PFAS: Polyfluoroalkyl Substances: "Forever Chemicals": History and Future

Background

PFAS (Per- and Polyfluoroalkyl substances) have been nicknamed "forever chemicals" because their unique chemistry makes them particularly persistent under typical environmental conditions. The basic polymer backbone is the Carbon (C) – Fluorine (F) bond which is one of the strongest of all organic chemical bonds. One of the key properties of these materials is that they are "ampiphobic," meaning that they repel both water and oil-based substances. This property makes the substances very versatile and useful while at the same time very difficult to break down, hence the term "forever chemicals. In addition to breaking down very slowly, they are persistent, often building up in people, animals, and the environment. These PFAS substances have been around and in use since the 1940's and while very useful, their toxicity is now becoming better understood. Some of the more notable and prevalent chemicals beginning in the early 1950's are known also as household names, such as Teflon (DuPont) and Scotchgard (3M).

The EPA has identified over 14,000 PFAS substances and they can be present in our water, soil, air, and food as well as in materials found in our homes or workplaces, including drinking water. An abridged list of PFAS uses include firefighting foams, plastics manufacturing, electroplating, semiconductor processing, nonstick cookware, waterproof clothing, carpeting, food packaging, dental floss, cosmetics, medical equipment, bicycle lubricants, ski wax, firefighter gear, pharmaceuticals, pesticides, menstrual products, and waterproofing sprays.

Human Health Impacts

PFAS manufacturers identified adverse health effects in workers in 1962. However, this information was withheld from the public. According to the Agency for Toxic Substances and Disease Registry (ATSDR), PFAS can harm our heart, liver, reproductive, renal systems and cause certain cancers. There is some evidence that they can increase cholesterol levels and increase blood pressure in pregnant women, leading to birth defects and dangerous conditions such as pre-eclampsia (A condition in pregnancy characterized by high blood pressure, sometimes with fluid retention and proteinuria.). PFAS can change liver enzymes and decrease the vaccine response in children.

During the years of 2004-2013 the "C8 study" (study of chemicals with 8 or more consecutive carbon bonds) connected drinking water PFAS exposure to several diseases including high cholesterol, ulcerative colitis, thyroid disease, and testicular and kidney cancer.

In 2022, the National Academies of Science, Engineering, and Medicine (NASEM) report identified strong associations between PFAS exposure and 4 health conditions: decreased antibody response, dyslipidemia (a condition of abnormal blood lipid levels, which can increase the risk of heart and circulation problems), decreased infant and fetal growth, increased risk of kidney cancer.

In 2024, PFOS was labeled a Group 1 Known Human Carcinogen while PFOA was labeled a Group 2B, which is a Possible Human Carcinogen.

Contamination Sources

PFAS substances enter into our environment from many sources including.

- Industrial Facilities: Facilities that produce PFAS or use them in manufacturing.
- Military, Emergency Training, and Airports: Aqueous Fluorinated Firefighting Foam (AFFF) used in routine emergency response drills.
- Landfills: PFAS leaches from household waste, disposal of industrial PFAS wastes
- Wastewater Treatment Plants: PFAS from upstream sources concentrates in filtration systems, passes through unchanged, or is transformed into other PFAS species.
- Fracking: PFAS identified in proprietary fracking fluids across the US
- Agricultural Sludge: Wastewater sludge containing PFAS is donated to farmers to spray on fields.

Environmental Fate and Transport of PFAS Chemicals

- Stable: weatherproof characteristics = long lifespan
- Mobile: carried through the water cycle and have been identified in global rain and arctic ice
- Persistent: some molecules and chemicals adhere to soils and biosolids, leading to long lasting, high concentrations
- Bio accumulative: identified in fish and game tissues as well as wildlife across the world.

Persistence in the Human Body

- Long-chain (polymer chains with 6+ consecutive carbon bonds) PFAS stay in the body for years with a half life of approximately three years. In 2006, manufacturers of PFAS chemicals agreed to phase them out by 2015.
- Short-chain (polymer chains containing 6 or fewer consecutive carbon bonds) PFAS stay for months or weeks with a half-life of approximately 30 days.
- The National Health and Nutrition Examination Survey (NHANES) has repeatedly identified PFAS in >99% of nationally representative blood serum samples.

Current Activities

- While the manufacture of long chain PFAS has been banned since 2015, industry continues to produce short chain PFAS substances.
- Regulatory agencies have approached the PFAS class one molecule at a time. Once one comes under scrutiny, another takes its place.
- The industry as a whole is building knowledge by studying industry documents and thousands of studies are helping to understand the risks and impacts of PFAS.
- Technology is continually improving, promising new filtration and destruction methods which may help us reduce the extensive PFAS burden.

Maximum Contamination Level (MCL) Challenges

- Cost: Treatment technology is expensive. Federal support is available to help water systems comply with MCLs, but ratepayers may see cost increases.

- Waste Management: Water treatment results in concentrated waste - how do we safely dispose of it?
- 0.043% of PFAS: The 2024 MCL regulation only addresses six PFAS compounds.
- Downstream Focus: Drinking water treatment does not address the primary source of contamination.

Evolving Drinking Water Guidance

In 2009, the Environmental Protection Agency (EPA) began issuing Provisional Health Advisory Levels (HAL) for PFAS chemicals. The initial values were a maximum of 200 parts per trillion (ppt) and 400 ppt for the PFOS and PFOA categories, respectively. As more research and testing has been conducted, ever increasing the body of knowledge, the HAL maximum levels have become increasingly more stringent. The EPA maximum contaminant level for both the PFOS and PFOA categories is now 4 ppt. As more chemicals are identified, more categories have been added including short chain replacements for Teflon (PFOA) under the category of Gen x and Scotchgard (PFOS) under the category of PFBS. Both of these recent additions in 2022 have maximum levels of 10 ppt. There are two other troubling categories that have been added in 2024. They are PFNA, a group of chemicals that are surfactants and are persistent organic pollutants. The other group is PFHxS, a group of surfactants that are highly persistent with bio accumulative properties.

Beginning in 2027, public water systems must test for these PFAS and will be required to complete ongoing monitoring and public disclosures. Public water systems in exceedance must take action to reduce these PFAS by 2029. But how? Removing PFAS from water is difficult. Some PFAS are removed with granulated activated carbon (GAC) or reverse osmosis filtration, resulting in concentrated PFAS waste (i.e., spent filters). Some PFAS are unaffected by standard waste water treatment plant (WWTP) methods. Influent treatment can increase total PFAS concentrations in effluent. Much more research and testing is needed.

Because of their widespread use and their persistence in the environment, many PFAS are found in the blood of people and animals all over the world and are present at low levels in a variety of food products and in the environment. PFAS are found in water, air, fish, and soil at locations across the nation and the globe.

PFAS in PA

- In 2013 - 2015, PFAS substances were identified in public drinking water systems through the **third Unregulated Contaminant Monitoring Rule** (UCMR 3) which was published on May 2, 2012. UCMR 3 required monitoring for 30 contaminants (28 chemicals and two viruses) between 2013 and 2015 using analytical methods developed by the EPA and consensus organizations. This monitoring provides a basis for future actions to protect public health.
- In 2018, the State of Pennsylvania (PA) established a State PFAS Action Team.
- During 2020-2021, 412 PA public drinking water systems were sampled for PFAS under Action Team plan.
- In 2023, PA adopts maximum contaminant levels (MCLs) for 2 PFAS in public drinking water.
- PA State Attorney General files lawsuit against 3 PFAS manufacturers
- Currently, PA contracts with USGS to sample for 33 PFAS in surface water
- In 2024, the EPA established the MCL at 4 ppt.

What is next?

A drastic reduction in the manufacture and use of PFAS is the only way that this current problem can be solved. Research is ongoing to find replacement substances that are environmentally less damaging and break down easier and faster. Many of the PFAS chemicals are very beneficial in their everyday use. The problem is that they are so stable, mobile, and persistent that they are found virtually everywhere, soil, air, and water. Their potential and known health impacts are now being realized and the impacts are negative to humans and the environment.

Improved test methods and source identification will help us understand better how to mitigate the pollution. Awareness by the general public through education will at least let people know the dangers and risks associated with the use of PFAS.

This paper is summarized from the following on-line presentation:

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