Addressing PFAS Challenges

A Framework for Understanding, Managing and Mitigating PFAS Risk

BATTELLE

Manufacturers today face mounting pressure from both consumers and regulators to remove PFAS (per- and polyfluoroalkyl substances) from their products, packaging, supply chains and waste streams. Battelle offers a lifecycle solution to help companies identify, quantify and evaluate PFAS, understand their associated risks and liabilities, and create a practical plan for PFAS replacement.

The Challenge with PFAS

PFAS are found in a wide range of consumer and industrial products, from non-stick cookware, water-repellent clothing, stain-resistant fabrics and carpets, to firefighting foams, electroplating, pharmaceuticals, and many more. Their unique properties—such as high thermal stability, resistance to degradation, surfactant qualities, and water and oil resistance—make them highly useful for a variety of applications.

These same chemical properties make some PFAS highly resistant to breaking down in the environment or in biological tissue, leading to their oft-used nickname of "forever chemicals." In recent years, a small number of PFAS have come under increasing scrutiny because of their persistence and potential health and environmental impacts. While research is ongoing, studies have linked exposure to certain PFAS chemicals to various health issues, including reproductive and developmental challenges, liver and kidney damage, immune system effects and some cancers. There are also growing concerns about PFAS accumulation in the environment, including in surface and groundwater, drinking water, treated wastewater and biosolids, soil, wild and cultivated plants and animal tissues.

As a result, PFAS are increasingly regulated in the U.S. and internationally, with regulations addressing their use, production, disposal and remediation. These regulations aim to reduce human exposure, limit the release of PFAS into the environment, and clean up areas already contaminated with significant levels of PFAS. Consumer awareness of PFAS risks has also grown in recent years, leading to increased demand for transparency and safer alternatives in products. Public pressure has spurred advocacy groups and non-governmental organizations to push for stricter regulations and better enforcement of existing laws. These factors are driving a significant shift in how companies approach the use and management of PFAS.

However, companies face significant challenges in addressing PFAS risks and liabilities. First, complex supply chains and manufacturing processes can make it difficult to identify exactly where PFAS exists in materials, finished products and waste streams and how to quantify the potential exposures. Second, due to the unique chemical nature of PFAS, it is often hard to remove PFAS from products or processes or identify safer drop-in alternatives that provide similar benefits.

Evaluating PFAS Risks, Exposures and Replacement Options

Where does PFAS currently exist in products, processes, packaging, supply chains and waste streams?

What regulations govern PFAS in the places in which the company operates?

What functional benefit does PFAS currently provide in products or processes, and how essential is that benefit?

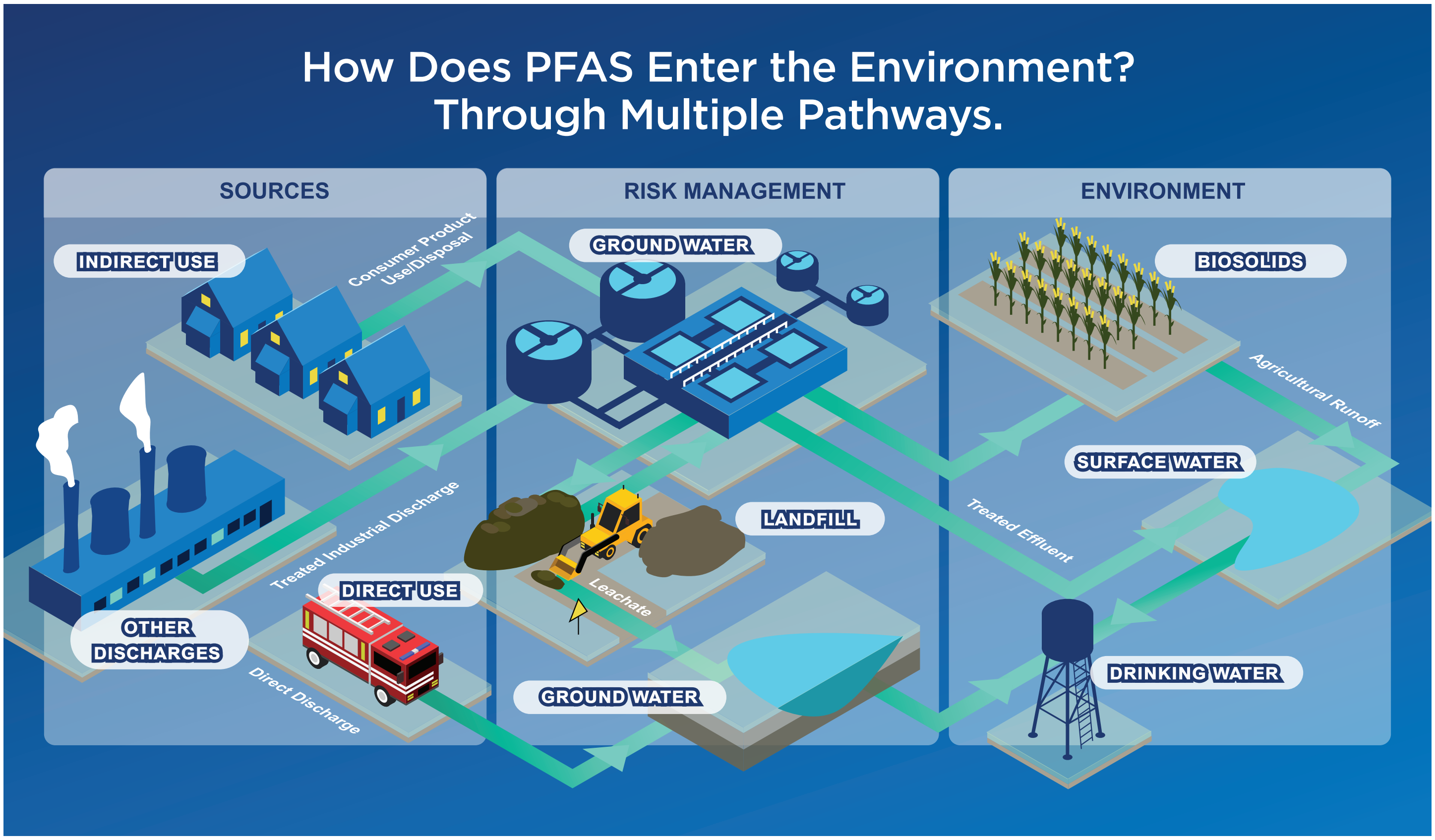
What are the options for removing or replacing PFAS in products and processes?

What next steps must be taken to reduce current and potential risks and liabilities related to PFAS?

What are PFAS?

Per- and polyfluoroalkyl substances (PFAS) are a class of synthetic organofluorine chemical compounds that consist of a fully or partially fluorinated carbon chain. These compounds are characterized by the presence of multiple carbon-fluorine (C-F) bonds, which are among the strongest in organic chemistry.

Various technical and regulatory definitions exist for PFAS. Depending on the definition used, there may be between several thousand to nearly a billion known PFAS chemicals.



Do You Have a PFAS Challenge?

Many companies may not have a full understanding of their PFAS risks, leading to potential blind spots in managing these persistent chemicals. This lack of awareness can stem from several factors, including:

- **Opaque Supply Chains:** PFAS are not always clearly listed on Safety Data Sheets (SDS), and proprietary formulations may not disclose the type or amount of PFAS present. This lack of transparency makes it challenging for companies to identify and address all potential sources of PFAS in their operations.
- **Presence in Packaging and Third-Party Components:** PFAS can be present in packaging materials or components supplied by third parties, even if these chemicals are not directly added to the products. This can introduce a hidden source of PFAS into the supply chain.
- **Contamination from Process Water:** Even if PFAS are not used directly in a company's products, processes or packaging, contamination can occur through process water or other indirect sources. Most municipal water treatment centers do not have the technology to remove PFAS chemicals from wastewater, which means that process water used for industrial applications may already be contaminated with PFAS. This can lead to unintentional introduction of PFAS into products or, ultimately, waste streams.
- **Latent Liability and Litigation Risks:** Companies may face latent liabilities or litigation risks from PFAS used in the past or from historical environmental emissions and/or accidental releases. These risks can persist long after the use of the chemicals has ceased. If PFAS is found near a company's manufacturing operations, it can be difficult to verify the source of the PFAS and prove or refute a liability claim.
- **Limited Testing Options:** There are limited laboratory methods for PFAS in products, and many matrices are challenging to test. Different matrices (e.g., water, soil, air, biota, manufactured materials, etc.) require different testing methods. While testing methods for water are well established, fewer labs have the capacity for testing in other matrices. Validated testing methods may not exist for unique matrices such as textiles or other manufactured materials, which may require solvent extraction and cleanup steps to isolate PFAS for analysis. Not all PFAS are equally harmful, and the large number of PFAS chemicals in existence also creates challenges, as only a handful have been studied extensively. This makes it difficult for companies to determine which PFAS are relevant, which laboratory methods to consider, and how to accurately assess their PFAS risks and manage them effectively.

Understanding PFAS Risks

Manufacturers face various risks associated with PFAS, including regulatory, brand/reputation, litigation, financial and supply chain risks. Each of these risk categories presents unique challenges that companies must navigate to manage their PFAS liabilities effectively.

REGULATORY

- Rapidly evolving regulations
- Varying state, national and international rules
- Emerging bans on PFAS chemicals
- Increased enforcement action

STAKEHOLDER

- Consumer preferences
- Investor demands/ESG requirements
- Neighboring community concerns

LITIGATION

- Government enforcement (remediation)
- Firefighting foam (aqueous film-forming foams or "AFFF")
- Drinking water contamination
- Product-related litigation
- Personal injury claims

FINANCIAL

- Loss of customers seeking PFAS-free products
- Litigation costs and judgments
- Remediation/cleanup costs
- Alternatives research, re-engineering, and/or re-formulation costs

SUPPLY CHAIN

- Material obsolescence
- Supply chain disruptions
- Missing information from suppliers
- Lack of suitable replacements

Regulatory Risk

The regulatory landscape for PFAS is rapidly evolving. As a result, companies face a complicated patchwork of state, national and international regulations impacting product development, waste management and mitigation requirements. These regulations not only impact the use of PFAS chemicals in products but also address environmental contamination (including air, water and soil) and remediation requirements. For example:

- In April 2024, as part of their comprehensive PFAS Strategic Roadmap, the U.S. Environmental Protection Agency (EPA) set the first-ever limits on certain PFAS in drinking water. The enforceable maximum contaminant level (MCL) for PFOA and PFOS was set at 4 parts per trillion. The MCL for PFNA, PFHxS and HFPO-DA (GenX chemicals), as well as mixtures containing two or more, was set at 10 parts per trillion. Many states have their own criteria that may be more stringent than the federal limits.
- Between 2009 and 2022, the Stockholm Convention on Persistent Organic Pollutants added several PFAS chemicals to its list of banned substances, including PFOS, PFOA, PFOSF, PFHxS, and related salts and compounds. They are currently reviewing long-chain perfluorocarboxylic acids (LC-PFCAs).
- The EU's REACH proposal, submitted to the European Chemicals Agency (ECHA) January 2023, could potentially ban the entire class of PFAS chemicals, marking a significant step in global regulatory action.
- Emerging regulations at the state level further complicate compliance; for example, more than a dozen states require reporting of PFAS chemicals in consumer products. Many states, such as California,have banned their use in many types of products from cookware, to cosmetics, rugs, and carpets, textiles, and apparel, while others, such as Maine and Minnesota, are prohibiting PFAS in all consumer products by 2032.

The regulatory landscape continues to evolve, with more state, national and international regulations anticipated. These future regulations are likely to cover a broader range of PFAS and extend beyond drinking water to include comprehensive product regulations.

Stakeholder Risk

Stakeholder awareness and expectations around PFAS are increasing. Consumers are becoming more educated about the health and environmental risks associated with PFAS and are increasingly likely to look for PFAS-free products. Companies also face investor scrutiny, leading to more transparent and PFAS-free Environmental, Social and Governance (ESG) report cards and sustainability practices. Finally, communities impacted by PFAS contamination are demanding accountability from regional and local manufacturing operations. Companies face potential reputational and brand damage if they fail to address these concerns adequately.

Legal Risk

The presence of PFAS in products and processes can expose companies to legal risks and liabilities related to environmental exposures from releases, consumer health risks from product use, and occupational exposures affecting worker health and safety. Since 1999, more than 9,800 PFAS complaints have been filed in 123 courts, naming 357 companies operating in 140 industries. Damages from PFAS lawsuits are expected to continue to rise. The current legal environment is characterized by extensive litigation related to PFAS contamination, with companies facing cumulative lawsuits and settlements. As legal precedents are established, the scope of liability is likely to grow, further increasing the potential legal risks for companies.

Financial Risk

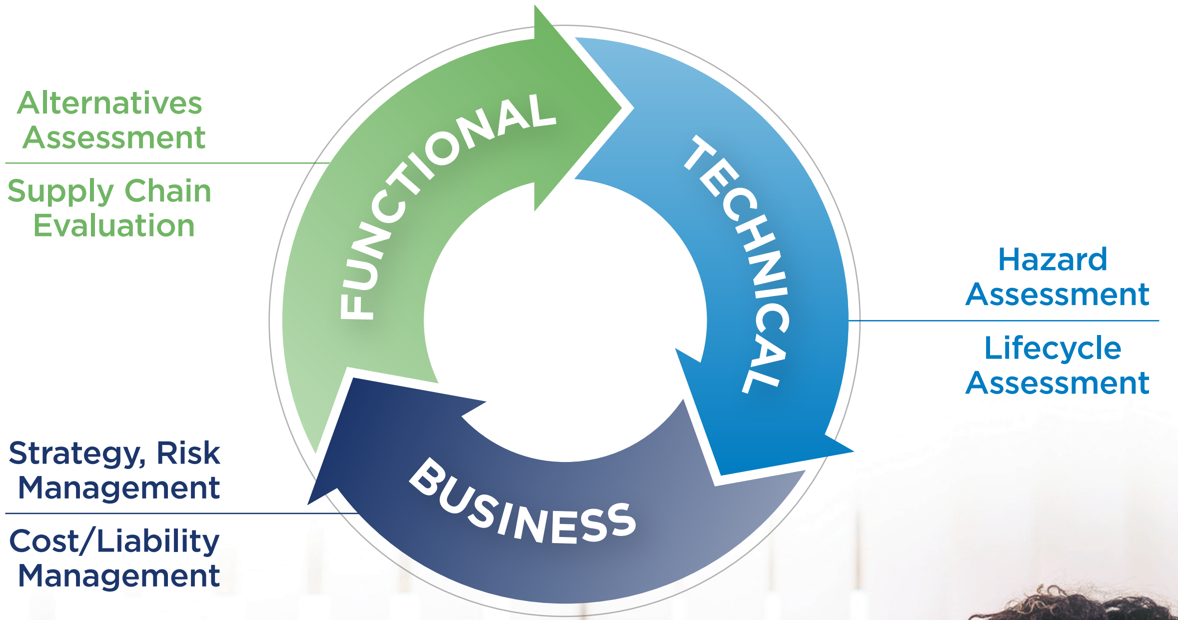
PFAS-related issues can lead to substantial financial risks for companies. Litigation costs can be significant, as can the expenses associated with cleanup and remediation of contaminated sites. Additionally, companies may incur costs related to the reformulation of products, development of alternative materials, and replacement of PFAS-containing components. There are also potential losses in sales and market opportunities as consumers and investors favor PFAS-free products and companies.

Supply Chain and Obsolescence Risk

Supply chain risks arise from the potential obsolescence of PFAS chemicals and PFAS-containing materials used in manufacturing processes and products. Some PFAS have already been banned, and some large suppliers are voluntarily removing certain classes of PFAS from their product portfolios. For example, 3M has announced that it is exiting PFAS manufacturing by the end of 2025, which is expected to lead to potential supply chain disruptions. Finding alternatives that provide the same functional benefits as PFAS can be challenging. At the same time, it can be difficult to determine the exact composition of materials in the supply chain due to proprietary formulations and the lack of disclosure on safety data sheets (SDS). This opacity makes it harder for companies to ensure compliance and identify suitable alternatives for PFAS used in their products and processes.

A Framework for PFAS Risk Mitigation

Battelle offers a comprehensive framework for PFAS risk mitigation and response that can include vulnerability assessment, analytical services, risk assessment and ranking, material alternative assessment, and environmental remediation. This multi-faceted approach helps organizations identify, quantify, evaluate and mitigate PFAS-related risks effectively—including risks presented by "hidden" sources of PFAS in supply chains and waste streams.



Desktop Review

The vulnerability assessment typically starts with a desktop review to identify potential risks and exposures related to product formulations, supply chains, the regulatory environment in the areas in which the company operates, and environmental exposures. Desktop review may include some or all of the following:

Functional Assessment	Technical Assessment	Cost/Liability Management	Strategy/Risk Management
• Where is PFAS used in product formulations or processes? Across the supply chain? • How necessary is the function provided by PFAS in the product or process? • Are there suitable alternatives to support the function?	• Are PFAS chemicals documented in formulations/ Safety Data Sheets (SDS)? If not, is analytical testing required? • What are the specific PFAS present, and are they persistent, bioaccumulative, toxic, or mobile? • Are the chemicals being or have they been released to the environment? Have there been human exposures? • What is the environmental impact across the lifecycle?	• What PFAS-related regulations apply in the areas in which the company operates or sells products? • What additional regulations are anticipated in these areas? • What types of permitting and regulatory compliance actions are required? • Have environmental reserves been calculated to address liabilities?	• Based on functional, technical, and cost assessment, what are the highest priorities? • Establish and rank high-, medium- and low-risk priority by operations/ geography. • Develop management and mitigation plan to address current risks and plan for future potential risks.

Analytical Evaluation

A variety of analytical tests can be used to verify and quantify the presence of PFAS in products, raw materials or the environment and characterize the specific PFAS present. Analyzing PFAS presents several significant challenges due to the unique properties and complexities associated with these chemicals.

Battelle has pioneered novel validated testing methods to expand the range of PFAS that can be accurately detected and characterized, as well as the matrices that can be tested. That allows companies to answer critical questions about PFAS in their products, supply chains and processes. Analysis often starts with a simple and inexpensive screening test to confirm the presence of PFAS. Further analytical testing methods are determined based on the specific questions that must be answered for effective risk mitigation.

Questions	Methods	Matrices
• Screening Test (Is PFAS present? Yes/No) • PFAS Characterization (Which PFAS chemical(s) are present?) • Total Concentration (How much PFAS is present?) • Environmental Passive Sampling (What kinds/how much PFAS are present in an environment?) • Fingerprinting (What type of PFAS is present in the environment? What is the likely source?)	• Liquid Chromatography Tandem Mass Spectrometry (LC-MS/MS) • Gas Chromatography-Mass Spectrometry (GC-MS) • High-Resolution Mass Spectrometry (HRMS)	• Water • Soil/sediment • Air • Biological tissue (plant, animal, fungal) • Firefighting foams • Materials (polymers, coatings, electronic components, mold release agents, lubricants, etc.) • Finished products (textiles, plastics, personal care products, home goods, industrial products, etc.) • Packaging (paper/corrugate, coatings, linings)

Risk Assessment and Ranking

Assessing and ranking the risks associated with PFAS is a critical step for organizations seeking to manage and mitigate their exposure effectively. This process involves identifying the types of risks, evaluating their magnitude based on likelihood and potential impact, and developing targeted mitigation strategies.

Likelihood Assessment X	Impact Assessment =	Composite Risk Score
The probability of a risk occurring, based on historical data, current trends and expert analysis of the hazard.	The potential severity of consequences, including operational, financial, legal and reputational impacts.	Calculated based on the likelihood and impact scores.

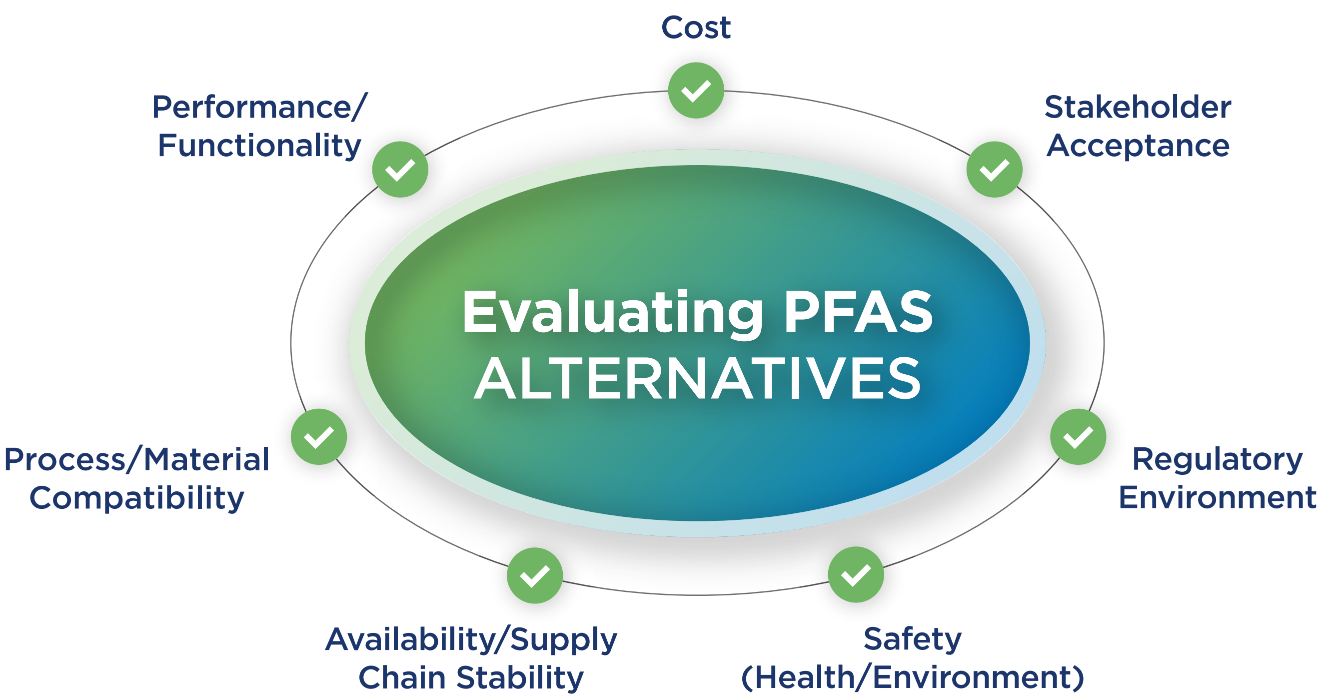
This scoring method allows ranking, prioritizing, and identifying which risks require immediate action. For the highest-ranked risks, specific mitigation strategies are developed to reduce their likelihood and impact. These might include material substitution, process changes, compliance programs, environmental remediation, or other de-risking strategies.

Material Alternative Assessment

Assessing the potential for replacing PFAS with safer alternatives involves evaluating whether the functions provided by PFAS are essential and exploring viable alternatives that fulfill the same purposes but with lower risks. Questions to consider include:

- Is the function provided by PFAS integral to the performance or safety of the product?
- Are there ways to redesign the product or modify the process to eliminate the need for PFAS without compromising quality or functionality?
- Can alternative technologies or materials be used to achieve the same results?

If PFAS functions are deemed necessary, the next step is to explore potential alternatives that could fulfill the same purposes but with lower risk profiles. This involves identifying both safer, less regulated PFAS and non-PFAS that can serve as substitutes.



Environmental Remediation

Environmental remediation may be required if it is determined that the environment has been contaminated by PFAS from a company's processes and waste streams. Companies may undertake remediation to comply with regulatory or legal action or in response to local community concerns or internal Environmental, Social and Governance (ESG) initiatives. The environmental remediation process involves identifying and quantifying PFAS sources, understanding their behavior in the environment, and selecting appropriate treatment and destruction methods.

Environmental remediation for PFAS is complicated by its persistence and mobility in the environment and the difficulty of breaking down the C-F bonds in PFAS molecules. While several potential remediation and disposal methods exist, most do not completely destroy PFAS. Some types of incineration, may have undesirable byproducts. When developing a remediation strategy, it is important to consider the specific characteristics of the contaminated site (including geology, hydrology and the presence of co-contaminants), the goals of remediation efforts, the efficacy and suitability of remediation options, and cost and feasibility.

Battelle developed an innovative PFAS destruction method based on supercritical water oxidation (SCWO). **PFAS Annihilator®** breaks down PFAS and other recalcitrant chemical compounds via a chemical process that uses increased temperature and pressure in the presence of an oxidant. This is currently the only proven method to completely break down PFAS chemicals to non-detect levels in water, landfill leachate, AFFFs and other substrates.

Site Characterization	Fate and Transport Modeling	Remediation and Deconstruction
Where does PFAS exist in the environment? How much and what kind? • Passive sampling methods (water, air) • Sample collection and analysis (water, soil, sediment) • Source attribution/ fingerprinting	How does PFAS move in the environment? Where will it end up? • Hydrological (surface/groundwater) • Soil/sediment • Air dispersion • Bioaccumulation	What is the best way to get rid of PFAS in the environment? • Adsorption (granular activated carbon (GAC) and ion exchange) • Reverse osmosis • Incineration • Supercritical water oxidation and other oxidation processes • Landfilling • Deep well injection

Battelle: Your Partner in PFAS Risk Reduction

At Battelle, we are working with companies to solve some of the toughest challenges in PFAS analysis, remediation, replacement and risk reduction. We've been the leader in PFAS management and mitigation for more than two decades. We can help you reduce or eliminate PFAS risk across the entire product lifecycle, from material selection and formulation to waste management and treatment. ***Service offerings include: Analytical Testing, Environmental Remediation, Formulation and Material Development, Regulatory Compliance and Risk Management and Strategy.***

Our History of PFAS Innovation

PFAS Annihilator® Destruction Technology

GAC Renew® Technology
Granular Activated Carbon renewal

PFAS Insight® Passive Sampling Technology and PFAS Air Insight™ Technology
Sampling technologies for air and water

PFAS Signature® Advanced Analytics Tool
Advanced analytics and PFAS fingerprinting

PFAS Predict® Groundwater Fate and Transport Modeling

Visit **battelle.org/pfas** for more information and to connect with an expert.

Sources
[1]U.S. Department of Health and Human Services. (n.d.). Perfluoroalkyl and Polyfluoroalkyl Substances (PFAS). National Institute of Environmental Health Sciences. https://www.niehs.nih.gov/health/topics/agents/pfc#:~:text=PFAS%20are%20a%20group%20of,the%20 U.S.%20Environmental%20Protection%20Agency.
[2] Williams, A. J., Gaines, L. G., Grulke, C. M., Lowe, C. N., Sinclair, G. F., Samano, V., Thillainadarajah, I., Meyer, B., Patlewicz, G., & Richard, A. M. (2022a). Assembly and curation of lists of per- and polyfluoroalkyl substances (PFAS) to support Environmental Science Research. *Frontiers in Environmental Science, 10.* https://doi.org/10.3389/fenvs.2022.850019
[3]Centers for Disease Control and Prevention. (2024, January 18). *Potential health effects of PFAS Chemicals.* Centers for Disease Control and Prevention. https://www.atsdr.cdc.gov/pfas/health-effects/index.html
[4]Sims, J. L., Stroski, K. M., Kim, S., Killeen, G., Ehalt, R., Simcik, M. F., & Brooks, B. W. (2022). Global occurrence and probabilistic environmental health hazard assessment of per- and polyfluoroalkyl substances (pfass) in groundwater and Surface Waters. *Science of The Total Environment*, 816, 151535. https://doi.org/10.1016/j.scitotenv.2021.151535
[5]Smalling, K. L., Romanok, K. M., Bradley, P. M., Morriss, M. C., Gray, J. L., Kanagy, L. K., Gordon, S. E., Williams, B. M., Breitmeyer, S. E., Jones, D. K., DeCicco, L. A., Eagles-Smith, C. A., & Wagner, T. (2023a). Per- and polyfluoroalkyl substances (PFAS) in United States tapwater: Comparison of underserved private-well and public-supply exposures and associated health implications. *Environment International*, 178, 108033. https://doi.org/10.1016/j.envint.2023.108033
[6]Mroczko, O., Preisendanz, H. E., Wilson, C., Mashtare, M. L., Elliott, H. A., Veith, T. L., Soder, K. J., & Watson, J. E. (2022). Spatiotemporal patterns of pfas in water and crop tissue at a beneficial wastewater reuse site in central Pennsylvania. *Journal of Environmental Quality*, 51(6), 1282–1297. https://doi.org/10.1002/jeq2.20408
[7]Wang, W., Rhodes, G., Ge, J., Yu, X., & Li, H. (2020). Uptake and accumulation of per- and polyfluoroalkyl substances in plants. Chemosphere, 261, 127584. https://doi.org/10.1016/j.chemosphere.2020.127584
[8]Brake, H. D., Langfeldt, A., Kaneene, J. B., & Wilkins, M. J. (2023). Current per- and polyfluoroalkyl substance (PFAS) research points to a growing threat in animals. Journal of the American Veterinary Medical Association, 1–7. https://doi.org/10.2460/javma.22.12.0582
[9]Environmental Protection Agency. (n.d.). PFAS Strategic Roadmap: EPA's Commitments to Action 2021-2024. EPA. https://www.epa.gov/pfas/pfas-strategic-roadmap-epas-commitments-action-2021-2024
[10]Stockholm Convention Persistent Organic Pollutants (POPs) Review Committee . (n.d.). Overview: PFAS. Stockholm Convention website. https://chm.pops.int/Implementation/IndustrialPOPs/PFAS/Overview/tabid/5221/Default.aspx
[11]European Chemicals Agency (ECHA). (2024, February 7). ECHA publishes PFAS restriction proposal. ECHA. Retrieved from https://echa.europa.eu/-/echa-publishes-pfas-restriction-proposal
[12]State of California. (2021). California Assembly Bill No. 1200 Retrieved from https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=202120220AB1200
[13]Maine Department of Environmental Protection. (2024, July 9) PFAS in Products. Retrieved from https://www.maine.gov/dep/spills/topics/pfas/PFAS-products/
[14]Groth, D., Grulkowski, T. Anderson, M.B., Loughran, D., Tibbets, G. (2023) *The forever chemical risk is now: An actuarial reserving study can help insurers prepare for PFAS claims and mitigation.* Millman. https://www.milliman.com/en/insight/-/media/f67faadb03d64c d880e33cbf0ef79ac0.ashx
[15]Tabuchi, H. (2024, May 28). Lawyers to plastics makers: prepare for 'astronomical' pfas lawsuits. *The New York Times.* https://www.nytimes.com/2024/05/28/climate/pfas-forever-chemicals-industry-lawsuits.html
[16]3M. (2022, December 20). 3M to exit PFAS manufacturing by the end of 2025. News.3m.Com. Retrieved from https://news.3m.com/2022-12-20-3M-to-Exit-PFAS-Manufacturing-by-the-End-of-2025.

800.201.2011 | solutions@battelle.org | www.battelle.org

ID 911 08/24

It can be done