limitations and reliance on natural attenuation processes and enhance in situ remediation of PFAS and other contaminants.
- Assess the potential effects of co-contaminants on PFAS removal through mechanisms like co-metabolism.
- Advance laboratory findings on microbial dehalogenation and biotransformation into field demonstrations, including field assessment of biotransformation rates and pathways.
- Improve microbial characterization under various environmental conditions and hydrogeologic settings, focusing on identifying key microbes involved in PFAS degradation.
- Develop risk assessment frameworks to understand how microbial processes alter PFAS compositions and integrate findings into broader transport modeling to predict microbial behavior and contaminant interactions.

Fate and Transport Modeling

- Analyze the effects of conditions such as drought and fire on contaminant transport and behavior, leveraging insights from specialists in these areas.
- Expand research to assess contaminant loading in urban stormwater environments and investigate waters in the midwestern United States.
- Improve modeling techniques for estimating transport properties and time-of-travel, particularly through the development of refined reach-to-reach transit equations that account for fluctuations in hydrologic cycles.
- Explore PFAS concentrations using cumulative waste models, comparing typical wastewater treatment discharges against established benchmarks.
- Enhance communications regarding variability and uncertainty in modeling results for more informed decisions.
- Integrate health risk assessments into models of occurrences of PFAS and other contaminants to better understand potential effects.

Human and Wildlife Exposure Routes and Risks

Human Exposure and Risk—Drinking Water

- Assess differential exposure sources to PFAS, including bottled, public, and private supply drinking water to understand their effect on exposure levels.
- Evaluate the effectiveness and usage of point-of-entry and point-of-use filtration devices for PFAS removal from drinking water, utilizing information from the EPA and other Federal or State agencies.
- Conduct comprehensive risk assessments through a broader sampling of home and workplace exposure routes, including drinking water, food, and dust, to better understand relative risks.
- Develop analytical methods to assess drinking-water and environmental exposures, with a focus on the risks posed by fluoro-pharmaceuticals and fluoro-pesticides.
- Foster collaborative efforts among stakeholders to address PFAS issues comprehensively, including gathering state-level data and engaging local communities, particularly in under-researched and underinformed (private-well-dependent) areas.
- Explore the potential of structure-activity relationship (SAR) and quantitative SAR (QSAR) modeling to fill data gaps in toxicity thresholds for groundwater and surface water while also considering risks to companion animals from PFAS exposure.

Human Exposure and Risk—Food

- Assess and clarify primary PFAS exposure routes, including food, air, and drinking water, while investigating the role of biosolids in agriculture and their contribution to contamination in the food supply chain.
- Examine socioeconomic disparities in PFAS exposure linked to dietary choices and access to information, working alongside social scientists to bridge scientific findings with societal influences.
- Address analytical challenges in measuring PFAS in different food matrices and develop standard reference materials to improve measurement accuracy.
- Investigate biosolids and dust as potential significant sources of PFAS exposure and study the effects of concentrated animal feeding operations and reclaimed water on shallow aquifers.
- Develop communication strategies for fish consumption advisories, particularly for Tribal and high-consumption communities while incorporating prepared foods into discussions of exposure routes.
- Create frameworks to integrate datasets from water quality, contaminated soils, and food safety to improve predictive modeling of agricultural uptake and to investigate the influence of urban farming practices on PFAS exposure.

Aquatic and Terrestrial Wildlife—Food Web

- Identify sensitive species that can effectively represent exposure and effects across diverse environments, ensuring a focus beyond endangered species.
- Determine how exposure indicators (presence of PFAS) are related to exposure responses (measured changes in health or indicators of health) to improve monitoring and assessment strategies.
- Explore the role of sensitive insect taxa in aquatic and terrestrial environments for PFAS monitoring while investigating specific life stages and gender differences associated with PFAS uptake.
- Develop models to understand PFAS movement through food webs and corresponding effects at different trophic levels, considering how PFAS is compartmentalized within various tissue types.
- Investigate significant sources of PFAS contamination, including urbanization, industrialization, and biosolids application, while using historical land-use data from protected areas to find potential contamination sources.
- Research the relationship between PFAS and certain pesticides and develop simplified models to evaluate vulnerabilities based on land management practices.
- Explore potential connections between harmful algal blooms (HABs) and PFAS concentrations to address potential HAB accumulation of PFAS and consequent effects on aqueous PFAS levels.

Bioconcentration, Bioaccumulation, and Biomagnification

Uptake in Aquatic Systems

- Sample whole microbial communities of bacteria, fungi, and eukaryotes at lower trophic levels to better understand the role of microbes in the food web.
- Investigate PFAS partitioning in biofilms and biotransformation processes occurring within microbial communities.
- Explore the application of isotope labeling to study small organisms and enhance the understanding of environmental components while monitoring feeding activities in surface microlayers as indicators of environmental hazards.
- Investigate the utilization of passive samplers to measure bioconcentration and accumulation of PFAS, addressing variability in their performance in field versus laboratory conditions.
- Develop appropriate tools to measure bioaccumulation from sediments and pore water (water contained in pores of rock or soil), including evaluations of biosolids and microcosm (small-scale ecosystem) and mesocosm (controlled, self-contained outdoor ecosystem) experiments.
- Utilize mobile laboratories for real-time assessments of water exposure on aquatic organisms to enhance the understanding of PFAS effects on target species and improve data on transient concentrations in sediment and water.

Uptake in Terrestrial Systems

- Develop improved nonlethal biological sample collection methods (for example, assessing PFAS levels in blood, fur, mucus, and scales) to study PFAS exposure effectively.
- Establish dedicated air monitoring locations for PFAS to better assess airborne exposures and inform related studies.
- Enhance communication and collaboration among scientific disciplines (for example, biology, hydrology, and chemistry) to facilitate opportunistic sampling and data sharing.
- Provide guidance and training for biologists on appropriate PFAS sample collection and analysis techniques, to support increased monitoring of biotic exposures to PFAS.
- Integrate biological and macro-environmental sampling efforts in known PFAS-contaminated areas to gain an integrated understanding of contamination effects on ecosystems.
- Research the role of gut microbiomes in PFAS uptake and transformation processes, develop predictive models for contamination sources, and implement monitoring systems for ongoing oversight of PFAS presence in infrastructure.

Trophic Transfer and Food Web Modeling

- Address the lack of data on partitioning coefficients by exploring empirical approaches in research to derive these coefficients and understand PFAS behavior in various environments.
- Develop comprehensive lab and field datasets, such as those gathered through mussel studies to assess how water quality, flow, and seasonal changes affect PFAS uptake.
- Establish paired studies that create a feedback loop between lab findings and field studies to ensure that findings are accurate and applicable to real-world scenarios.
- Identify key areas, including species sensitivity to PFAS and consumption patterns of significant end members (for example, deer and cows), while aligning research priorities with the unique water uses of Tribes and under-researched communities.
- Incorporate soil complexities and potential exposure pathways, such as plant matter decomposition, into models that utilize integrated science for improved accuracy and future-sampling prioritization.
- Foster collaboration among Federal, State, and nongovernmental entities to combine datasets and enhance understanding of specific food webs and accumulation pathways related to PFAS exposure.

Ecotoxicology and Effects

Effects of Regulatory Concern

- Identify and establish acceptable endpoints for various organisms to assess effects of regulation, focusing on transitioning non-apical endpoints to accepted standards.
- Develop and harmonize methodologies for assessing aquatic and terrestrial organisms, emphasizing life-cycle studies and multigenerational tests.
- Foster collaboration between ecological risk assessors and regulatory bodies to create a robust framework for interpreting non-apical endpoints and genomic data related to population effects.
- Evaluate novel endpoints (for example, behaviors and transcriptomics) in regulatory frameworks by aligning methods with current scientific understanding and emphasizing long-term exposure studies for chronic effects of PFAS.
- Integrate disparate datasets through collaboration between agencies and researchers to inform regulatory decisions effectively and address statistical backing for ecological risk assessments.
- Establish a collaborative platform for harmonizing methodologies, data sharing, and informing regulatory criteria based on emerging scientific findings related to PFAS impacts on organisms and the environment.

Mode of Action

- Enhance understanding of the specific modes of action (MOA) for PFAS exposure effects, particularly regarding immune function and reproduction, while standardizing terminology, such as using "sum of PFAS" instead of "total PFAS."
- Increase research on MOA in mammals to facilitate cross-species comparisons and better understand how different species are affected by PFAS, especially in the context of commonplace simultaneous exposures to multiple PFAS.
- Conduct paired laboratory and field studies to balance acute and chronic exposures, establishing causation and biomarkers while providing contextual data.
- Gather more data on concentration thresholds for mortality or trans-generational effects, and investigate PFAS interactions and combined effects, including chronic versus acute exposure.
- Leverage pharmaceutical industry models and tools for drug discovery to investigate PFAS MOA while coordinating efforts to utilize existing tools and develop new in vitro assays to reduce reliance on animal studies.
- Engage a diverse range of experts across disciplines to fill knowledge gaps, streamline research efforts, and address the long-term effects of PFAS in contaminated sites, considering historical profiles and resultant influence on current ecological and health outcomes.

Cross-Species Extrapolation and Identifying Sensitive Bioindicators Across Species

- In the laboratory, employ species and experimental conditions that more closely resemble those in the environment to better understand fish and wildlife responses and ensure that research findings apply to real-world scenarios, focusing on similarities and differences in exposures and effects.
- Develop standardized biomarkers across studies to facilitate effective comparisons, particularly for non-model organisms, and address the significant gap in mammal research compared to fish and invertebrates.
- Expand research to include a broader array of species, emphasizing cross-species differences in sensitivity to PFAS and integrating genomic data to enhance interdisciplinary collaboration.
- Foster collaboration among genomics, computational toxicology, and environmental science experts to improve project design and execution.
- Develop predictive models that connect chemical exposures to biological effects, establishing adverse outcome pathways that link molecular triggers to broader ecological consequences.
- Investigate gut microbiome responses for cross-taxa comparisons and clarify regulatory complexities related to biomarker testing and acceptance across taxa.

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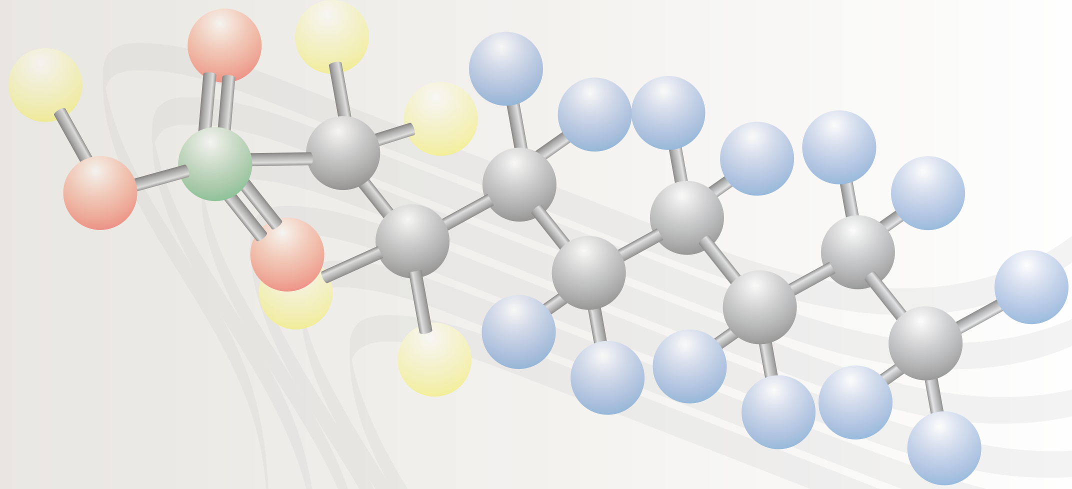

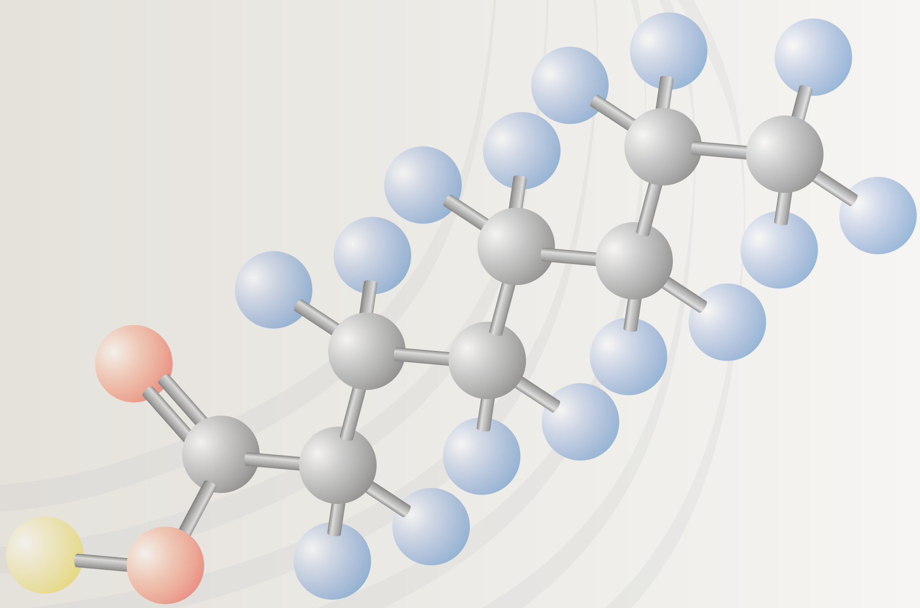

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