What We Know: Per- and polyfluoroalkyl substances (PFAS)

From waterproof clothing and stain-resistant upholstery and carpeting to nonstick cookware and pizza boxes, per- and polyfluoroalkyl substances (PFAS) are all around us. This class of thousands of synthetic organic chemicals have been produced for decades to make products resistant to water, heat, and stains.

Not enough is known about the health impacts of most PFAS but they can affect the immune, endocrine and metabolic systems. Trace doses of several of the most-researched compounds have been linked to health issues from cancers and increased cholesterol levels to preeclampsia during pregnancy.1

An increasing number of communities across the United States are investigating PFAS in their drinking water. Sources of contamination include not only industrial and manufacturing facilities, but landfills where PFAS have leached into groundwater, and places where PFAS-based firefighting foam known as Class B aqueous film-forming foam (AFFF) has been used.

Designed for long-term stability, PFAS do not easily break down and are difficult to destroy. PFAS cycle through the environment: incineration facilities can release PFAS into the air; contaminated biosolids produced by wastewater treatment facilities have been linked to PFAS in vegetables grown on farm fields where it was applied.2,3 These chemicals are so persistent that they are known as “forever chemicals.”

In our blood and daily life

Nearly everyone has been exposed to these toxic substances by consuming contaminated water and food, breathing in dust with PFAS, and through contact with consumer products that contain PFAS.4 Evidence of harmful health effects led to the phase out of two of the most researched chemicals, PFOA and PFOS, after they were linked to kidney and testicular cancer, liver damage, increased cholesterol, thyroid disease, decreased fertility, and increased risk of pregnancy-induced hypertension and preeclampsia.5

At a glance ...

Per- and polyfluoroalkyl substances (PFAS) are a class of thousands of synthetic chemicals used to make products resistant to water, heat, and stains. PFAS, often referred to as “forever chemicals,” do not easily break down in the environment and are difficult to destroy. Detected in drinking water and drinking water sources throughout the United States, their chemical properties make PFAS difficult to treat and remove using conventional water treatment processes. Trace doses of several of the most-researched compounds have been linked to harmful health effects. There is not yet enough research to suggest safe exposure levels for each PFAS. An increasing number of communities across the United States are detecting these chemicals and working to address PFAS contamination.

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Research indicates that PFAS introduced as replacements for legacy, long-chain PFAS may also impact human health. These newer short-chain PFAS are just as difficult to break down as long-chain PFAS, persistent in the environment, and tend to be highly mobile, easily moving into ground and surface waters. Short-chain PFAS continue to be widely used in industry.

Most people in the United States have one or more specific PFAS in their blood, particularly PFOS and PFOA. But there is no treatment for PFAS exposure, and blood testing does not provide a clinical diagnosis or definitively say if a person’s health has been or will be affected.

**How much is too much?**

There is not yet enough information to set safe exposure levels for each of the hundreds of PFAS in use, either individually or cumulatively. Research is ongoing to assess the human health effects of exposure to PFAS. Very little is known about a majority of PFAS, including how long they linger in our bodies (referred to as half-life), their toxicity and how different PFAS may interact in our bodies. But research into the potential health implications of PFAS indicates reason for concern.

In 2016, the US Environmental Protection Agency (EPA) developed a lifetime health advisory level of 70 parts per trillion (ppt) for PFOS and PFOA, individually or combined. As of June 2022, the EPA has lowered the health advisories for PFOA, PFOS and set final health advisories for GenX and PFBS. The health advisories are now 0.004 ppt for PFOA, 0.02 ppt for PFOS, 10 ppt for GenX, and 2,000 ppt for PFBS. However health advisories are not an enforceable standard. Some states have enacted stricter limits for these and additional PFAS in drinking water, surface water and groundwater based on different health effects such as fetal and infant growth delays, thyroid dysfunction, infertility, alterations in liver function, and/or impaired immune function.

Recognizing the need for additional evidence, state and federal agencies are funding and conducting research to better understand these compounds to more effectively respond to public health concerns.

**PFAS in drinking water**

Detected in drinking water and drinking water sources throughout the United States, their chemical properties, particularly the strength of the carbon-fluorine bonds, make PFAS difficult to treat and remove using conventional water treatment processes. The costly burden of PFAS treatment and remediation often falls to communities and states.

The EPA has not yet regulated PFAS in drinking water. In recent years, many states have adopted or proposed limits for PFAS in drinking water, required monitoring for PFAS in public drinking water systems, issued health guidance and set up interagency task forces and action plans to address PFAS.

Beginning in 2023, the EPA will require some of the largest public drinking water systems to monitor for 29 different PFAS.

**Sources of contamination**

Communities near industrial facilities that manufactured or used PFAS were among the first to raise concerns about health threats. Industrial facilities in the United States largely phased out PFOS and PFOA but continue to use other PFAS.

PFAS do not biodegrade. The persistence of PFAS means that disposal of materials containing PFAS often becomes a source of contamination. Landfills can leach PFAS. Incineration facilities can discharge PFAS into the air, which enter rainwater or otherwise settle back to land. Wastewater treatment plant outflows can contain PFAS and can affect the drinking water supplies of downstream communities. Biosolids produced by wastewater treatment plants are often applied to fields. If they contain PFAS, the food grown on the fields can contain PFAS.

**Much remains unknown**

Despite decades of use, detecting the hundreds of different PFAS in the environment may not even be possible yet because there aren’t established analytical methods to identify most PFAS. Most methods currently target a set of fewer than 40 individual PFAS but at least 600 different PFAS are known to be used in industrial and consumer products.

Research has shown that some PFAS have adverse health effects at trace levels of parts per trillion in drinking water, but there are still many toxicological unknowns. Carcinogenicity studies are only available for four PFAS: PFOS, PFOA, PFHxS, and GenX.

The Interstate Technical and Regulatory Council (ITRC)
Another significant source of PFAS in the environment is the use of the firefighting foam AFFF. Used to extinguish fuel and other flammable liquid fires, AFFF is widely used at airports, military sites, chemical plants, and aboveground petroleum storage tank facilities. Many fire departments use AFFF for training and emergency response. There have been instances of AFFF contaminating groundwater after being used to extinguish vehicle fires. When AFFF is used, runoff may enter sewers or contaminate soil and groundwater. Military installations and airports where AFFF may have been used for years are areas of concern. The Department of Defense is investigating more than 100 of its sites across the United States.\(^{16}\)

### Sources of exposure

People consume PFAS through **drinking water**, eating **food** that was packaged in materials that contain PFAS, or grown in fields with biosolids contaminated by PFAS, and eating **fish** from contaminated waters. People can swallow **dust** or **soil**. Using **consumer products** that contain PFAS such as non-stick cookware, stain-resistant carpeting, and water repellant clothing can also expose people to PFAS.\(^{17}\)

### Monitoring and detecting PFAS

There are limited techniques to measure PFAS levels in water. Different analytical techniques are necessary for different types of PFAS and the accuracy of methods varies, including the lowest levels of PFAS that can be reliably detected. Most analytical methods target a set of fewer than 40 individual PFAS. Accurately measuring PFAS concentrations at the parts per trillion level requires expensive laboratory equipment and careful sample preparation; analysis can be costly.

Some state programs focused on measuring PFAS at or near potential sources, such as industrial sites, military bases, airports, other locations where firefighting foam containing PFAS was used, landfills, and wastewater treatment plants. A few states have begun to conduct extensive sampling campaigns. Evaluating PFAS in drinking water requires robust monitoring plans to monitor PFAS in drinking water and in water sources, identify sources and pathways of PFAS, and prevent contamination. Multiple state agencies need to coordinate to protect public health.
Water treatment
PFAS cannot be easily removed by most municipalities’ existing conventional water treatment technologies. Water treatment produces PFAS contaminated waste that then requires proper management and disposal to prevent further contamination.

The established water treatment technologies for PFAS can be costly and vary in their effectiveness at removing different PFAS, the most commonly used are activated carbon, ion exchange (IX) and reverse osmosis. Results can also depend on local factors such as water quality and waste treatment options.

Some communities choose to remediate sources of contamination, shutdown contaminated wells or other sources, and install in-home treatment such as reverse osmosis or activated carbon filters in affected households.

There are several emerging and innovative methods for reducing PFAS in drinking water, including chemical and electrochemical oxidation, ozofractionation, and novel sorbents. Some of the most promising ones are in the early stages of development and may be several years away from implementation.

Destroying persistent pollutants
It is not easy to dispose of PFAS. Landfills and incineration facilities have emerged as sources of PFAS contamination across the country.

High-temperature incineration is currently one of the most common methods to destroy PFAS, but without sustained temperatures above 1,400 degrees Celsius, incineration facilities may discharge PFAS into the air. Incomplete burning of PFAS can release smaller PFAS, about which we know very little. Research is being conducted to determine the conditions required for the destruction of PFAS as well as how PFAS behave in air emissions. The EPA is currently considering alternative disposal techniques to more effectively treat and dispose of PFAS.

Taking action to regulate
The EPA has begun to develop a national primary drinking water standard for PFOA and PFOS and is considering ways to evaluate additional PFAS. Under the Toxic Substances Control Act, manufacturers are now required to submit detailed information on some PFAS to the EPA to guide potential regulatory action and are prohibited from using certain long-chain PFAS without prior review and approval. No PFAS have been designated hazardous substances yet.

In recent years, states have regulated the presence of PFAS in drinking water, food packaging and consumer products; restricted use of PFAS firefighting foam; allocated funds for cleanup and remediation and sued manufacturers of PFAS chemicals.

Some experts and environmental advocates suggest regulating PFAS as a class rather than trying to regulate each chemical individually, establishing a single drinking water standard for the entire PFAS class, for example. Other potential strategies include regulating groups of PFAS, or subclasses, that have similar chemical properties such as perfluorinated carbon chain length or regulating by common adverse health effects, co-occurrence with other PFAS or a combination of these characteristics.

Some suggest that PFAS should be restricted to essential uses and only permitted when there are no safer alternatives. Uses of PFAS in products such as food packaging, non-stick cookware, water repellant clothing, and stain resistant carpeting and textiles may not be essential, but medical devices could be deemed essential. This regulatory approach led to the reduction of ozone-depleting chlorofluorocarbons 30 years ago. There are already many functional alternatives to PFAS that provide adequate technical performance and continued innovation will deliver many more.

The Department of Defense is researching effective alternative fire-fighting foams to AFFF.

FOR MORE INFORMATION
The AAAS EPI Center helps local and state leaders understand the current scientific evidence as they seek to address potential PFAS contamination. Additional information can be found in our Addressing Per- and Polyfluoroalkyl Substances (PFAS) in Drinking Water: Guides for Local and State Leaders. The information in these guides can help people engage community members, drinking water providers, local and state regulatory agencies, and federal agencies to address PFAS in drinking water. The first guide provides an overview of the current scientific evidence of PFAS occurrence and toxicology, as well as what remains unknown and requires additional research. It explains the properties, history, toxicology, exposure pathways, and the current status of federal and state regulations of PFAS. Additional guides explain monitoring, treatment and mitigation of PFAS in drinking water and communicating risk.


