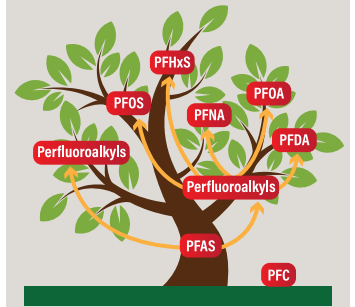


HUMAN ENVIRONMENTAL AND ECOLOGICAL HEALTH: PURDUE RESEARCH ON IMPACTS OF "FOREVER CHEMICALS"

What are "Forever Chemicals"?

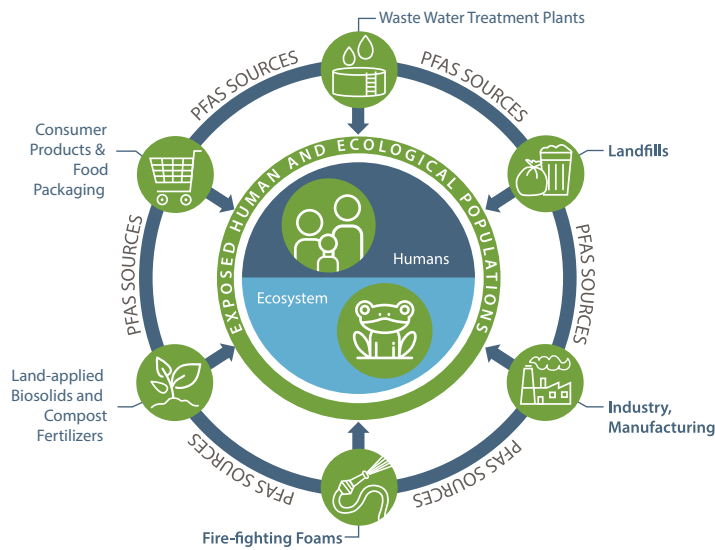
"Forever chemicals" is a catch-all term that refers to a family of over 4,000 types of chemicals designed to repel grease, water, and oil. They can take millennia to break down, and often degrade into smaller-chain chemicals that can also impact human health. They appear in hundreds of common domestic products including stick-free cookware, water-proof treated fabrics and carpets, cleaning products, food packaging and firefighting foams.



Family Tree of perfluoroalkyl and polyfluoroalkyl Substances

What are some sources in the environment?

Though some identified PFAS are no longer produced in the U.S., alternative chemicals with similar molecular structures persist in many consumer processes and end products. They also appear as industrial by-products from factories and waste water treatment plants, leading to possible health risks.



Potentially harmful levels of PFAS exist in food packaging, ranging from bags for popular snacks, pizza boxes and popcorn containers



PFAS typically biodegrade slowly moving through soils and water, impacting ecosystems and food webs.

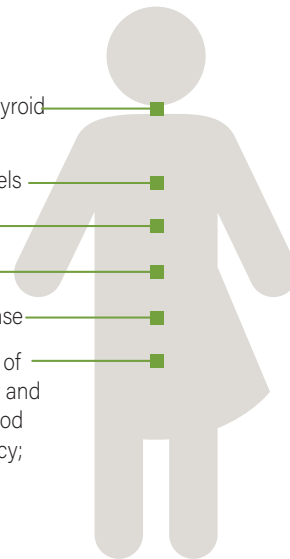


What are some possible health risks?

Also known by their more technical names, PFAS have been shown to increase the risk of cancer, increase cholesterol levels, impact the immune system as well as hormonal functioning in animals and humans.

Having been widely used around the globe since the 1940s, they are found in tissues of most humans. A key challenge is identifying potential risks and combining strategies of reduction and remediation.

- Increased incidence of thyroid disease
- Increased cholesterol levels
- Increased cancer risk
- Altered metabolism
- Reduced immune response
- In women: increased risk of diabetes, reduced fertility and fetal growth, elevated blood pressure during pregnancy; risks to baby increase.

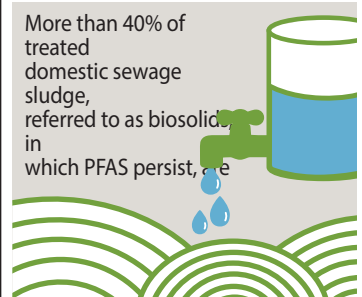


By some research estimates, up to 19 million people in the U.S. are exposed to PFAS contaminated water



Can PFAS be removed or filtered from water?

While some long-chain PFAS (e.g. PFOS and PFOA) can be at least partially removed through processes such as full-scale granulated activated carbon and reverse osmosis, they are not as effective for small-chain PFAS. However, filtered chemicals are not destroyed; rather, some are captured by filters that cannot be safely disposed of while others are still released into the environment. In addition, PFAS cannot be safely destroyed through incineration.



Recent USEPA Actions through Action Plan 2022

- Established 4 new water health advisories for certain PFAS chemicals, lowering acceptable concentrations for drinking water .
- Issued drinking water PFAS fact sheet for the public: <https://www.epa.gov/water-research/water-research-fact-sheets>
- Established grant mechanism to address PFAS and other emerging contaminants in drinking water.
- Proposed the first Clean Water Act aquatic life criteria for PFAS, focusing on PFOA and PFOS.
- Added five PFAS to a list of risk-based values for site cleanups.

State Level Initiatives

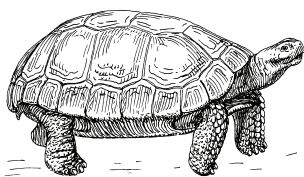
- States that have adopted or proposed limits for PFAS in drinking water include CA, CO, CT, MA, MI, MN, NH, NJ, NY, NC and VT.
- Numerous states, including Indiana, have passed or introduced legislation banning the use of firefighting foam containing PFAS for training or testing purposes.
- Several states — including CA, CO, CT, MD, MN, ME, NY, WA and VT—have taken regulatory steps to ban or limit the use of PFAS in foodservice packaging.

What are ways that PFAS Contamination can be Addressed?

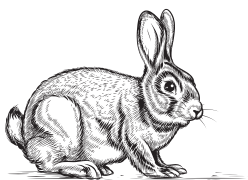
- PFAS levels can be reduced by limiting manufacturing and use of products that contain this class of chemicals (carpets, food packaging, textiles, beauty products, etc.).
- The presence of PFAS in drinking water and wastewater can be reduced by regulating influx into water treatment facilities.
- Food containers containing PFAS can be replaced by PFAS-free containers such as those using natural sources (bamboo, palm leaves or corn byproducts — e.g. Ingeo® brand) or with suitable oil-resistant coatings.
- Increased testing can improve targeted approaches to identifying sources of contamination (i.e. pretreating influent from industry or landfill with high PFAS levels).
- Biosolids with PFAS can be blended to dilute negative impacts on soils.

Key Take Away

- Indiana can incentivize innovation and implementation of alternative products and processing.
- *Go slow* on regulating at extremely low acceptable levels, *go fast* on reducing production and use of existing and new products with PFAS and short-chain replacements.



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How is Purdue addressing the problem?

Through Purdue University's Institute for a Sustainable Future and its PFAS working group, faculty researchers from various departments work to share expertise, create teams, engage in research and work with government, industry and nonprofits to help identify risks and find solutions to fundamental problems associated with PFAS and related forever chemicals. Major areas of investigation at Purdue includes study of the toxicity of PFAS mixtures and replacement chemicals; effects of PFAS on the thyroid, endocrine and central nervous systems; persistence of PFAS in soil, water and waste effluents; toxicity of firefighting foam; management and remediation strategies; and ecological effects of PFAS on aquatic communities.

Purdue Research on Impacts of "Forever Chemicals"

"Forever chemicals" is a catch-all term that refers to a family of over 4,000 types of chemicals designed to repel grease, water, and oil. They can take millennia to break down, and often degrade into smaller-chain chemicals. They appear in hundreds of common domestic products including stick-free cookware, water-proof treated fabrics, cleaning products, food packaging and fire-fighting foams. Key issues our researchers are working include: studies of the toxicity of PFAS mixtures; effects of PFAS on the thyroid, endocrine and central nervous systems; persistence of PFAS in soil, water and waste effluents; and ecological effects of PFAS on aquatic communities.

We're getting them in our foods through food packaging, in our homes from our furniture and carpet, and we get it from our drinking water.

Linda Lee

Distinguished Professor, Agronomy & Program Head for Ecological Sciences & Engineering Interdisciplinary Graduate Program
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Linda Lee's research focuses on developing a mechanistic understanding of the processes that govern the environmental fate, and possible remediation, of contaminants. This information, in turn, can be used in decision tools and management guidelines for industrial and agricultural settings. Over the last fifteen years, she has further focused on PFAS and other organic endocrine-disrupting chemicals of emerging concern. Lee also works with wastewater treatment plants across the state of Indiana to develop strategies to decrease PFAS that exit the plants through effluent and sludge.

Jason Hoverman

Professor of Vertebrate Ecology
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Jason Hoverman's research program focuses on environmental stressors in freshwater ecosystems. He seeks to understand the effects of both man-made and natural stressors on animals and their environments. In collaboration with Drs. Sepúlveda and Lee, he has worked on the development of toxicity reference values for amphibians exposed to perfluoroalkyl and polyfluoroalkyl substances, PFAS. Recently, his research team received funding from the Michigan Dept. of Natural Resources to assess the ecosystem-level effects of PFAS contamination on wetland food webs. This work will improve our understanding of the bioavailability, bioaccumulation, and biomagnification potential of PFAS within freshwater ecosystems.

Marisol Sepúlveda

Professor of Ecology and Natural Systems
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Marisol Sepúlveda's interests in ecotoxicology include looking at the sublethal effect of contaminants and environmental stressors on the developmental and reproductive physiology of aquatic organisms. In collaboration with Drs. Hoverman and Lee, she is developing PFAS toxicity reference values (or TRVs) for amphibians and have exposed different life stages of frogs, toads and salamanders to a range of PFAS and compared uptake and toxicity across different routes of exposure.

Basically these bonds are indestructible. They're the strongest bond in nature, carbon and fluorine. These chemicals are out there now, everywhere.

Zhi (George) Zhou

Associate Professor of Civil Engineering and Environmental and Ecological Engineering
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Dr. Zhou's research focuses on environmental microbiology and the application of biotechnologies in engineering systems. His work on PFAS includes evaluation of PFAS removal in drinking water and how microbial growth in POU systems affects PFAS removal efficiencies. This work will help mitigate human health risks by guiding the development of better strategies for the design and operation of POU systems to remove PFAS.

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Jason Cannon

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Jason Cannon performs mechanistic research on environmental exposures and neurological disease while also identifying and testing novel therapeutic strategies. He is interested in researching late-life neurological consequences of developmental PFAS exposures using nematode, amphibian, and rodent models. Current research is focused on how developmental PFAS exposures may increase risk for the development of neurodegenerative and psychiatric diseases.

We have almost 90,000 chemicals in commerce, and of that number we have decent toxicology data for only a few hundred.

Jennifer Freeman

Professor of Toxicology in the School of Health Sciences;
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Jennifer Freeman looks to define the underlying genetic and epigenetic mechanisms of the toxicity of environmental stressors with a current focus on pesticides, metals, radiation, and emerging contaminants. She looks at adverse health outcomes throughout the lifespan as linked to various levels of exposure to PFAS using the zebrafish as a model system. Recently, she has focused on the neurotoxicity of PFAS mixtures in firefighting foams with funding from the US Centers for Disease Control and Prevention and the National Institutes of Health.

Carlos Martinez

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Drs. Martinez and Youngblood PFAS research focuses on developing a PFAS-free foam formulation (PFAS-FFF) that satisfies the MilSpec requirements and can serve as a drop-in replacement. Their approach is built on a recognition that no single material can replace PFAS— however, proper combinations of foam ingredients released at the times they are needed to transform the properties of the foam after application, may overcome the challenges of building a fluorine-free firefighting foam.

Jeffrey Youngblood

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Chongli Yuan

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Dr. Yuan's research focus on the impact of neurotoxicity of PFAS during a developmental window. Her group develops imaging and analysis pipelines for assessing cell vulnerability to growth and aging challenges after PFAS exposure. In collaboration with Dr. Freeman, her group is examining the impact of low-dose PFOA and GenX exposure on the fitness of DA-like neurons.

Aaron Specht

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Dr. Specht's research focuses on the development, application, and understanding of exposure assessment for elemental and radiation exposures in environmental and occupational health studies, including exposure to PFAS. He has developed non-invasive and non-destructive measure techniques using x-ray fluorescence.

We don't want to see these biosolids wind up in landfills or incinerators. These approaches are not sustainable solutions and would eliminate an incredible source of carbon and nutrients that can improve soil and plant health. So, we need to do research to find ways to reduce their mobility from biosolids and remove them in the wastewater plants.

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Linda Lee



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