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In This Issue:

PFAS- the Forever Chemicals

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Per- and polyfluoroalkyl substances (PFAS) are a class of ubiquitous, synthetic chemicals commonly used to make water, grease, and stain-resistant products. They have been used in innumerable household products ranging from carpets and furniture to non-stick cookware. PFAS have also been a prominent ingredient in firefighting foams used around the world. Although PFAS were created to make our lives more convenient, it has become increasingly apparent that these chemicals may be doing more harm than good. Critical to this point, they do not readily degrade in the environment nor are they effectively metabolized in the human body. Due to this, they are often called "forever chemicals." Initially, it was presumed that PFAS were biologically inert but new research has linked them with a wide range of clinical conditions detrimental to human health. However, humans are not the only living beings to be affected by these chemicals. Substantial amounts of PFAS have been detected in the bodies of animals all over the world, ranging from aquatic to terrestrial species. Due to their harmful nature, there are significant concerns over their chronic effects on the many people, animals, and environments that have been exposed.

History: PFAS were initially synthesized in the 1940s; the two most mass produced are PFOS (Perfluorooctane sulfonic acid) and PFOA (Perfluorooctanoic acid). PFOA was first used as a key component in non-stick cookware sold by DuPont under the brand name Teflon. In 1953, PFOS was accidentally spilled onto a 3M chemist's shoe. When trying to remove the substance, it was serendipitously discovered that the PFOS left an oil and water-resistant coating on the shoe, paving the way for it to be used as a protective coating on many other products such as furniture carpets, and fabrics. These 3M products have been commonly sold under the brand name Scotchgard. In July 1967, another key event shaped the PFAS industry. A massive fire broke out on the United States aircraft carrier Forrestal, killing 134 sailors. Knowing about these chemicals' ability to reduce surface tension and consequently repel water and oil, that Navy worked with 3M to develop a firefighting foam containing PFOA and PFOS in an attempt to prevent future tragedies from occurring. These products, known as Aqueous Film Forming Foams (AFFFs), proved to be highly effective in extinguishing fires and became commonly used in airports, military bases, and firefighting training facilities around the world. In the late 1970s, studies by 3M showed that PFOS and other PFAS accumulate in the human body and potentially could cause adverse health conditions. A paper published in 2023 argues that the PFAS industry suppressed for decades unfavorable research results to distort public perception (1). In the 1980s, detectable levels of PFOS were found in numerous samples of drinking water. With increasing concern over the toxicity of these chemicals, 3M announced that it would begin to phase out its production in 2000 and replace them with shorter chain, allegedly less toxic and less persistent fluorosurfactants.

General Properties and Common Exposures: At present there are over 12,000 chemicals classified as PFAS (1). The general chemical structure of PFAS chemicals consists of an eight-carbon chain which led to them being called C8 compounds. Each of these carbons are bound to multiple fluorine atoms with a terminal carbon bound to a hydrophilic group. Figure 1 illustrates the chemical structure of PFOS and PFOA. The strength of the C-F covalent bonds allows the PFAS to persist in the environment without degrading (2). These bonds also directly contribute

to the hydrophobic and lipophilic nature of PFAS, so they repel both water and oils. PFAS have an affinity for proteins, especially albumin, and remain in the bloodstream (3).

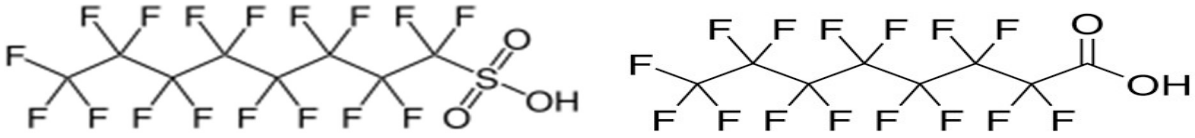

Figure 1. The chemical structures of PFOS (C8F17SHO3) on the left and PFOA (C8F15HO2) on the right.

There are numerous ways in which exposure to PFAS can occur. One common route is through Teflon coated non-stick cookware. When food is cooked in these pans, small particles of PFOA can become airborne, leading to respiratory exposure. More often, PFAS can contaminate the food and enter the body when ingested. In addition, carpets and furniture that have been treated with PFOS (i.e., Scotchgard) may also release tiny particles of it into the air, which then accumulate and settle as dust. As seen with lead poisoning, children are at a greater risk of exposure because they typically play in areas with carpets and furniture and often put their hands in their mouths. Recent research shows that PFAS can easily contaminate drinking water when products that contain them, such as AFFFs, are spilled onto the ground to run off into rivers or lakes and are absorbed into the groundwater. A 2023 paper by the U.S. Geological Survey (USGS) estimated that 45% of all American drinking water supplies are contaminated with PFAS (4). Figure 2 shows the sites tested.

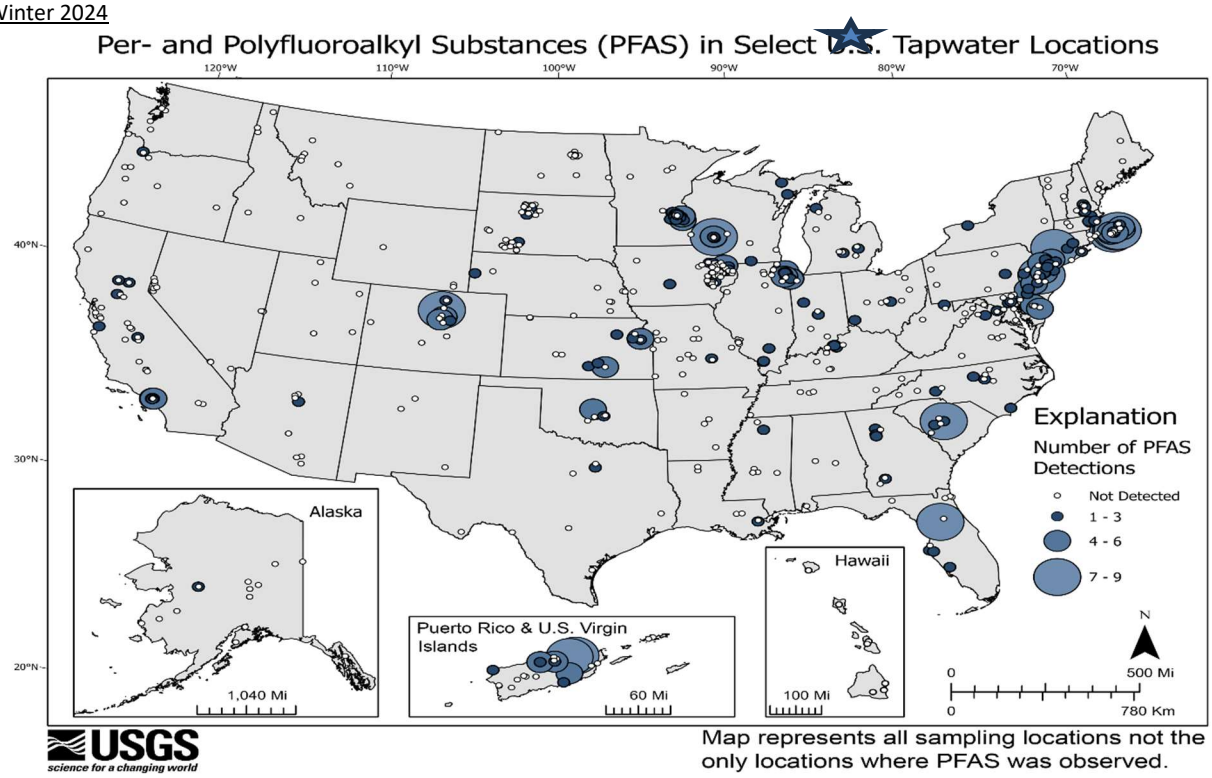

Figure 2. USGS map of PFAS-tested locations and their results. The authors added a star to indicate the location of the prior Wurtsmith Air Force Base.

Pharmacology: After PFAS is absorbed by the body they reach peak concentrations in the liver, kidneys, and blood (5). They can be transmitted *in utero* and through nursing (4). PFAS are not effectively metabolized in the body. The half-life of PFOS in humans is ~4.8 years and PFOA is ~3.5 years (6). When PFAS are eventually excreted they are primarily found in the urine (5). Some of the adverse health conditions associated with PFAS include increased risk of developing certain cancers (prostate, kidney and testicular), preeclampsia, decreased fertility, decreased immune response, altered thyroid function, and ulcerative colitis (5, 7).

While there are no accepted medical procedures to remove PFAS from the body, methods that help reduce the risk of exposure include avoiding the use of products that contain them. If drinking water is a concern, then installing carbon-based water filters in the household or utilizing reverse osmosis can be helpful. A report by the Centers for Disease Control and Prevention (CDC) in 2019 shows the ubiquitous nature of PFAS in the U.S. They found

detectable PFAS in the blood of ~97% of Americans based upon biomonitoring samples collected for the National Health Nutrition and Examination Survey (NHANES, 8).

Lab Testing: At present, few laboratories conduct testing for PFAS. Testing is usually limited to a few PFAS compounds conducted at government labs, large commercial labs like NMS or small focused labs located near major contamination sites. Lab procedures usually involve solid phase extraction followed by liquid chromatography-mass spectrometry (9). Clinical testing usually involves taking samples of blood in order to quantify the levels of PFAS. However, results do not reflect how safe or unsafe an individual is from being affected by these chemicals (10). Some laboratories test water samples for the presence of multiple PFAS. In March 2023, the Environmental Protection Agency (EPA) proposed Maximum Concentration Limits (MCL) for six PFAS to try and set safe drinking levels. The MCLs for PFOA and PFOS are 4 ng/L (4).

Affected Areas: As of September 2023, there were more than 3,180 PFAS contamination sites located across all 50 states 11). The state of Michigan has the most locations affected. A major epicenter of PFAS contamination is the prior Wurtsmith Air Force Base in Oscoda, Michigan, a declared federal Superfund site. Beginning in the 1970s, PFAS used in firefighting foams at the base leaked from storage tanks into the ground and local water supplies. Without knowing, servicemembers at the base and local civilians were drinking contaminated water. In 2017 the EPA tested the local water for PFAS and found it contained staggering levels. PFAS was detected at 80,000 parts per trillion, significantly higher than the permissible limit of 70 parts per trillion (12). Now, veterans of the Wurtsmith Air Force Base are advised to seek legal counsel if they have developed a disease since the time that they served. Residents have also been advised to limit their consumption of local wildlife, in particular fish and deer (Figure 3). Recently, 3M has agreed to pay $10.3 billion to settle lawsuits regarding the presence of these chemicals in various drinking water supplies. The company claims that production of these chemicals will cease to exist by the year 2025.

Figure 3. Health advisory signs posted near Wurtsmith Air Force Base to not eat local wildlife.

Conclusion: Though the production of the PFAS forever chemicals is phasing out in the U.S., there is great concern over past exposures. Recent research indicates that most Americans have PFAS present in their blood, and that it is commonly found in drinking water. It is vital that this publicly driven research continues. On a positive note, NHANES biomonitoring data indicate decreased levels of PFOA and PFOS from 1999 to 2018. The heightened awareness about the harmful effects of PFAS will hopefully ensure proper funding is made available for those adversely impacted as well as environmental remediation of major contamination sites. Those seeking to learn more about PFAS are encouraged to visit the EPA online site.

References:

1. N. Gaber, L. Bero, & T. Woodruff (2023). The devil they knew: chemical documents analysis on industry influence on PFAS science. *Annals of Global Health*, 89(1): 37, 1-17.

2. Y. Liu, L. Jiang, H. Wang, H. Wang, W. Jiao, …, X. Jiang (2019). A brief review for fluorinated carbon: synthesis, properties, and application. *Nanotechnology Review*, 8, 573-586.

3. N. Ding, S. Harlow, J. Randolph, R. Loch-Caruso & S. Park (2020). Perfluoroalkyl and polyfluoroalkyl substances (PFAS) and their effects on the ovary. *Human Reproduction Update*, 26, 724-752.

4. K. Smalling, K. Romanok, P. Bradley, M. Morriss, J. Gray, …, T. Wagner (2023). Per- and polyfluoroalkyl substances (PFAS) in United States tap water: comparison of underserved private-well and public-supply exposures and associated health implications. *Environmental International,* 178, doi: 10.1016/j.envint.2023.108033

5. Agency for Toxic Substances and Disease Registry (ATSDR, 2021). Toxicological profile for perfluoroalkyls. Link ATSDR Perfluoroalkyls (PFAS) Tox Profile (cdc.gov)

6. Biomonitoring Summary, CDC (2021, September 2). Biomonitoring Summary | CDC

7. R. Lewis, L. Johns & J. Meeker (2015). Serum biomarkers of exposure to perfluoroalkyl substances in relation to serum testosterone and measures of thyroid function among adults and adolescents from NHANES 2011-2012. *International Journal of Environmental Research and Public Health,* 12(6): 6098- 6114.

8. A. Calafat, K. Kato, K. Hubbard, T. Jia, J. Botelho & L. Wong (2019). Legacy and alternative per- and polyfluoroalkyl substances in the U.S. general population: paired serum-urine data from the 2013-2014 National Health and Nutrition Survey. *Environment International,* doi: 10.1016/j.envint.2019.105048

9. C. Delonas (2022, January 21). Detecting environmental PFAS using liquid chromatography-tandem mass spectrometry. *Chromatography Online*. Detecting Environmental PFAS Using Liquid Chromatography–Tandem Mass Spectrometry (chromatographyonline.com)

10. Blood testing for PFAS, ATSDR (2023, March 3). Blood testing for PFAS | ATSDR (cdc.gov)

11. EWG (n.d.). Interactive Map: PFAS Contamination Crisis. Retrieved September 8, 2023, from Interactive Map: PFAS Contamination Crisis: New Data Show 3,186 Sites in 50 States (ewg.org)

12. PFAS exposure at Wurtsmith Air Force Base, Atraxia Law (n.d.), Retrieved June 30, 2023, from PFAS Exposure at Wurtsmith Air Force Base | Atraxia Law

Editor's Corner:

Dear TDM/Toxicology Division Members:

Happy New Year to all the members!

We need your ideas and article contributions for this newsletter. It is a good opportunity to put authorship in resume. Please contact Pradip Datta, Newsletter editor at p.datta581@gmail.com.

ADLM TDM TOX Web Resources:

https://www.myadlm.org/community/divisions/tdm-and-toxicology/

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