FOREVER CHEMICALS: RESEARCH AND DEVELOPMENT FOR ADDRESSING THE PFAS PROBLEM

JOINT HEARING

BEFORE THE

SUBCOMMITTEE ON ENVIRONMENT
SUBCOMMITTEE ON RESEARCH AND TECHNOLOGY

OF THE

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

OF THE

HOUSE OF REPRESENTATIVES

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Appendix: Answers to Post-Hearing Questions

FOREVER CHEMICALS: RESEARCH AND DEVELOPMENT FOR ADDRESSING THE PFAS PROBLEM

TUESDAY, DECEMBER 7, 2021

House of Representatives,
Subcommittee on Environment,
joint with the Subcommittee
on Research and Technology,
Committee on Science, Space, and Technology,
Washington, D.C.

The Subcommittees met, pursuant to notice, at 10:01 a.m., via Zoom, Hon. Mikie Sherrill [Chairwoman of the Subcommittee on Environment] presiding.

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON ENVIRONMENT
SUBCOMMITTEE ON RESEARCH AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

HEARING CHARTER

Forever Chemicals: Research and Development for Addressing the PFAS Problem

Tuesday, December 7, 2021
10:00 a.m. ET
Online via Zoom

Purpose

The purpose of this hearing is to discuss the role of federal research and development to better understand the class of man-made chemicals known as per- and polyfluoroalkyl substances (PFAS). There remains much uncertainty surrounding their toxicity and human health effects, how to safely and effectively remove them from the environment, and how to detect and quantify the thousands of different PFAS compounds that exist. The hearing will provide an opportunity to explore gaps in federal research efforts, methods for improved interagency coordination, opportunities to collaborate with state governments and non-government entities, and ideas for improving public understanding and education about PFAS. While there is a lot of attention on regulation and remediation of PFAS, there remains a great deal of work to better understand PFAS chemicals and the role the federal government can play to support the development of detection, monitoring, treatment, and destruction methods and technologies.

Witnesses

- **Dr. Elsie Sunderland,** Gordan McKay Professor of Environmental Chemistry, Harvard John A. Paulson School of Engineering and Applied Sciences, Harvard T.H. Chan School of Public Health
- **Ms. Abigail Hendershott,** Executive Director, Michigan PFAS Action Response Team (MPART)
- **Ms. Amy Dindal,** Director of Environmental Research and Development, Battelle Memorial Institute
- **Dr. Peter Jaffé,** Professor, Department Civil and Environmental Engineering, Princeton University

Overarching Questions

- What are the ongoing research and development (R&D) efforts related to PFAS within and outside of the federal government?
- What are the current gaps in PFAS research?
- What are opportunities for further federal investment in PFAS R&D efforts?
- What is the role of collaboration and coordination within the federal government and with non-federal entities in advancing PFAS R&D?

Background
Per- and polyfluoroalkyl substances (PFAS) or "forever chemicals" are a class of man-made chemicals that have been in use since the 1940s and include Perfluorooctanoic Acid (PFOA) and Perfluorooctane Sulfonate (PFOS), GenX, and others. Products such as non-stick pans, firefighting foam, food packaging, paints, and many other everyday products contain PFAS. There are currently more than 5,000 types of registered PFAS compounds. Due to the strong molecular structure of the carbon-fluorine bond, PFAS are resilient against water and oil, which makes them appealing for commercial uses, but difficult to remove or destroy.

PFAS are widespread and persistent in nature. Surveys conducted by the Centers for Disease Control and Prevention (CDC) show that most people in the United States have been exposed to PFAS and have PFAS in their blood.[1] Research shows that people can be exposed through drinking contaminated water, eating animals that were exposed to contaminated water, eating foods packaged with PFAS-containing materials, breathing air contaminated with PFAS, or using the long list of items that contain PFAS.[2] PFAS can also be emitted and transported in the air—an area that needs further study.

There is growing evidence that PFAS adversely impact both human health and other living organisms. PFAS have been found to accumulate and remain in the body for a long time, and can lead to serious health effects including cancer, low infant birth weights, liver and kidney issues, reproductive and developmental problems, and more. PFAS contamination is also an environmental justice issue, as low-income communities and communities of color are more likely to live near PFAS-contaminated areas.[3]

Some PFAS have been more widely used and studied than others. PFOA and PFOS are two of the most widely used and studied PFAS chemicals, and they have been mostly replaced in recent years with new PFAS that were thought to be safer. However, these new short-chain PFAS compounds, like GenX, have been found to be "widely detected, more persistent and mobile in aquatic systems," and may pose more risks to human and ecosystem health than earlier, long-chain PFAS compounds.[4]

While the PFAS chemical class is not generally restricted for commercial use nor regulated by the federal government, the EPA did announce on February 20, 2020, a proposal to regulate PFOS and PFOA in drinking water.[5] The draft rule is expected in the fall of 2022, and a final rule is expected in 2023.[6] The EPA is also taking steps to increase reporting of and transparency about the use and manufacturing of PFAS.[7] Given the U.S. currently has no federally enforceable PFAS standards, many states have taken the lead in establishing legally enforceable standards for certain PFAS in drinking water and other environmental media, and have been conducting R&D to address PFAS. This has led to the emergence of patchwork quilt of state standards. This includes New Jersey, which was the first state to establish a Maximum Contaminant Level (MCL) for specific

[1] https://www.atsdr.cdc.gov/pfas/health-effects/us-population.html
[2] https://www.epa.gov/pfas/our-current-understanding-human-health-and-environmental-risks-pfas
[3] https://www.ucsusa.org/sites/default/files/2019-10/abandoned-science-broken-promises-web-final.pdf
[4] https://doi.org/10.1016/j.cej.2019.122506
[5] https://www.epa.gov/newsreleases/epa-announces-proposed-decision-regulate-pfoa-and-pfos-drinking-water
[6] https://www.epa.gov/pfas/pfas-strategic-roadmap-epas-commitments-action-2021-2024
[7] https://www.epa.gov/newsreleases/epa-continues-take-action-pfas-protect-public

PFAS in drinking water.[8] Other states that have established MCLs include Michigan,[9] New Hampshire,[10] Massachusetts,[11] and Vermont.[12]

Federal PFAS Research and Development Activities[13]

Environmental Protection Agency (EPA) – On April 27, 2021, EPA Administrator Regan established a new "EPA Council on PFAS" that was charged with building on the agency's ongoing work to better understand and ultimately reduce the potential risks caused by PFAS.[14] The Council released a PFAS Strategic Roadmap on October 18, 2021 that laid out the EPA's approach to tackling PFAS and set timelines for concrete actions to be taken by the agency over the next three years.[15] According to the Roadmap, the EPA is focused on three central directives to address PFAS: (1) research, (2) restrict, and (3) remediate. The EPA is investing in research, development, and innovation to increase understanding of PFAS exposures and toxicities, effects on human and ecological health, and effective interventions. Within the EPA, the Office of Research and Development (ORD) plays a major role in carrying out the Roadmap. It collaborates across different levels of government and with utilities and academia to develop better PFAS detection methods, assess human health and environmental risks from PFAS, and develop better technologies to reduce PFAS in the environment.

Department of Defense (DOD) – DOD manages the largest research and development program in the nation devoted to PFAS detection, treatment, and destruction—with over $150 million in investments and another $70 million devoted to a PFAS-free replacement firefighting foam.[16] The DoD has utilized Aqueous Film Forming Foam (AFFF) to extinguish fires since the 1970s. AFFF mixtures contain significant quantities of PFAS, which have accumulated at DOD sites. DOD is currently conducting PFAS cleanup assessments at the nearly 700 military installations where PFAS was used. EPA and DOD research efforts also resulted in expanded testing capabilities to detect more types of PFAS in a variety of environmental media (soil, groundwater, etc.).[17]

DOD sponsors the Strategic Environmental Research and Development Program (SERDP) and the Environmental Security Technology Certification Program (ESTCP), both of which are engaged in PFAS research and development. SERDP is carried out in partnership with the Department of Energy and the EPA. It invests in basic and applied research, as well as advanced technology development. ESTCP is the DOD's demonstration and validation program that promotes the

[8] https://www.nj.gov/dep/newsrel/2020/20_0025.htm
[9] https://www.michigan.gov/som/0,4669,7-192-47796-534660--,00.html
[10] https://www4.des.state.nh.us/nh-pfas-investigation/?p=1185
[11] https://www.mass.gov/info-details/per-and-polyfluoroalkyl-substances-pfas#massachusetts-drinking-water-standard-and-health-information-
[12] https://dec.vermont.gov/water/drinking-water/pfas
[13] Several federal agencies are involved in PFAS R&D activities, including many outside of the Science Committee's jursidiction. The information in this charter should not be considered an exhaustive list of all federal PFAS R&D efforts.
[14] https://www.epa.gov/newsreleases/epa-administrator-regan-establishes-new-council-pfas
[15] https://www.epa.gov/pfas/pfas-strategic-roadmap-epas-commitments-action-2021-2024
[16] https://www.whitehouse.gov/briefing-room/statements-releases/2021/10/18/fact-sheet-biden-harris-administration-launches-plan-to-combat-pfas-pollution/
[17] https://www.epa.gov/newsreleases/epa-announces-first-validated-laboratory-method-test-pfas-wastewater-surface-water

transfer of technologies from proof of concept to field or production use. Both programs issue annual solicitations for proposals from the federal government, academia, and industry.[18]

National Institutes of Standards and Technology (NIST) – NIST work on PFAS is conducted by both NIST's Material Measurement Laboratory and Engineering Laboratory. As part of the work done by the Material Measurement Lab, NIST researchers work to create reference materials and data resources that can be used by government, academic, and industrial labs to increase confidence in quantitative and qualitative PFAS measurements, as there are limited chemical standards for PFAS measurements and a wide range of PFAS structures in existence. As of May 2021, NIST provides nine different reference materials that have measured amounts of PFAS and are developing more.[19] Work done by the Material Measurement Lab also helps to ensure measurement quality by performing inter-lab comparison studies. NIST collaborates with other agencies such as the Department of Defense, NOAA, EPA, the Army Corps of Engineers, and the CDC. NIST is currently working with FDA to develop reference materials for PFAS in commercial meat products and is exploring other food and agricultural products. Additionally, NIST is developing a reference material for low levels of PFAS in municipal drinking water and reference data for the identification of novel PFAS.[20] As part of the work done by the Engineering Lab, NIST researchers are examining firefighter gear to determine the type, prevalence, and concentration of PFAS in firefighting gear. They are also examining the concentration and source of the PFAS and the mechanism of its release.[21] NIST researchers have also received SERDP funding to create reference materials for AFFF.

National Science Foundation (NSF) – NSF supports fundamental research through multiple Foundation directorates to understand PFAS and chemicals like PFAS. This work includes funding research to better understand the fate and transport of PFAS in environmental systems, the transformation of PFAS in natural and engineered systems, and impacts of PFAS contamination on communities, including social impacts. NSF also funds research on potential technologies to degrade, destroy, or permanently sequester PFAS in the environment. One example of this is a special funding focus announced in June 2020 on Engineering Research to Advance Solutions for Environmental PFAS (ERASE-PFAS) focused on new science and technologies for the treatment and remediation of PFAS.[22] In August 2021, NSF announced the funding of 13 awards under the special funding focus.[23] NSF also supports STEM education to train the next generation of PFAS researchers.

National Oceanic and Atmospheric Administration (NOAA) – Researchers at NOAA's National Centers for Coastal Ocean Science (NCCOS) are working to evaluate the ecotoxicity of formulations intended to replace PFAS-containing AFFFs in marine and estuarine organisms.[24]

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[18] https://www.serdp-estcp.org/About-SERDP-and-ESTCP/About-SERDP
[19] https://www.nist.gov/programs-projects/measurement-science-and-polyfluoroalkyl-substances-pfas
[20] Ibid.
[21] Ibid.
[22] https://www.nsf.gov/pubs/2020/nsf20090/nsf20090.jsp
[23] https://www.nsf.gov/news/news_summ.jsp?org=NSF&cntn_id=303258&preview=false
[24] https://coastalscience.noaa.gov/project/ecotoxicity-of-perfluorooctane-sulfonate-and-fluorine-free-fire-fighting-foams-in-estuarine-organisms/

Department of Health and Human Services (HHS) – HHS reviews the rapidly evolving science on human health and PFAS, including through a groundbreaking study by Centers for Disease Prevention and Control (CDC) and Agency for Toxic Substances and Disease Registry (ATSDR) in eight states that will provide information about the health effects of PFAS exposure. The CDC has collected biomonitoring data from humans for a long-term study of chemical exposure, including PFAS. The CDC's studies indicate widespread exposure to PFAS in the U.S. population.[25]

National Institutes of Health (NIH) – At NIH, the National Institute of Environmental Health Sciences (NIEHS), in collaboration with the National Toxicology Program, supports research to better understand the health impacts of PFAS exposure. It also provides over $10 million in extramural grants annually for research on the PFAS health effects.[26]

Food and Drug Administration (FDA) – The FDA works with other federal agencies to identify routes of PFAS exposure, understand associated health risks, and reduce the public's exposure to those health risks.[27] The FDA is also engaging with industry to phase-out the use of certain PFAS substances, or it can revoke food contact authorizations when the agency determines there is no longer a reasonable certainty of no harm.[28] The FDA is working to develop new methods of detecting PFAS in foods at low concentrations and assess exposure to PFAS through food.[29]

United States Department of Agriculture (USDA) – The USDA is currently engaging in research to determine the impacts of PFAS on agriculture. PFAS can accumulate in agricultural products through the application of biosolids to soils, and the usage of PFAS-contaminated groundwater.[30]

Federal Aviation Administration (FAA) – The FAA is conducting research on the use of firefighting foam containing PFAS in emergencies and using technology to reduce PFAS discharges in testing of firefighting equipment. Additionally, the FAA and DOD are working to find a PFAS-free firefighting foam alternative. While the FAA no longer mandates use of firefighting foam containing PFAS at airports,[31] the FAA is still conducting research at its Aircraft Rescue and Fire Fighting Research Facility to authorize foam alternatives that can meet the same standard. This research has encountered delays due to COVID-19 disruptions.[32]

National Aeronautics and Space Administration (NASA) – While NASA does not conduct dedicated PFAS R&D activities, the agency is investigating and addressing PFAS that has been associated with its history of space and aeronautics hardware development, testing, and flight

[25] https://www.cdc.gov/biomonitoring/PFAS_FactSheet.html
[26] https://www.niehs.nih.gov/research/programs/pfas/index.cfm
[27] https://www.fda.gov/food/chemical-contaminants-food/and-polyfluoroalkyl-substances-pfas
[28] https://www.whitehouse.gov/briefing-room/statements-releases/2021/10/18/fact-sheet-biden-harris-administration-launches-plan-to-combat-pfas-pollution/
[29] https://www.fda.gov/food/chemical-contaminants-food/testing-food-pfas-and-assessing-dietary-exposure
[30] https://conservationwebinars.net/webinars/pfas-in-agricultural-operations/?searchterm=PFAS
[31] https://www.faa.gov/airports/airport_safety/certalerts/media/part-139-cert-alert-21-05-Extinguishing-Agent-Requirements.pdf
[32] https://www.faa.gov/about/office_org/headquarters_offices/ang/redac/media/full/2021/april/fullComm-apr2021-AirportsSubcommitteeReport.pdf

operations.[33] For example, NASA conducts ongoing monitoring of the groundwater at and around its Wallops Flight Facility, in Wallops Island, VA, to ensure continued success of a treatment system installed after PFOA and PFOS were detected there in 2017.[34] As of July 2021, the Agency has undertaken work to begin a Preliminary Assessment effort, under CERCLA guidelines, to identify areas of potential concern for the presence of PFAS at all NASA Centers, which will be followed by on-site investigations and sampling.[35]

Interagency Coordination – The 2021 National Defense Authorization Act directed the Director of the Office of Science and Technology Policy (OSTP), acting through the National Science and Technology Council (NSTC), to establish an interagency working group to coordinate federal activities related to PFAS research and development.[36] The interagency working group in the bill is responsible for coordinating the activities of the federal government to identify and address important research gaps and policy implications. It would include 19 different federal agencies, including the EPA, DOD, NIST, OMB, and more. It is charged with developing a strategic plan that will assess the current state of PFAS R&D at the federal level, associated federal funding, and scientific and technological challenges that must be addressed. It is also charged with establishing goals, priorities and metrics for federally funded PFAS R&D and developing an implementation plan for federal agencies. OSTP recently stood up the Joint Subcommittee on Environment, Innovation, and Public Health that would be responsible for carrying out this mandate. The Joint Subcommittee held its first meeting on November 8, 2021.

Research Gaps and Opportunities

Despite two decades of research on PFAS fate and transport, biological effects, and environmental emissions, critical gaps in our fundamental understanding of PFAS remain. Several challenges have hindered our ability to fill these knowledge gaps, including the diversity of the PFAS class of chemicals; analytical challenges in detecting, characterizing, and quantifying PFAS; and a lack of transparency by industry on the chemical identity, use location, and production quantities of PFAS.[37] A number of urgent questions for PFAS in the 21st century remain and include topics related to global production volumes of PFAS, locations where are PFAS used, PFAS hotspots in the environment, safe management of PFAS-containing waste, and understanding the health effects of PFAS exposure.[38]

Detection and Measurement – One of the greatest PFAS research needs is developing analytical techniques to detect and measure PFAS and validate the methods to understand the types and quantities of PFAS that are present. Detection falls into two broad categories of targeted and non-targeted methods.[39] *Targeted analysis* is used when researchers have a defined analyte to compare a sample to. *Non-targeted analysis* uses high resolution mass spectrometry to identify novel PFAS, for which there is no standardized comparable sample. Current techniques typically measure

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[33] https://www.gao.gov/products/gao-21-205
[34] https://www.nasa.gov/feature/background-latest-information-on-pfas-at-nasa-wallops/
[35] https://science.house.gov/imo/media/doc/Gibbs%20Testimony.pdf
[36] https://uscode.house.gov/view.xhtml?req=granuleid:USC-prelim-title15-section8963&num=0&edition=prelim
[37] Ibid.
[38] https://pubs.acs.org/doi/pdf/10.1021/acs.est.1c03386
[39] https://www.epa.gov/water-research/pfas-analytical-methods-development-and-sampling-research

individual PFAS chemicals in certain media, particularly in drinking water.[40] More work is needed to develop reliable analytical methods to identify and measure additional PFAS in air emissions, ambient air, and land.[41] There is also a need to develop "total PFAS" detection methods as a potential rapid, low-cost screening tool.[42]

Human Health and Environmental Impacts – More research is needed to understand the occurrence, fate, transport of PFAS, as well as exposure pathways. Additionally, more research is needed to collect toxicity data to inform hazard assessments. Similarly, relatively little is known about the ecological effects of PFAS contamination in the environment.

Treatment and Remediation – While some methods have been developed to remove or reduce PFAS in drinking water and wastewater, knowledge gaps remain to further advance PFAS treatment and remediation. This includes determining fate and transformation in conventional wastewater treatment, identifying approaches for site characterization and remediation, and evaluating treatment efficacy and approaches for managing residuals and spent materials.

Destruction and Disposal – Safe and effective disposal of PFAS through destruction or containment in a way that prevents re-introduction of PFAS into the environment is an area of active research. Some "conventional" methods of destruction or disposal include incineration, landfilling, underground injection control, and granular activated carbon (GAC) reactivation. However, additional research is needed to understand the efficacy and potential byproducts of current removal strategies and to develop new technologies and strategies.

[40] https://www.epa.gov/pfas/epa-pfas-drinking-water-laboratory-methods
[41] Ibid.
[42] https://www.epa.gov/water-research/pfas-analytical-methods-development-and-sampling-research

Chairwoman SHERRILL. That sounds great. This hearing will come to order. Without objection, the Chair is authorized to declare a recess at any time. Pursuant to *House Resolution Eight,* today the Committee is meeting virtually. I want to announce a couple of reminders to the Members about the conduct of this remote hearing. First, Members should keep their video feed on as long as they are present in the hearing. Members are responsible for their own microphones. Please also keep your microphones muted, unless you are speaking. Finally, if Members have documents they wish to submit for the record, please e-mail them to the Committee Clerk, whose e-mail address was circulated prior to the hearing.

So good morning, and welcome to today's joint hearing of the Environment and Research and Technology Subcommittees on PFAS research and development (R&D). Per- and polyfluoroalkyl substances, or PFAS, are a class of human-made chemicals. They're used in many industrial and everyday consumer products such as firefighting foam, food packaging, nonstick cookware, carpets, and even dental floss. PFAS are known as forever chemicals due to their widespread use, persistence in the environment, and strong molecular structure that makes them nearly impossible to break down. Despite being in use since the 1940's, PFAS are considered contaminants of emerging concern as we continue to understand the negative human health and ecological impacts of these substances. There's growing consensus that PFAS are linked to negative health consequences including, but not limited to, cancer, infertility, liver and kidney disease, hormone disruption, and damage to the immune system, especially in children.

As a former Navy pilot, I have spent countless days on military bases. Unbeknownst to me and my fellow servicemembers, I was in frequent contact with PFAS. Firefighting foam used on military bases, also known as Aqueous Film Forming Foaming or AFFF, contains PFAS. AFFF has caused PFAS contamination at levels deemed unsafe by the CDC (Centers for Disease Control and Prevention). That's why I helped secure funding in the *National Defense Authorization Act* to help cleanup our military installations, including the Picatinny Arsenal in north Jersey. The extensive use of PFAS has led to most, if not all, Americans to have these forever chemicals in their body to some degree. This is something I'm seeing across my district, from North Haledon to Verona to Stanhope, and everywhere in between. In fact, this issue is so critical in my district that one of my ten community project submissions was for PFAS remediation in Hopatcong.

While this issue is extensive in all communities across the country, it has disproportionate impacts on small communities who have trouble bearing the expense of remediation. It's concerning how little we know about these harmful chemicals and, even further, how limited our understanding is about what we still need to learn. I am proud to say that New Jersey is the first in the Nation to set PFAS drinking water standards, but we've only just begun to scratch the surface. Unfortunately, actions we are taking in New Jersey to reduce our exposure to PFAS through drinking water are expensive for our municipalities.

I'm proud that the bipartisan infrastructure law is making real investments to fund lead pipe remediation and removal of PFAS contaminants from water systems, ensuring we have safe drinking water, but without doing so on the backs of taxpayers in New Jersey and across the country. This is a great start. But given the scale of this issue, and the cost to our communities, it's clear we need to do more to support our municipalcities fighting these harmful chemicals, so we must support R&D to make remediation easier and less expensive. If we don't, the costs to our communities' health will continue to compound, and that's unacceptable.

There are many outstanding questions related to PFAS fate and transport, toxicity, exposure pathways, treatment and destruction, remediation, and essential use. We know PFAS are dangerous and harmful, but we don't know exactly how many PFAS chemicals there are, but they're in the thousands. In many cases we don't have the ability to detect PFAS that are present or measure their concentration. Questions also remain about global production volumes of PFAS, where PFAS are used, and PFAS hotspots. To answer these questions, we must support an interdisciplinary, collaborative, and integrated approach. It's critical to develop partnerships between State and local entities, academia, nongovernmental stakeholders, and the Federal Government.

Due to the cross-cutting nature of PFAS, numerous Federal agencies are essential to addressing the problem. The National Institutes of Health's (NIH's) National Institute of Environmental Health Sciences (NIEHS), DOD (Department of Defense), NIST (National Institute of Standards and Technology), NSF (National Science Foundation), NOAA (National Oceanic and Atmospheric Administration), FAA (Federal Aviation Administration), and of course EPA (Environmental Protection Agency) are all essential to conducting and funding research efforts for PFAS. This is an even more timely hearing for the Committee, as the EPA has just released their PFAS Strategic Roadmap, a comprehensive strategy to combat the persistent challenges of PFAS. I'm particularly pleased to see the EPA prioritizing investments in research, development, and innovation to strengthen our understanding of PFAS and accelerate remediation efforts. Additionally, the roadmap's emphasis on protections for disadvantaged communities that have been disproportionately impacted by PFAS is key as we strive to address environmental justice (EJ) concerns.

There's significant ongoing PFAS research and development activities, and even more in the pipeline. That's why I am pleased to welcome our esteemed panel of PFAS experts, who are well-versed on the current state of research and development. I look forward to hearing their testimony to better understand the gaps in our scientific understanding, and also to identify future research needs. I'm also eager to hear their recommendations for how this Committee can help facilitate research and development collaborations between Federal and non-Federal entities and identify opportunities for interagency coordination at the Federal level.

[The prepared statement of Chairwoman Sherrill follows:]

Good morning and welcome to today's joint hearing of the Environment and Research and Technology Subcommittees on PFAS research and development.

Per- and polyfluoroalkyl substances, or PFAS are a class of human-made chemicals. They're used in many industrial and everyday consumer products such as firefighting foam, food packaging, nonstick cookware, carpets, and even dental floss.

PFAS are known as “forever chemicals” due to their widespread use, persistence in the environment, and strong molecular structure that makes them nearly impossible to break down. Despite being in use since the 1940’s, PFAS are considered contaminants of emerging concern, as we continue to understand the negative human health and ecological impacts of these substances. There is growing consensus that PFAS are linked to negative health consequences including but not limited to, cancer, infertility, liver and kidney disease, hormone disruption, and damage to the immune system especially in children.

As a former Navy pilot, I have spent countless days on military bases. Unbeknownst to me and my fellow servicemembers, I was in frequent contact with PFAS. Firefighting foam used on military bases, also known as Aqueous Film Forming Foaming or “AFFF”, contains PFAS. AFFF has caused PFAS contamination at levels deemed unsafe by the CDC. That is why I helped secure funding in the *National Defense Authorization Act* to help clean up our military installations, including the Picatinny Arsenal in north Jersey.

The extensive use of PFAS has led to most, if not all, Americans to have these forever chemicals in their body to some degree. This is something I’m seeing across my district, from North Haledon to Verona to Stanhope—and everywhere in between. In fact, this issue is so critical in my district, that one of my ten community project submissions was for PFAS remediation in Hopatcong.

While this issue is extensive in all communities across the country, it has disproportionate impacts on small communities who have trouble bearing the expense of remediation. It is concerning how little we know about these harmful chemicals and, even further, our limited understanding about what we still need to learn.

I am proud of my home state of New Jersey for being the first in the nation to set PFAS drinking water standards. But we have only just begun to scratch the surface. Unfortunately, actions we are taking in New Jersey to reduce our exposure to PFAS through drinking water are expensive for our municipalities. I’m proud that the Bipartisan Infrastructure Law is making real investments to fund lead pipe remediation and removal of PFAS contaminants from water systems, ensuring we have safe drinking water but without doing so on the backs of taxpayers in New Jersey and across the country. This is a great start.

But given the scale of this issue, and the cost to our communities, it’s clear we need to do more to support our municipalities fighting these harmful chemicals. So, we must support R&D to make remediation easier and less expensive. If we don’t, the costs to our communities’ health will continue to compound, and that is unacceptable.

There are many outstanding questions related to PFAS fate and transport, toxicity, exposure pathways, treatment and destruction, remediation, and essential use. We know PFAS are dangerous and harmful, but we don’t know exactly how many PFAS chemicals there are—but they’re in the thousands. In many cases, we don’t have the ability to detect PFAS that are present or measure their concentration. Questions also remain about global production volumes of PFAS, where PFAS are used, and PFAS hotspots.

To answer these questions, we must support an interdisciplinary, collaborative, and integrated approach. It is critical to develop partnerships between state and local entities, academia, non-governmental stakeholders, and the Federal government.

Due to the cross-cutting nature of PFAS, numerous Federal agencies are essential to addressing the problem. The National Institutes of Health’s National Institute of Environmental Health Sciences (NIEHS), DoD, NIST, NSF, NOAA, FAA, and of course EPA-all are essential to conducting and funding research efforts for PFAS.

This is an even more timely hearing for the Committee as the EPA has just released their PFAS Strategic Roadmap, a comprehensive strategy to combat the persistent challenges of PFAS.

I am particularly pleased to see the EPA prioritizing investments in research, development, and innovation to strengthen our understanding of PFAS and accelerate remediation efforts. Additionally, the Roadmap’s emphasis on protections for disadvantaged communities that have been disproportionately impacted by PFAS is key as we strive to address environmental justice concerns.

There is significant ongoing PFAS research and development activities, and even more in the pipeline. That is why I am pleased to welcome our esteemed panel of PFAS experts who are well-versed on the current state of research and development. I look forward to hearing their testimony to better understand the gaps in our scientific understanding of PFAS and to also identify future research needs.

I am also eager to hear their recommendations for how this Committee can help facilitate research and development collaborations between Federal and non-Federal entities and identify opportunities for interagency coordination at the Federal level.

Chairwoman SHERRILL. With that, I will turn it over, and so the Chair now recognizes Environment Subcommittee Ranking Member Bice for an opening statement.

Mrs. BICE. Good morning. Thank you, Chairwoman Sherrill, and Chairwoman Stevens, for holding this joint Subcommittee hearing today, and thank you to our witnesses for taking the time to testify before us. Per- and polyfluoroalkyl substances, known as PFAS, are a large and diverse family of synthetic chemicals. It is not just one product, or one strand, that we can say is good or bad. Each individual chemistry in the family of PFAS has its own unique properties and uses. In fact, according to the EPA there are approximately 650 PFAS currently manufactured or used in the U.S. Many of these chemistries are essential to products driving our lives in the 21st century. Cell phones, tablets, computers, things we use every day, components of clean energy sources like solar and wind, modern medical devices that keep us healthy, sophisticated aircraft the U.S. military uses to keep us safe. In each of these, PFAS is the common denominator that makes them possible to produce.

But because of the strength and durability PFAS provides, these chemicals have a strong molecular bond that is not easily broken down or destroyed. That is why you will hear PFAS referred to as forever chemicals. As you might imagine, a chemical that is the backbone of Aqueous Film Forming Foam, which is a highly effective—highly effective at putting out the most difficult to suppress fires, is purposefully designed to withstand the most extreme conditions that would destroy most other products. That presents us with the main problem associated with PFAS, removing what is already out there. Because PFAS has been used in industry and consumer products since the 1940's, we know that exposure has already happened, and we face the problem of legacy contamination in water, soil, air, and food.

To overcome this challenge, I am looking forward to hearing from one of our witnesses, Ms. Amy Dindal from Battelle Memorial Institute, on her research regarding PFAS identification and destruction in the environment. Ms.—as Ms. Dindal will further explain, Battelle's development of PFAS Annihilator technology has destroyed 99.9 percent of PFOA and PFAS in water. This type of scalable technology provides proof that economically feasible, safe, complete, and reliable destruction of PFAS is within our grasp, thus solving the most fundamental issues that come with using these chemicals.

As we look to the future, it is important to remember not to villainize the entire category of chemicals. The hazard and risk profiles of various PFAS are immensely different. A broad categorical ban on PFAS would be detrimental to our manufacturing sector, and actually put lives at risk by reducing safety. Using certain PFAS in controlled, responsible manner is safe and effective. Understanding the distinct properties of each of these chemicals will allow us to continue the important uses and benefits of PFAS technologies.

At the end of the day, removing harmful PFAS from production, and cleaning up legacy contaminations to protect human health is a bipartisan issue. In 2019 the Trump Administration's EPA issued the PFAS Action Plan, which was the agency's first national research, management, and risk communication plan to address the challenges of PFAS. I was pleased to see this October that a Biden Administration—the Biden Administration's EPA released a PFAS Strategic Roadmap which builds on the Action Plan. In today's political environment, everything tends to be polarized, but when it comes to the common good of protecting human health, not every precious action has to be repealed or replaced. We can, and should, build off of productive work, no matter the political party. It is my hope that moving forward bipartisan efforts continue, and the same science-based decisionmaking, and weighted benefits, are considered with any proposed regulation.

I want to again thank the witnesses for testifying before the Committee today, and I look forward to engaging in the discussion. I yield back the balance of my time.

[The prepared statement of Mrs. Bice follows:]

Thank you, Chairwoman Sherrill and Chairwoman Stevens, for holding this joint subcommittee hearing today. And thank you to our witnesses for taking the time to testify before us.

Per- and Polyfluoroalkyl Substances, known as PFAS, are a large and diverse family of synthetic chemicals. It's not just one product or one strand that we can say is good or bad. Each individual chemistry in the family of PFAS has its own unique properties and uses.

In fact, according to the EPA, there are approximately 650 PFAS currently manufactured or used in the United States. Many of these chemistries are essential to products driving our lives in the 21st century.

The cellphones, tablets, and computers we use every day; components of clean energy sources like solar and wind; modern medical devices that keep us healthy; sophisticated aircraft the U.S. military uses to keep us safe. In each of these, PFAS is the common denominator that makes them possible to produce.

But because of the strength and durability PFAS provides, these chemicals have a strong molecular bond that is not easily broken down or destroyed. That is why you will hear PFAS referred to as "forever chemicals." As you might imagine, a chemical that is the backbone of aqueous film-forming foam, which is highly effective at putting out the most difficult to suppress fires, is purposely designed to withstand the most extreme conditions that would destroy most other products.

That presents us with the main problem associated with PFAS: removing what is already out there. Because PFAS has been used in industry and consumer products since the 1940s, we know that exposure has already happened and we face the problem of legacy contaminations in water, soil, air, and food.

To overcome this challenge, I look forward to hearing from one of our witnesses, Ms. Amy Dindal from Battelle Memorial Institute, on her research regarding PFAS identification and destruction in the environment.

As Ms. Dindal will further explain, Battelle's development of PFAS Annihilator technology has destroyed 99.9% of PFOA and PFOS in water. This type of scalable technology should give us all comfort that economically feasible, safe, complete, and reliable destruction of PFAS is within our grasp, thus solving the most fundamental issue that comes with using these chemicals.

As we look to the future, it's important we remember not to villainize this entire category of chemicals. The hazard and risk profiles of various PFAS are immensely different. A broad, categorical ban on PFAS would be detrimental to our manufacturing sector and actually put lives at risk by reducing safety.

Using certain PFAS in a controlled, responsible manner is safe and effective. Understanding the distinct properties of each of these chemicals will allow us to continue the important uses and benefits of PFAS technologies.

At the end of the day, removing harmful PFAS from production and cleaning up legacy contaminations to protect human health is a bipartisan issue.

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In today's political environment, everything tends to be polarized, but when it comes to the common good of protecting human health, not every previous action has to be repealed and replaced. We can and should build off productive work, no matter the political party.

It is my hope that moving forward, bipartisan efforts continue and the same science- based decision making and weight of benefits are considered with any proposed regulation.

I want to again thank all of our witnesses for testifying before the Committee today and I look forward to an engaging discussion. I yield back the balance of my time.

Chairwoman SHERRILL. Thank you. The Chair now recognizes Ms. Stevens, Chairwoman of the Research and Technology Subcommittee, for an opening statement.

Ms. STEVENS. Well, thank you, Chairwoman Sherrill. It is a huge honor to be co-chairing today's hearing, particularly from your Chairmanship on the Science Committee, Subcommittee on Environment, on PFAS. And thank you to our panelists for joining us. I am particularly excited and honored to welcome Ms. Abigail Hendershott, a fellow Michigander, and the Executive Director of the Michigan PFAS Action Response Team, MPART.

PFAS has been a topic of profound relevance for us in Michigan. In fact, it has just been a rallying call, given the number of sites that we have. And, as has been discussed, PFAS is—PFAS are a group of human-made chemicals that have been manufactured since the 1940's, and can be found in a wide range of both consumer and industrial products. There's growing evidence that these chemicals are linked to adverse health outcomes including liver damage, thyroid disease, an increased risk of cancer, and reduced antibody response, particularly in children. Research has also shown that there are numerous pathways through which humans can be exposed to these chemicals. Unfortunately, PFAS is extremely resistant to degradation in the environment, and, as has been discussed, this is why PFAS is known as forever chemicals, and exposure to these chemicals continues to harm the health and wellbeing of families across America.

Again, my home State of Michigan has the most PFAS identified contaminated sites in the country, thus making it the State's biggest environmental crisis in half a century. That is our State's biggest environmental crisis in half a century. Just this weekend I was at the holiday parades, talking to municipal leaders who were saying up north I can't even drink the water, I can't fish in the water at my up north cabin. This is such a risk aversion for us in our State. That is why we have Ms. Hendershott in the role that she is in, but this is also why we must rely on Federal responses for how we're going to tackle PFAS, and PFAS cleanup, and obviously prevention.

So we can recognize here, and—particularly the Science Committee, that the scientific knowledge is certainly still developing, and, almost to our chagrin as we learn more about the serious health effects in humans and in animals, but the more we find out, the worse the picture appears. Last month, just last month, the EPA sounded the alarm bell and asked its Science Advisory Board to review new analyses and data that suggest that two chemicals which have been found in many drinking water and surface waters in Michigan and around the country are far more toxic than previously thought. So while officials in Michigan have taken steps to address this issue, this crisis, there's more that can be done. Our efforts have to be strengthened by congressional action. We must recognize—you know, and I'm proud to co-sponsor Congresswoman Debbie Dingell's *PFAS Action Act,* an expansive bill to regulate, cleanup PFAS contamination. This bill also includes my *PROTECT Act,* which directs the EPA to add PFAS chemicals to the list of hazardous air pollutants under the *Clean Air Act.* It's a bipartisan bill, that's absolutely our spirit here today, and it's awaiting action in the Senate.

So while we still have more to learn about the extent of PFAS contamination and the health risks associated with prolonged exposure, we need to acknowledge PFAS as an environmental hazard and conduct much-needed research so that we fully understand the danger, as well as the efforts to clean up. The National Science Foundation—and certainly this is going to be a whole of government approach, and this is why it's very unique to have the Science Committee delving in in the way that we are. The National Science Foundation supports fundamental research through multiple directorates to better understand PFAS, including the fate and transport of PFAS in environmental systems, and the effects of PFAS contamination on communities. NSF-supported research also focuses on developing technologies to effectively degrade, destroy, or permanently sequester PFAS in the environment. The technologies are so essential here to this cleanup. We are very thrilled to be delving into this today in our hearing. And additionally, the National Institute of Standards and Technology, NIST, works to create reference materials and data resources that can be used by government, academic, and industrial labs to increase confidence in PFAS measurements, and the critical work of chemical structures of PFAS.

So those are just two agencies that serve as examples. And, with that, I'm slightly over time, Madam Chair, so I'll yield back. Thank you.

[The prepared statement of Ms. Stevens follows:]

Thank you, Chairwoman Sherrill, it is great to be chairing this hearing with you this morning. And welcome to all of our witnesses. Thank you for joining us to share your expertise on a very important issue, I'm looking forward to your testimony. I'm particularly excited to welcome our witness, Abigail Hendershott, a fellow Michigander, and the Executive Director of the Michigan PFAS Action Response Team, MPART.

PFAS are a group of human-made chemicals that have been manufactured since the 1940's and can be found in a wide range of both consumer and industrial products. There is growing evidence that these chemicals are linked to adverse health outcomes including liver damage, thyroid disease, an increased risk of cancer, and reduced antibody response, especially in children. Research has also shown that there are numerous pathways through which humans can be exposed to these chemicals. Unfortunately, PFAS is extremely resistant to degradation in the environment—that is why they are known as "forever chemicals."

Exposure to PFAS chemicals continues to harm the health and wellbeing of families across America. My home state of Michigan has the most PFAS-contaminated sites in the country thus making it the state's biggest environmental crisis in half a century.

Although scientific knowledge regarding PFAS is still developing, PFAS are linked to serious adverse health effects in humans and animals. And the more we find out, the worse the picture appears. Last month, the EPA sounded the alarm bell and asked its Science Advisory Board (SAB) to review new analyses and data that suggest the two chemicals—which have been found in many drinking water and surface waters in Michigan and around the country—are far more toxic than previously thought. While officials in Michigan have taken steps to address this crisis, there is so much more to be done at every level of government.

Our efforts in Michigan need to be strengthened by congressional action. In order to adequately address this threat, we need the federal government to step it up. That is why I was proud to cosponsor Representative Dingell's *PFAS Action Act,* an expansive bill to regulate, cleanup PFAS contamination. This bill included my own *PROTECT Act,* which directs the EPA to add PFAS chemicals to the list of hazardous air pollutants under the *Clean Air Act.* This bipartisan bill passed the House, but is still awaiting action in the Senate.

While we still have a lot to learn about the extent of PFAS contamination and the health risks associated with prolonged exposure. We need to acknowledge PFAS as an environmental hazard and conduct much-needed research so that we fully understand the danger that contamination poses for Americans across the country. Given the widespread applications of PFAS, a whole-of-government approach is required to research and address these chemicals. Agencies in the Science Committee's jurisdiction have a critical role to play in this effort.

The National Science Foundation (NSF) supports fundamental research through multiple directorates to better understand PFAS, including the fate and transport of PFAS in environmental systems, and the effects of PFAS contamination on communities. NSF-supported research also focuses on developing technologies to effectively degrade, destroy, or permanently sequester PFAS in the environment. Additionally, the National Institute of Standards and Technology (NIST) works to create reference materials and data resources that can be used by government, academic, and industrial labs to increase confidence in PFAS measurements, critical work given the wide range of chemical structures of PFAS and the limited availability of chemical standards for these measurements.

These are just two of the many federal agencies who are conducting excellent research to address the PFAS problem. I'm encouraged by the work and coordination that is taking place but there is still much we do not know and much more we must do to address this crisis in our communities. I look forward to hearing from our witnesses on the gaps in the federal approach and how we can best leverage the work done by Federal agencies and their partners.

Thank you, and I yield back.

Chairwoman SHERRILL. Well, thank you so much. And now the Chair recognizes the Research and Technology Subcommittee Ranking Member Waltz for an opening statement.

Mr. WALTZ. OK, good morning, and thank you, Chairwoman Sherrill, Chairwoman Stevens. Thanks for holding this joint Subcommittee—and certainly appreciate our witnesses, and their participation. And, you know, as a number of folks have said, and I think always worth repeating, that PFAS makes possible many of the products that power our everyday lives. Batteries, solar panels, alternative energy sources, PPE (personal protective equipment) firefighting foams for first responders, pipeline safety, and it's also critical to our military and aerospace operations, again, as others have noted.

However, it does—what makes these chemicals so reliable is also what makes them long lasting when out and sitting in our environment. And obviously—which we're going to hear from our witnesses today, that that can be hazardous to human health, particularly when they pollute the water supply. Scientific research is determining that not all PFAS chemicals entail the same risks, and I believe the signals that more research is needed to better understand the individual properties and characteristics of PFAS, and increase research, can help us determine how to best remove legacy PFAS that are harmful to human health and the environment. And additional research can also lead to alternatives that retain the most valuable properties of PFAS, so much more targeted solutions are out there. They do require additional research to fully understand and implement.

There are multiple R&D efforts, Chairman Steven mentioned a—Stevens mentioned a number of them, across Federal science agencies to advance PFAS innovations. But despite these efforts, critical knowledge gaps still remain regarding our ability to detect it, to understand its effects, to identify viable alternative options, and a coordinated Federal effort, in partnership with the private industry, I certainly believe, is needed to help close these gaps.

One of the concerns about PFAS that hits close to home for me, as a combat veteran, is hearing of elevated levels in PFAS in groundwater on our military bases, and the health risk this poses for our military members and their families. And while high concentrations are mostly due to the use of Aqueous Film Forming Foam concentrates, and I won't say that three times quickly, but—to put out fires quickly and effectively, replacing this foam with a reliable non-PFAS alternative has proven incredibly difficult. So that's why I'm also eager to hear from our witness Ms. Amy Dindal from Battelle Memorial Institute on her work to create a product that can destroy the vast majority of PFAS in water in a scalable, and very importantly, a cost-effective manner. Advances—advancements such as this gives us more tools in the toolbox to be able to combat toxic chemicals in our environment, and, obviously, to improve public health.

I also look forward to hearing about the work and research our other witnesses are conducting. I'm particularly interested in hearing what they believe the greatest research questions on this topic are, and what steps we should be doing—we should be taking to answer them, and how this Committee can help. Thank you again to our witnesses for being here today. I look forward to your testimony. Before I yield back, I request unanimous consent to submit a statement and questions from Representative Posey into the record. I assume I can get unanimous consent?

[The prepared statement of Mr. Waltz follows:]

Good morning and thank you, Chairwoman Sherrill and Chairwoman Stevens for holding today's joint subcommittee hearing. And thank you to our witnesses for your participation here today.

PFAS is the acronym for a large and diverse group of manufactured chemicals used in industry and consumer products, and valued for their strength, durability, and resilience to heat, stains, water, and grease.

PFAS make possible many of the products that power our everyday lives: from lithium batteries and solar panels for alternative energy sources, to PPE and firefighting foams used by first responders, to pipeline operations safety equipment and fuel system seals.

Additionally, PFAS are critical to military and aerospace operations. Heat and chemical resistant PFAS are used in safety equipment to protect our military in extreme environments and against chemical warfare. Insulating, chemical and weather resistant PFAS are used in hydraulic fluids for aircraft control systems, fluid seals, and aircraft communications and navigations systems.

However, what makes these chemicals so reliable is also what makes them long-lasting in our environment. That can be hazardous to human health, particularly when they pollute water supplies.

Science is determining that not all PFAS chemicals entail the same risks. I believe this signals that more research is needed to better understand the individual properties and characteristics of PFAS. Increased research can help us determine how to best remove legacy PFAS that are harmful to human health and the environment. Additional research can also lead to alternatives that retain the most valuable properties of PFAS. Solutions are out there, but they require research to fully understand and implement.

There are multiple R&D efforts across federal science agencies to advance PFAS innovations. Despite these efforts, critical knowledge gaps still remain regarding our ability to detect PFAS, understand their effects, and identify viable alternative options. A coordinated federal effort, in partnership with the private industry, is needed to help us close these gaps.

A concern about PFAS that hits close to home for me as a combat veteran is hearing of elevated levels of PFAS in groundwater on military bases and the health risk this poses to our military members and their families. PFAS have been an issue in my home state of Florida, including the district to my south represented by our colleague on the Science Committee, Mr. Posey.

While the high concentrations are mostly due to the use of Aqueous Film-Forming Foam Concentrates to put out fires quickly and effectively, replacing this foam with a reliable non-PFAS alternative has proven incredibly difficult.

That is why I'm eager to hear from our witness, Ms. Amy Dindal from Battelle Memorial Institute, on her work to create a product that can destroy the vast majority of PFAS in water in a scalable and cost-effective manner. Advancements such as these give us more tools in the toolbox to be able to combat toxic chemicals in our environment and improve public health.

I also look forward to hearing about the work and research our other witnesses are conducting. I'm particularly interested in hearing what they believe the greatest research questions on this topic are and what steps we should be taking to answer them.

Thank you again to our witnesses for being here today and I look forward to your testimony. Before I yield back, I request Unanimous Consent to submit a statement and questions from Representative Posey into the record.

Thank you and I yield back.

Mr. WALTZ. Before I yield back, I request unanimous consent to submit a statement and questions from Representative Posey into the record. I assume I can get unanimous consent?

Ms. STEVENS. So moved, so moved.

Chairwoman SHERRILL. Sorry, I was having trouble with my unmute button. Yes, without objection.

Mr. WALTZ. Great. Thank you. I yield back.

[The prepared statement of Mr. Posey follows:]

PFAS are dubbed the "forever chemicals" because they have shown resistance to degradation in the natural environment. They are a national concern and pose threats to human health and safety.

This is particularly true in my Spacecoast Florida district. To free Spacecoast communities from the legacy of PFAS, I've been fighting for legislation to address these forever chemicals. In this Congress, I am an original co-sponsor of H.R. 2467, the *PFAS Action Act of 2021* which passed the House on July 21st. In a major step to remedy PFAS contamination, the bill directs the Environmental Protection Agency (EPA) to designate the PFAS perfluorooctanoic acid (PFOA) and perfluorooctanesulfonic acid (PFOS) as hazardous substances under the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980,* thereby requiring remediation of releases of those PFAS into the environment. Within five years, the EPA must determine whether the remaining PFAS should be designated as hazardous substances.

I've also worked with my colleagues to further address the legacy of PFAS in other ways. I co-led a major amendment to the *National Defense Authorization Act* adopted by the House. This amendment closes a loophole that currently allows manufacturers to underreport their PFAS discharges into the air and water, requires the EPA to establish a national drinking water standard for two specific PFAS—PFOA and PFOS—within two years, expands the temporary moratorium on the unsafe burning of PFAS-based firefighting foam by the Pentagon, ensures the EPA uses the most health- protective definition of PFAS for reporting and regulatory matters, and directs the Secretary of Defense to provide Defense Department medical providers with mandatory training with respect to the potential health effects of PFAS. I recently led a letter from twelve House Members to Senate leadership asking that they include the House amendment in the Senate NDAA and the conference bill.

With Representative Slotkin, I introduced H.R. 4975, the *PFAS Free Military Purchasing Act.* This bill prohibits DOD from procuring or purchasing specified items containing PFAS. DOD may not authorize the sale of any specified item containing PFAS on DOD property, such as commissaries or online exchange shops.

We owe our military members and their families, and the communities that host them on bases along the Spacecoast and throughout the country, protection and remediation of the effects of these harmful forever chemicals. I am committed to DOD and others fully addressing and cleaning up these substances and removing the harm they cause from the lives of all our people.

I look forward to hearing the testimony from our panel of scientists. If we can work to close gaps in our national research strategy on PFAS, then we can contribute to advancing the day that we provide complete, effective, and timely treatment and remediation of these "forever chemicals."

Questions:

1). What are the most critical research needs that will help advance the treatment and remediation of PFAS contamination at DOD facilities like Patrick Air Force Base in my district?

2). The U.S. Geological Survey (USGS) has played a pivotal role in water resources research throughout their history. Can you please tell the committee what you know about USGS efforts to study PFAS presence and transport in surface and ground waters and what more we might ask them to do to contribute to closing gaps in PFAS R&D?

3). Some of the testimony provided today suggests that recent scientific research may offer some hope for developing successful biodegradation strategies for treating and remediating PFAS contamination. Can each of you please evaluate this possibility and comment on whether Congress should work toward providing a priority and more resources for such research?

4). Please provide a brief description of a science-based strategy for remediating PFAS at DOD facilities like Patrick Air Force Base. In your statement, please include a short-term response to expedite near term remediation based on available technologies and a longer-term strategy that will depend on improved techniques that are developed by the scientific community. In short, how should remediation best proceed in the short and long-term and provide for expedited treatment and remediation?

Chairwoman SHERRILL. Great. And the Chair now recognizes the Full Committee Ranking Member, Mr. Lucas, for an opening statement. Is Mr. Lucas on? I don't think he's on yet. OK. If there are any Members who wish to submit additional opening statements, your statements will be added to the record at this point.

[The prepared statement of Chairwoman Johnson follows:]

Thank you, Chairwoman Sherrill and Chairwoman Stevens for having this important hearing on PFAS research and development.

As my colleagues mentioned, these chemicals are widely-used and dangerous for our health.

Nearly half a million Texans live within three miles of sites where groundwater has been contaminated by PFAS. Many of these sites are former and active military bases near Dallas, Austin, and San Antonio. Firefighting foam containing PFAS has been in use on military bases since the 1970s. This has led to PFAS contamination at much higher levels than what the CDC deems safe. For decades, residents near thousands of military bases around the country haveunknowingly showered, cooked with, and drunk contaminated water.

The alarming reality is that virtually all Americans have been exposed to PFAS. Research shows many pathways for human exposure to these chemicals, including contaminated drinking water, soil, air, and food.

Contamination by PFAS is also an environmental justice issue. Many known and likely sources of PFAS contamination are located near low-income communities and communities of color.

These include military bases, airports, industrial facilities, and waste management and disposal sites.

Congress has done significant work to regulate PFAS in recent years. However, the Federal government must do more to address this pervasive problem. And we need a whole-of-government approach. Federal civilian science agencies play a critical role in researching and better understanding these chemicals. In addition to the DOD, agencies under the jurisdiction of the Science, Space, and Technology Committee such as the EPA, NSF, NIST and others, play important roles in addressing PFAS. I'm encouraged by the Biden-Harris Administration's commitment toward protecting the public from these harmful chemicals.

Given the pervasive nature of PFAS, R&D efforts and solutions must include coordination across different sectors and groups. We need robust participation from Federal, state, local, and Tribal agencies, research institutions, academia, non-profits, industry, and manufacturers.

As we work to regulate, remediate, and mitigate PFAS, it is critical that these decisions are informed by science. Risk management decisions must be based on the best science to ensure they are effective and safeguard public health. There is much more to be understood about PFAS. Many outstanding questions remain about their sources, exposure, fate and transport, human and environmental effects, and treatment technologies. I look forward to hearing from our expert panel of witnesses today who will provide a broad set of perspectives on this issue.

I'm confident in the progress we can make with a science-based, whole-of-government approach. I look forward to working with our Federal agencies and their partners. We must come together with every tool we have to achieve a safer future for all Americans.

Thank you, and I yield back.

Chairwoman SHERRILL. At this time I'd like to introduce our witnesses. Our first witness is Dr. Elsie Sunderland. Dr. Sunderland is the Gordan McKay Professor of Environmental Chemistry at Harvard University. Dr. Sunderland's research aims to better understand how chemicals released by human activity interact with natural ecosystems and affect living systems. Prior to joining the faculty at Harvard she spent five years at the Environmental Protection Agency. Dr. Sunderland is also Research Group Leader at the Center for Sources, Transport, Exposure, and Effects of PFAS, STEEP, a partnership between the University of Rhode Island and Harvard. As a part of STEEP, Dr. Sunderland works to develop statistical methods for better identifying sources of PFAS contamination in drinking water, and fish, and how geochemical factors affect the transport of PFASs away from contaminated sites.

And then at this time I'd like to give the opportunity for Ms. Stevens, Chairwoman of the Research and Technology Subcommittee, to introduce her fellow Michigander, Ms. Hendershott. I yield to Chairwoman Stevens.

Ms. STEVENS. Well, thank you, Congresswoman Sherrill, and, yes, as a proud Michigander, I'm honored to introduce our next witness, Ms. Abigail Hendershott, the Executive Director of the Michigan PFAS Action Response Team, or MPART. Michigan is a—unfortunately, but we are a national leader in responding to PFAS contamination. Through MPART's work, Michigan has adopted enforceable PFAS standards for drinking water and groundwater, in addition to water quality standards for two of the most common PFAS chemicals.

Ms. Hendershott has 30 years of experience with the Michigan Department of Environment, Great Lakes, and Energy, otherwise known as EGLE, and has focused on PFAS response activity since 2017. She's led the team responsible for Michigan's PFAS contamination response to date, and we're so lucky to have her today testifying, and I—not only do I want to thank her, but I also want to thank her for testifying during MPART's third annual PFAS Summit. So we're looking forward to hearing about her work and research to investigate PFAS contamination in Michigan, and how to apply these lessons learned on the Federal level. Thanks.

Chairwoman SHERRILL. Thank you, Chairwoman Stevens. Our next witness is Ms. Amy Dindal. Ms. Dindal is currently the Director of Environmental Research at the Battelle Memorial Institute, and leads Battelle's PFAS Program. Prior to joining in 2002, Ms. Dindal was a research assistant with Oak Ridge National Laboratory for ten years.

And our final witness is Dr. Peter Jaffé. Dr. Jaffée is a Professor at the Department of Civil and Environmental Engineering at Princeton University. Dr. Jaffé's research interests relate to the physical, chemical, and biological processes that govern the transport and transformation of pollutants in the environment, and their application for the remediation of contaminated systems. Dr. Jaffé's research has demonstrated a biological pathway of PFAS degradation by an organism found in New Jersey soil, and his group is working on developing methods for bioremediation schemes for PFAS removal.

As our witnesses should know, you will have five minutes for your spoken testimony. Your written testimony will be included in the record for the hearing. When you've completed your spoken testimony, we'll begin with questions. Each Member will have five minutes to question the witnesses. And we'll start with Dr. Sunderland.

TESTIMONY OF DR. ELSIE SUNDERLAND, GORDAN MCKAY PROFESSOR OF ENVIRONMENTAL CHEMISTRY, HARVARD JOHN A. PAULSON SCHOOL OF ENGINEERING AND APPLIED SCIENCES, HARVARD T.H. CHAN SCHOOL OF PUBLIC HEALTH

Dr. SUNDERLAND. Thank you, Chairwoman Sherrill, and Chairwoman Stevens, for the invitation to speak with you all today. It's a pleasure to go through some information on the diverse chemical family known as per- and polyfluoroalkyl substances, or PFAS. So as you've heard already, until the 1940's or 1950's, the only source of organoflourine compounds were a few rare plant species that produced them as natural poisons. Since the 1950's, these chemicals have been widely used in modern commerce for their ability to repel both oil and water. Today we find them in diverse consumer products, such as food packaging, dental floss, carpet, furniture coatings, clothing, outdoor gear, and cosmetics.

Airports and military bases across the country have been contaminated by use of a product that we've all heard pronounced this morning, Aqueous Film Forming Foams, or AFFF, for firefighting and fire training activities. CDC data show that 98 to 99 percent of Americans have detectable levels of at least one PFAS in their blood. A recent peer reviewed study by the Environmental Working Group estimated that 18 to 80 million Americans have concentrations of PFAS in their drinking water that exceed 10 nanograms per liter. So, for reference, this is in the same range as where many of the States are setting maximum contaminant levels (MCLs) for drinking water today.

Exposures to PFAS have been associated with many negative health effects on humans. I think the former director of NIEHS, Dr. Linda Birnbaum, summarized it best when she opened a scientific meeting on PFAS a couple years ago, when she said, "If you are a public health researcher, these are the chemicals for you, because PFAS have now been associated with an adverse impact on every major organ system in the human body." Ongoing support for NIH and CDC/ATSDR (Agency for Toxic Substances and Disease Registry) research is essential for fully understanding the health effects associated with PFAS. We now have two major tasks. The first one is to remediate contaminated sites across the country to address the legacy pollution issue. And the second, in my opinion, is to control ongoing production and use of these compounds in our products by deciding where uses of PFAS are essential, and where they could be replaced by better, less toxic alternatives.

Next to contaminated communities, drinking water is known to be the predominant exposure source. However, we have only anecdotal understanding of PFAS exposure sources for the U.S. general population, despite their presence in all of us. Exposure research falls outside of the mandate of most ongoing research programs. Typically this would fall within the mandate of EPA, but both their internal and extramural research has been substantially underfunded over the past decade. In Europe, dietary intake has been established as the predominant exposure source for the general population. There PFAS have been frequently detected in seafood, milk, various meats, processed foods, particularly those that use food packaging containing PFAS.

The FDA (Food and Drug Administration) recently undertook a total diet survey, but the number of samples and detection limits for their analyses were insufficient to characterize the food supply and risks to the population. In States such as Maine and Michigan, high levels of PFAS have been detected on farmlands due to application of biosolids mixed with industrial sludge. These PFAS spread from the soils to hay and corn, then cows, then the farmers who drink the milk from their own animals. In one tragic case in Maine, a farmer and his wife had to close a dairy farm that had been in their family for more than 100 years.

Another major challenge for PFAS research is that limitations in current analytical methods mean we are systematically underestimating exposures to these compounds. The chemical family, as you've heard, consists of thousands of compounds, and industry is continuously introducing new ones into our product stream. Standard methods endorsed by EPA and NIST currently do not detect most of the compounds found in products and the environment.

As a final note, the DOD currently supports the largest portfolio of PFAS research among the Federal agencies, however, DOD also caused PFAS contamination through use of firefighting foams at military sites across the country, which sets up a potential conflict of interest. And so, while this research program is commendable, it is essential that the other Federal agencies develop comparable research portfolios to fill the gaps above. Thank you.

[The prepared statement of Dr. Sunderland follows:]

December 5, 2021

Written Testimony of Elsie M. Sunderland, Gordon McKay Professor of Environmental Chemistry, Harvard University

Forever Chemicals: Research and Development for Addressing the PFAS Problem

Thank you, Chairwoman Sherill and Chairwoman Stevens, for inviting me to testify today.

I appreciate the opportunity to speak with you about the diverse class of chemicals known as per- and polyfluoroalkyl substances (PFAS).

Some PFAS last forever in the natural environment because fluorine is such a unique element. It's the 13th most common element on Earth. However, until the 1950s, only a few rare plant species produced organofluorine compounds as a natural poison. Innovators then figured out how to use various high-energy manufacturing techniques to swap hydrogen with fluorine atoms in ***organic*** molecules. Unlike naturally occurring organic molecules, these fluorinated molecules are so strongly bonded that they persistent indefinitely in the environment and some accumulate in living tissues over time.

Since the 1950s, these chemicals have been widely used in modern commerce for their ability to repel both water and oil. Today, we find them in diverse consumer products such as food packaging, dental floss, carpet, furniture coatings, clothing, outdoor gear, and cosmetics. PFAS are used by industries such as textile companies, the metal plating industry, and plastics manufacturers. Airports and military bases across the country have also been contaminated by use of a product known as aqueous film-forming foam (AFFF). AFFF is extremely effective at fighting oil-based fires. The Department of Defense (DOD) currently supports research aimed at developing PFAS-free foams, but still requires PFAS in AFFF as part of military specifications.

Center for Disease Control (CDC) data show that 98-99% of Americans have detectable levels of at least one PFAS in their blood. A recent peer-reviewed study by the Environmental Working Group (EWG) estimated that 18-80 million Americans have concentrations of PFAS in their drinking water that exceed 10 ng/L (parts per trillion). This concentration is in the same range as where many of the states are setting maximum contaminant levels for drinking water.

Exposures to PFAS have been associated with many negative effects on human health. I think the former director of the National Institute of Environmental Health Sciences, Dr. Linda Birnbaum, summarized it best when she said at the opening of a scientific meeting on PFAS in 2019: "If you are a public health researcher, these are the chemicals for you because PFAS have now been associated with an adverse impact on every major organ system in the human body."

My colleague in the School of Public Health at Harvard, Dr. Philippe Grandjean, has been studying the effects of PFAS on the immune health of children for many years. In one of his early studies, he found that each doubling of these compounds in the blood of children at age 5 leads to a reduction by half of antibody production following routine vaccinations at age 7. This is one of the most potent immunotoxic responses ever observed for an environmental contaminant. Most recently, Dr. Grandjean found an association between the severity of Covid-19 and PFAS exposure. Many other adverse effects of PFAS have been reported, including evidence for increased risk of certain cancers and impaired cardiovascular health. Ongoing support for NIH and CDC/ATSDR research is essential for better understanding the full extent of health effects associated with PFAS exposure.

Industry has not been forthcoming with some of the health concerns associated with exposure to these compounds. Discovery documents from recent court cases have revealed that, on average, there was a 22-year lag between industry documents that first described some of the well-known health effects of PFAS and publication in the academic literature. Let me emphasize that industry had ***clear evidence*** of negative health impacts **decades** before the public. I believe it's worth asking whether we should expect innovators to be transparent about the chemical experiments that they are conducting on the public through their products.

Moving on to address this important public health issue, we now have two major tasks: 1) Remediate contaminated sites across the country to address the legacy pollution issue, and 2) control ongoing production and use of these compounds in our products by deciding where uses of PFAS are essential, and when PFAS could be replaced by better, less-toxic alternatives.

Support for the Federal agencies in addressing these broad challenges is essential for protecting public health. There are some major gaps in present understanding, that could be addressed by research and coordination among the Federal agencies.

We have insufficient data on PFAS exposure sources for the U.S. general population

Next to contaminated communities, drinking water is known to be the predominant exposure source. Efforts by the states and Federal agencies are successfully generating additional data on PFAS concentrations in drinking water and the effects of contaminated drinking water on health. This is where my own PFAS research has focused as part of an NIH Superfund center grant.

By contrast, we have only anecdotal evidence for understanding PFAS exposure sources for the U.S. general population. Major pathways of PFAS exposure include ingestion of food and drinking water, ingestion and inhalation of dust, and dermal uptake from personal care products and other sources. The relative importance of different exposure sources for the general population is unknown, impeding the development of effective risk mitigation strategies.

Dietary intake has been established as the predominant PFAS exposure source for the European general population. In the European Union, PFAS have frequently been detected in seafood, milk, various meats, and processed foods, particularly those that use packaging containing

PFAS. This has led to a ban of PFAS in food packaging in some countries such as Denmark and efforts to follow suit in some of our states.

By contrast, data on PFAS exposures in the U.S. food supply are extremely limited. The FDA recently undertook a total diet survey, but the number of samples and detection limits for their analysis were insufficient to characterize the food supply and risks to the population. In states such as Maine and Michigan, high levels of PFAS have been detected on farmlands due to use of biosolids mixed with industrial sludge that were used as fertilizer. These PFAS spread from the soils to hay and corn, then cows, and the farmers who drank the milk from their own animals. In one tragic case in Maine, the farmer and his wife had to close the dairy farm that had been in their family for more than 100 years.

Exposure research falls outside of the mandates of most ongoing U.S. PFAS research. The DOD supports a large portfolio of projects investigating the fate, transport, and remediation of these compounds. NIH focuses mainly on health outcomes associated with exposures. Typically, exposure research would fall within the mandate of EPA but both internal and extramural research have been substantially underfunded over the past decade. Joint research and unified public health advice from both EPA and FDA have been very effective in the past in areas such as fish advisories for contaminants and should be encouraged.

Exposures to PFAS are underestimated due to limitations in measurement techniques

Another major challenge for PFAS research is that limitations in current analytical methods mean we are systematically underestimating exposures to these compounds. The PFAS chemical family consists of thousands of different compounds, and industry is continuously inventing new PFAS that are introduced into our product stream. A large fraction of the compounds that are difficult to detect (known as precursors), degrade into other PFAS that are already known to pose risks to human health. Thus, is it essential to measure them in products, the environment, and humans.

New analytical tools are needed to detect PFAS precursors, and novel and emerging PFAS. Standard methods endorsed by EPA and NIST do not detect most compounds found in products and the environment. Commercially available standards needed for detection are unavailable for many PFAS found in modern AFFF and consumer products due to proprietary business information restrictions. You may hear the phrase “non-targeted mass spectrometry.” It is an essential component of our scientific toolbox ***but*** does not provide ***quantitative*** estimates that can be used for regulatory applications. It also requires highly trained analysts. For routine monitoring by communities and states, a simpler measurement technique is needed.

Several total fluorine and total organofluorine measurement methods have been developed by the academic community. Standardized methods and laboratory intercomparisons run by EPA and NIST are needed to ensure comparability of data generated across labs. Further developing these techniques could support regulations that screen for PFAS as a class, which would address the chemical whack-a-mole situation we are now experiencing. Support for partnerships between EPA and NIH are needed to better understand the toxicological and human health effects associated with exposure to novel and emerging PFAS.

Comprehensive data on atmospheric and aquatic PFAS sources are needed

In addition to detecting the broad suite of PFAS released into the environment, urgent action is needed to better characterize the sources of PFAS across the country. Databases such as EPA's Toxic Release Inventory (TRI) have only begun to be developed and efforts must be accelerated.

Most PFAS research has been on contaminated water, but it has become apparent that large quantities of PFAS are transported atmospherically away from some point sources and waste disposal sites. Following deposition, these atmospheric sources can contaminate water supplies and agricultural areas. Stack testing data and release estimates for major source categories are therefore urgently needed. USGS could further aid with monitoring of air and water across the country. Nationwide monitoring programs such as the National Atmospheric Deposition Program could provide the infrastructure needed to support an atmospheric surveillance network.

As a final note, the DOD currently supports the largest portfolio of PFAS research among the Federal agencies. However, DOD also caused PFAS contamination through use of fire-fighting foams at many sites across the country, which sets up a potential conflict of interest. While the DOD research program is commendable, it is essential that other Federal agencies develop comparable research portfolios to fill some of the research gaps described above.

I thank the committee for the opportunity to share my views on this subject.

Elsie Sunderland is the Gordon McKay Professor of Environmental Chemistry at Harvard University. She holds faculty appointments in the Harvard John A. Paulson School of Engineering and Applied Sciences, the Harvard T.H. Chan School of Public Health, and the Department of Earth and Planetary Sciences. Professor Sunderland's research aims to better understand how chemicals released by human activity interact with natural ecosystems and affect living systems. A main innovation of her group's work is to quantitatively analyze the entire exposure pathway for aquatic pollutants to identify key processes that have a large influence on their accumulation in biota. Prior to joining the faculty at Harvard, she spent five years working to inform environmental policy decisions with best-available science at the headquarters for the U.S. Environmental Protection Agency (U.S. EPA) in various offices. Her work at the U.S. EPA included regulatory impact assessments for Hazardous Air Pollutants and developing guidance on best use of environmental models to inform regulatory decisions. Much of Professor Sunderland's recent work has focused on characterizing diverse exposure sources for per- and polyfluoroalkyl substances (PFAS), including drinking water and seafood, and developing chemometric indicators for source attribution. She has also worked to understand the global biogeochemical cycle of mercury for more than 20 years, and presently works with the U.S. EPA and State Department to help inform the U.S. position in the UN Minamata Convention, the global treaty on anthropogenic mercury releases. She has trained >30 graduate students and postdoctoral fellows and has published >100 peer-reviewed papers. She is a member of the advisory board for several journals including *Environmental Science & Technology* and *Environmental Science Processes and Impacts.*

Chairwoman SHERRILL. Thank you. Next, Ms. Hendershott, the floor is yours.

TESTIMONY OF MS. ABIGAIL HENDERSHOTT, EXECUTIVE DIRECTOR, MICHIGAN PFAS ACTION RESPONSE TEAM (MPART)

Ms. HENDERSHOTT. Thank you. Just a second here. There we go. So thank you, Chairwomen Sherrill and Stevens, and to the Committees for inviting Michigan to provide testimony regarding the ongoing work of our Michigan PFAS Action Response Team to address PFAS issues. My name is Abigail Hendershott, and I am the Executive Director of the Michigan PFAS Action Response Team, or MPART, as we call ourselves, and I'm pleased to share with you the Michigan perspective on research needs, opportunities to collaborate, and the need for new PFAS treatment technologies.

In 2017 MPART was established as a first of its kind statewide coordinating body tasked with identifying and addressing PFAS contamination through the coordinated activities of seven different State agencies. Governor Whitmer has been a leader on PFAS, establishing MPART as an enduring body, and asking MPART to establish State drinking water standards. The focus on coordination and collaboration have allowed Michigan to effectively leverage the actions of all the agencies to swiftly identify and respond to PFAS in our communities. Today MPART is recognized as a national leader, and a model for other States to follow. While there are numerous research and development areas where Federal funding and studies would be helpful, I want to focus on a few examples where States could use Federal support, research on PFAS in the food supply, development of less toxic AFFF, improved PFAS remediation and treatment technologies, and continued research on PFAS toxicology.

So research on PFAS in the food supply. First, there is a need for additional studies of PFAS in the food supply. Michigan has a rich history of manufacturing and farming, and when those two exist together, there's a concern about the potential for PFAS to enter the food supply. Additionally, to support our strong and—hunting and fishing communities, and to inform public decision about fish consumption, Michigan has been strategically sampling fish from around our State. That is why we need our Federal partners to support research to understand potential health risks posed by PFAS in food to develop better understandings of how PFAS enters and affects the food supply, and to provide science-based guidance to food producers and consumers. More specifically, research and further evaluation of PFAS impacts to the food chain cycle through bioaccumulation and biomagnification is needed.

Development of less toxic AFFF. Second, the use of PFAS-containing firefighting foam, also known as Aqueous Film Forming Foam, or AFFF, results in the dispersal of PFAS into the air, surface waters, soil, and eventually groundwater. In Michigan we have collected over 51,000 gallons of AFFF from fire departments around the State to proactively keep PFAS-containing AFFF out of our environment. As long as the military, airport, and civilian fire departments use PFAS-containing AFFF, these negative consequences will continue to impact the surrounding communities, particularly in areas where residents rely on groundwater as their source of drinking water. Continued Federal support is critical to ensure that the next generation of AFFF products are less toxic to the environment, and also meet the appropriate performance standards needed by our firefighters.

Improved PFAS remediation and treatment technologies. As Michigan tackles the job of identifying sites of PFAS contamination, the even larger challenge of controlling, remediating, or otherwise reducing the spread of PFAS remains. In Michigan, historic use of PFAS, and use of AFFF over a large area, such as military, industrial, and airport properties, has resulted in large areas of land and groundwater in need of remediation. For example, one former automotive manufacturing site can yield millions of gallons of PFAS contaminated water, hundreds of thousands of cubic yards of PFAS contaminated soil that needs to be contained, or otherwise remediated at just one site alone. Over the past 4 years we have identified 194 PFAS sites, consisting of airport, industrial, landfill, plating, tannery, and military facilities. Additional cost-effective ways for in situ remediation of large quantities of soil and groundwater is needed to be identified to get to faster and more efficient cleanups.

Continued research to understand PFAS toxicology. It's well established that the exposure to PFAS is associated with adverse health impacts. In order to protect our citizens, Michigan has established water quality standards, State drinking water standards, and groundwater cleanup criteria for PFAS. We're exploring the potential for soil cleanup standards too, however, we really need better predictive models for PFAS behavior. This will enable better decisionmaking to protect groundwater, especially in areas where residents rely on the resource for their drinking water.

Thank you again for the opportunity to discuss Michigan's needs for PFAS research, and I welcome hearing from the other witnesses today, and look forward to answering your questions. Thank you.

[The prepared statement of Ms. Hendershott follows:]

WRITTEN TESTIMONY

OF

Abigail Hendershott
Executive Director, Michigan PFAS Action Response Team (MPART)

HEARING ON

"Forever Chemicals: Research and Development for Addressing the PFAS Problem"

Committee on Science, Space & Technology
Subcommittee on Environment & Subcommittee on Research and Technology
U.S. House of Representatives

December 7, 2021

Thank you, Chairwomen Sherrill and Stevens, for inviting Michigan to provide testimony regarding the ongoing work of our Michigan PFAS Action Response Team (MPART) to address Per and Polyfluoroalkyl Substances, PFAS, issues across our state. My name is Abigail Hendershott, and I am the Executive Director of the Michigan PFAS Action Response Team, MPART. I am pleased to share with you the Michigan perspective on research needs, opportunities to collaborate with state governments and non-government entities, and our needs for the development of new treatment technologies for PFAS.

The Michigan PFAS Action Response Team was created in 2017, as a temporary body by executive directive, to investigate sources and locations of PFAS and protect drinking water and public health. On February 4, 2019, Governor Gretchen Whitmer signed **Executive Order 2019-3**, establishing MPART as an enduring body to address the threat of PFAS contamination in Michigan, protect public health, and ensure the safety of Michigan's land, air, and water, while facilitating inter-agency coordination, increasing transparency, and requiring clear standards to ensure accountability.

Since 2017, MPART has solidified its role as a national leader in identifying and addressing PFAS contamination by the coordinated activities of seven different state agencies. This coordination and collaboration have allowed Michigan to effectively leverage the actions of all agencies to swiftly identify and respond to PFAS in our communities. These department agencies include Environment, Natural Resources, Transportation, Agriculture, Public Health, State Fire Marshal, and Military Affairs, all of which have teams of staff dedicated to continuously address PFAS issues. MPART currently has over 200 staff working on PFAS, many of whom are serving on committees that collaborate at a national level, including ITRC, ECOS, Great Lakes PFAS Task Force and many others.

The MPART strategic efforts are first and foremost focused on the protection of public health through sampling of drinking water and the identification and remediation of sources of PFAS contamination. As Michigan began to identify communities in need of alternate water supplies due to PFAS contamination of groundwater, surface water, and soils, the need for health-based cleanup standards became critical.

Using the expertise within the State and supported by national experts, Michigan took on the challenge of addressing PFAS in the absence of any existing PFAS standards. Michigan developed water quality standards for PFOA and PFOS,[1] and in January 2018, Michigan established groundwater cleanup standards for PFOA and PFOS. These enforceable standards laid the foundation for Michigan to require action to protect human health and the environment. In August 2020, EGLE completed promulgation of drinking water standards under the Safe Drinking Water Act for 7 PFAS compounds. Michigan also recognizes that additional research and improved techniques for reducing PFAS in our environment are necessary to enable Michigan, and all states, to effectively reduce the risks of PFAS.

While Michigan is actively requiring treatment and cleanup of PFAS contamination in groundwater, surface water discharges, and drinking water supplies, there is more to be done. MPART is encouraged by the actions laid out in the EPA PFAS Roadmap and the goals for coordinated and cooperative cross-agency efforts to develop improved tools to address PFAS as announced by the Biden Administration in October. A national, science-driven effort to support states and communities dealing with PFAS contamination will help to bring additional knowledge and support to PFAS investigations and cleanups and will ease the burden on states to develop state standards for drinking water and groundwater, as Michigan has done. Expanded, cross-agency research into PFAS remediation and treatment technologies, as well as investigation and guidance regarding PFAS in the food supply, will also help states better protect residents, consumers and producers.

The announcements regarding federal efforts to improve the understanding of how PFAS impacts the environment and human health are encouraging for states like Michigan and our fellow Great Lakes States that are already hard at work to conduct needed research with limited resources. Michigan urges all federal agencies working on furthering the understanding of PFAS to coordinate with states to maximize the impact and utility of federal PFAS research and synergize the response actions across our country. Michigan also urges Federal agencies that have PFAS contaminated properties to be leaders for the nation by expeditiously cleaning up these sites – even in the absence of perfect science. We cannot let imperfect information hold up the responsibility of protecting our citizens and natural resources today.

While there are numerous research and development areas where federal funding and studies will be helpful, I want to highlight a few examples of real-world areas where focused research and development can have a real benefit in Michigan and all states.

[1] PFOA is perfluorooctanoic acid and PFOS is perfluorooctanesulfonic acid

Research on Food Supply Impacts/Risks

First, there is a real need for additional studies of PFAS in the food supply to understand how PFAS enters and affects the food supply, and potential health risks from PFAS in food. Standardized testing methods are needed for crops, livestock, and food products to provide producers and consumers with useful and consistent information and to build the data set needed to begin establishing health-based standards for food. Consumers, farmers, state and federal regulators, and health agencies will all benefit from the development of health-based standards for PFAS in food.

Research and further evaluation of PFAS impacts to the food chain cycle, specifically bioaccumulation and biomagnification, is also needed. For example, wildlife and cattle may come into contact with PFAS by grazing on PFAS-contaminated fields and consuming PFAS-contaminated organisms. Also, fish are impacted by PFAS contamination in sediments and surface waters. While Michigan is working with other states and federal agencies to develop best practices for sampling and determining the presence of PFAS in livestock and wildlife, more studies are needed to determine how PFAS enters the food supply and to develop effective ways to protect the food supply.

An issue that goes hand-in-hand with evaluation of risks in the food supply is the need for a deeper understanding of the fate and transport of PFAS in the environment – how PFAS moves within and through the environment and the food chain. Understanding PFAS fate and transport is crucial to a complete understanding of the risks related to human consumption and to sensitive and threatened species. Additional research on how various PFAS are bioaccumulated and passed through the food chain is vitally important for a full assessment of the potential risk to various populations worldwide.

Development of Less Toxic AFFF

Second, the use of PFAS-containing firefighting foam, also known as aqueous film forming foam, or AFFF, results in dispersal of PFAS into the air, surface waters, soil, and groundwater. As long as military, airport, and civilian fire departments use PFAS-containing AFFF, these negative consequences will continue to impact surrounding communities, particularly in areas where residents rely on groundwater as a source of drinking water.

Federal support for research already underway to develop less toxic but still effective AFFF is essential to reducing harm from PFAS. Michigan urges the committees to consider all means to increase the incentives and resources available to researchers within the government and in the private sector. We must ensure that the next generation of AFFF products are less toxic to the environment, and meet appropriate firefighting standards for smothering fires, blanketing fuel, and ease of use.

Improved PFAS Remediation and Treatment Technologies

As Michigan tackles the job of identifying sites of PFAS contamination, the even larger challenge is identifying a cost-effective way of remediating the PFAS-impacted groundwater, soils, and sediments in place without large removal efforts.

In Michigan, historic industrial use of PFAS and use of AFFF over large areas, such as military, industrial and airport properties, has resulted in large areas of land and groundwater in need of remediation. Taking just one example specific to Michigan, a single former automotive manufacturing site has 2.5 miles of riverfront property highly impacted with PFAS, an estimated 10 million gallons of PFAS-contaminated groundwater that needs to be addressed, and over 150,000 cubic yards of PFAS-contaminated soil that needs to be contained or otherwise remediated at this site alone.

There is a pressing need to develop cost-effective ways to remediate--or at least sequester--PFAS found in soil to decrease the potential for contaminating groundwater. It is known that PFAS leaches from soil into groundwater, but the rates and processes by which this occurs, and the most effective means of preventing ongoing contamination, are not thoroughly understood. Michigan and other states are using existing technologies such as pump-and-treat combined with granular activated carbon and resin, but these treatment methods are costly on a large scale. While these technologies effectively remove PFAS from water, the captured PFAS is not destroyed and still must be handled and disposed of in a way that is protective of human health and the environment.

Michigan supports development of new and improved remediation techniques to enable long-term, cost-effective treatment of PFAS, including sequestration, foam fractionation, and destruction technologies. For our Great Lakes State, the remediation of our water is critical to the well-being of our ecosystem and the well-being of our communities and economy.

Continued Research to Understand PFAS Toxicology

It is well established that exposure to PFAS is associated with adverse health impacts. In Michigan, we are pursuing community-based health studies[2] to take this knowledge farther by identifying links between exposures to PFAS and health outcomes. We are doing this through two community-based studies in Michigan. While these studies are expected to yield important data, additional federal support is needed to further expand on our knowledge of the toxic effects of more of the thousands of PFAS in the environment.

To help predict how PFAS will impact people and resources after being released into the environment, scientists need to know more about the unique ways that PFAS behave in the environment. Existing models used to predict environmental behavior, such as movement of contaminants through soil and groundwater and leaching, are based mostly on studies using other contaminants. Laboratory and field studies have shown that these models are not accurate predictors of PFAS behavior in the environment, pointing to a need for PFAS-specific research and modeling. Better predictive models of PFAS behavior in the environment will enable better decision making to protect

[2] The Michigan PFAS Exposure and Health Study (MiPEHS) is being conducted in the communities of Parchment and Cooper Township in Kalamazoo County and the Belmont/Rockford area in Kent County; the Multi-Site Study (MSS) is a national study in seven communities across the U.S., the communities studies in the MiPEHS.

groundwater, especially in areas where residents rely on this resource for their drinking water.

There is also a need to develop PFAS-specific tools to predict risk based on the presence of PFAS mixtures in the environment, even if a full individual chemical analysis has not been completed for each specific PFAS formulation.

Because of the use of thousands of varieties of PFAS and the increasing analytical capabilities, our ability to accurately measure the presence of PFAS, have greatly outpaced our ability to perform risk assessments for each of these PFAS that are identified in the laboratory data. To help close this gap, research is needed to enable decision makers to protect public health based on chemical similarities among the thousands of PFAS and make reliable predictions about risk, using what we do know about the more-studied PFAS. This kind of research can be used to develop tools to allow regulators and health agencies to reliably predict PFAS characteristics, such as persistence, bioaccumulation, and toxicity, based on known relationships and similarities among PFAS. One such predictive tool is a Quantitative Structure Activity Relationship (QSAR) model. As the study and collection of empirical data for the wide variety of PFAS continues, a robust QSAR will give regulators and public health agencies tools to effectively advise the public and make sound decisions based on existing and available data.

Michigan has been fortunate to have a legislature who has supported the work to identify PFAS and protect public health by appropriating a significant amount of state funding to undertake this work. State funding is best spent on directly addressing contamination issues like cleaning up sites, hooking homes up to safe municipal water, and subsidizing the costs of treatment technology. Federal funding is best spent on research which has the dual purpose of providing benefits to all states while allowing states to focus their limited funding on projects that directly benefit their citizens.

Thank you again for the opportunity to discuss Michigan's leadership on the cutting edge of PFAS mitigation policy at the state level, and to discuss the research needed at the national level moving forward. I welcome hearing from the other witnesses today and I look forward to answering your questions.

If you would like additional information on Michigan's efforts, please visit the MPART website at www.michigan.gov/pfasresponse or see the Attchment below. Thank you.

Attachment:

<u>Additional Information on Michigan's PFAS Actions:</u>
MPART's coordinated strategic approach has led to the following accomplishments:

Public Health:

- Since ingestion via drinking water is the primary route of exposure for our citizens, Michigan systematically sampled all 2700 public water supply systems to determine the occurrence and concentrations of PFAS. This sampling showed that while most of our systems were below the EPA lifetime health advisory level, there were two public systems that were discovered to have concentrations above the health advisory level. Upon finding elevated concentrations in a school and a public water system, Michigan moved swiftly to provide alternate water and work with the systems to identify long term solutions.
- In early 2019, Michigan could not wait to protect our communities and resources and therefore began the process of establishing State Drinking Water Standards or MCLs as allowed under the Safe Drinking Water Act.
- In August 2020, Michigan completed that process and formally established Drinking Water Standards or MCLs for 7 different PFAS under the Michigan Safe Drinking Water Act, which protects our 2700 public water supplies that supplies drinking water for approximately 75% of Michigan residents.
- This past fiscal year, 2,700 public water supplies conducted compliance sampling for PFAS under the Michigan Safe Drinking Water Act.

Identification of PFAS Contamination:

- Developed groundwater cleanup criteria for 7 PFAS, which we are using to hold polluters accountable for cleanup efforts at PFAS sites.
- MPART has identified over 193 MPART sites with one or more of the 7 PFAS compounds exceeding groundwater cleanup standards. For each "MPART site", nearby residential wells are evaluated and sampled if any are determined to be at potential risk.
- Collected precautionary residential drinking water samples in neighborhoods around suspected PFAS sites, which were at risk for groundwater contamination.

Reduction and Elimination of PFAS Sources:

- Took 2,323 samples of our lakes and streams, which we used to track down sources of PFAS.
- Collected over 2,919 fish from our lakes and streams, which we use to issue fish consumption advisories.
- MPART worked with Wastewater Treatment Plants with Industrial Pretreatment Programs to identify potential sources of PFAS and sample their effluent concentrations to determine compliance with Michigan's Water Quality values.
- Requested groundwater sampling at all currently or formerly licensed solid waste landfills with known drinking water wells nearby.

- Awarded grants to 19 airports where firefighting foam (AFFF) was known to have been used, for testing PFAS in groundwater and storm water.
- Removed 51,400 gallons of firefighting foam from Michigan's fire stations and airports as part of a pickup and disposal program.

Collaboration

- MPART has broad collaboration with both federal and states including:
  - A member of the Great Lakes PFAS Taskforce with the Great Lakes St. Lawrence Governors & Premiers and are participating in sub committees on Foam, Wildlife, biosolids and air;
  - Environmental Council of States: PFAS subcommittee
  - Interstate Technology Regulatory Council: PFAS Workgroup
  - EPA coordination meetings with Office of Research and Development
  - New England Interstate Waters Pollution Control Commission for Biosolids collaboration

Public Health Studies:

- Conducted the MIPHES, health study: The Michigan Department of Health and Human Services (MDHHS) is working to identify links between exposures to PFAS and health outcomes. We are doing this through two community-based studies: (1) the Michigan PFAS Exposure and Health Study (MiPEHS) and (2) the Multi-Site Study (MSS). MiPEHS (pronounced: my-pez) is the Michigan PFAS Exposure and Health Study, conducted by MDHHS in the City of Parchment and Cooper Township in Kalamazoo County and the Belmont/Rockford area in Kent County.
- MSS is a study funded by the Centers for Disease Control and Prevention's (CDC) Agency for Toxic Substances and Disease Registry (ATSDR) in seven communities across the United States. ATSDR has partnered with MDHHS to conduct MSS in the same communities as MiPEHS. See the MSS webpage for more details about that study.
- The Michigan Department of Health and Human Services (MDHHS) is doing a research study to see if per-and polyfluoroalkyl substances (PFAS) exposure affects how the immune system responds to COVID-19 vaccines, including antibody production. **Learn more about the PFAS Exposure and Antibody Response to COVID-19 Vaccine Study**.
- The PFOMS (pronounced: p-foams) project is a statewide biomonitoring project focused on Michigan firefighters. The primary purpose of the project is to determine firefighters' average exposure to per- and polyfluoroalkyl substances (PFAS). The findings of the project will help inform decisions about how to minimize firefighters' exposure to PFAS. **Learn more about PFOMS**
- The North Kent County Exposure Assessment is a regional effort that studied the relationship between drinking water with PFAS and the amount in the human body. The research study involves collecting blood samples from people in the northern Kent County area whose drinking water wells were found to have PFAS. **Learn more about the North Kent County Exposure Assessment**.

Abigail Hendershott, Executive Director of the Michigan PFAS Action Response Team (MPART)

Abigail (Abby) Hendershott, a 30-year veteran of the Michigan Department of Environment, Great Lakes, and Energy (EGLE), is the Executive Director of the Michigan PFAS Action Response Team. MPART is a multi-agency task force charged with investigating PFAS contamination, overseeing clean-up and other response activities aimed at protecting Michigan's drinking water.

Ms. Hendershott has focused on PFAS response activities since 2017 and led the team responsible for Michigan's largest PFAS contamination response to-date, the investigation into the former Wolverine Worldwide tannery in Rockford. In that role, her team was responsible for a $113 million legal settlement establishing clean-up plans and municipal water connections for thousands of residents in northern Kent County.

She supervised the Remediation and Redevelopment Division's Grand Rapids district office and has more than 25 years of project management experience for complex environmental remediation projects.

Chairwoman SHERRILL. Thank you. Next is Ms. Dindal. I'm having trouble hearing you.

Ms. DINDAL. Is that better?

Chairwoman SHERRILL. That's great. Thank you.

Ms. DINDAL. OK. I had a double mute. I apologize for that.

Chairwoman SHERRILL. Thanks.

TESTIMONY OF MS. AMY DINDAL,
DIRECTOR OF ENVIRONMENTAL RESEARCH
AND DEVELOPMENT, BATTELLE MEMORIAL INSTITUTE

Ms. DINDAL. Good morning, everyone. Chairwoman Sherrill, Chairwoman Stevens, Ranking Member Bice, and Ranking Member Waltz, thank you for the opportunity to testify before the Subcommittee on Environment and the Subcommittee on Research and Technology. My name is Amy Dindal, and I am the Director of Environmental Research and Development at Battelle. Established more than 90 years ago through an Ohio charitable trust, Battelle is the world's largest independent nonprofit research and development organization. Our mission is to translate scientific discovery and technology advances into societal benefits. Tackling the current and future technology and research challenges of PFAS is true to our mission, and the DNA of Battelle. We are closely aligned with EPA's directive in its PFAS Strategic Roadmap to invest in research, development, and innovation that incorporate the best available science, and I'm proud to share with you today the advancements that we have made.

Our awareness of PFAS began more than a decade ago, when we were supporting a site investigation at a Navy site in Pennsylvania. There was a mysterious foam coming out of an air stripper at the site. We sent the foam to our laboratory in Massachusetts, where it was identified as containing PFOA and PFOS. It was then that we began tracking the suite of chemicals. In 2019 we made a corporate commitment through a multi-million investment to develop new technology around PFAS. We looked to DOD's critical needs outlined in a September 2017 DOD workshop to frame where we would invest in new technology for PFAS. In my written testimony, I have provided a summary of the technologies that we have developed to measure, sample, model, track, treat, and destroy PFAS. Each technology has a role in supporting current and future site investigation and remediation needs at both government and commercial sites.

One of Battelle's most significant investments is the development of a PFAS destruction technology. Our transformational innovation is powered by supercritical water oxidation, or SCWO. In December 2020 the EPA issued interim guidance on suggested technologies for PFAS management. Supercritical water oxidation was highlighted as one of the promising destruction solutions. SCWO is not a new technology, as it's been used since the 1980's to address difficult to treat compounds. What is new is the application and optimization of the technology for PFAS. We call our technology PFAS Annihilator, as it destroys PFAS in contaminated water to non-detect levels in seconds, leaving inert salts, carbon dioxide, and PFAS-free water behind.

If there is one thing you remember from my testimony today, it is that Battelle is ready to scale and deploy PFAS Annihilator. We have been testing the technology in the laboratory for more than 2 years. We have high confidence in the technology's ability to destroy PFAS, as we have been simulating field deployments with waste samples from sites around the country. We are preparing for a January field deployment of our mobile SCWO system, capable of treating up to 500 gallons per day. We are also constructing a second mobile unit that will be able to treat up to 5,000 gallons per day.

Because we are a nonprofit, Battelle is able to collaboratively work with EPA on this important research. EPA just published a journal publication demonstrating the efficacy of SCWO for treating PFAS and AFFF. We have proposed and received contracts for demonstration projects to DOD's SERDP (Strategic Environmental Research and Development Program) and ESTCP (Environmental Security Technology Certification Program) programs with EPA as a co-principal investigator. This enables EPA to actively contribute to the research and demonstration needs, as well as stay current on technology improvements and progress.

We would like to propose three additional opportunities to support the development of PFAS technologies. First, increase the number of opportunities for pilot-scale field demonstrations of innovative technologies. Second, utilize available advanced analytical techniques to increase known information early in the site investigation process. And third, leverage Federal and private sector partnerships and collaboration to drive forward solutions. Battelle's development of advanced technologies to monitor, sample, and destroy PFAS is indicative of the progress that can be made with focused commitment. We are ready to scale and deploy PFAS Annihilator.

Addressing PFAS in our environment is not easy, but with more opportunities to test promising technologies in a real-world environment, an openness to utilizing new approaches, and enhancing collaboration opportunities, it can and will be done. It is an honor to provide my testimony, and I'm happy to take any questions.

[The prepared statement of Ms. Dindal follows:]

HSST Committee Hearing
December 7, 2021
"Forever Chemicals: Research and Development for Addressing the PFAS Program"
Written Testimony of Amy Dindal, Battelle Memorial Institute

Chairwoman Sherrill and Chairwoman Stevens, Ranking Member Bice and Ranking Member Waltz, thank you for the opportunity to testify before the Subcommittee on Environment and the Subcommittee on Research and Technology. My name is Amy Dindal, and I am the Director of Environmental Research and Development at Battelle. Battelle is a non-profit 501(c)3 organization that was established more than 90 years ago through an Ohio charitable trust. The Battelle Memorial Institute was the vision of a metallurgist, Gordon Battelle, who had a passion for both science and philanthropy. We are the world's largest, independent, nonprofit research and development organization and deliver innovative science, technology and engineering outcomes to help solve our nation's most difficult challenges. Our mission is to translate scientific discovery and technology advances into societal benefits. Our primary customer is the federal government, supporting basic research and applied science and technology. We have supported EPA as a contractor to the Office of Research and Development for more than 40 years. Our charitable mission is extremely important to Battelle. As a non-profit, we invest significant resources into STEM education through our national STEMx network across nineteen states and the Army Educational Outreach Program. Our goal is to reach one million students by 2025, and we are well on our way to reaching that goal. We also invest heavily in internal research to address tomorrow's threats. Tackling the current and future technology and research challenges of PFAS is true to our mission and the DNA of Battelle. We are also closely aligned with the EPA's directive in its PFAS Strategic Roadmap to 'invest in research, development, and innovation that incorporate the best available science', and I am proud to share with you today the advancementswe have made.

Our awareness of PFAS began more than a decade ago when we were supporting a site investigation at a Navy site in Pennsylvania. There was a mysterious foam coming out of an air stripper at the site. We sent the foam to our laboratory in Massachusetts, where it was identified as containing PFOA and PFOS. It was then that we began tracking this suite of chemicals as an emerging contaminant. We first invested in analytical techniques so that we could detect and measure the compounds, and in 2018 became the first laboratory to gain accreditation under the DoD Environmental Laboratory Accreditation Program for measuring PFAS in drinking water using the newly revised EPA Method 537.1. In 2019 we made a corporate commitment through a multi-year, multi-million dollar investment to develop new technology and capabilities around PFAS. We looked to the US Department of Defense's (DoD's) current and future needs to frame where we would invest in new technology for PFAS. In September 2017, DoD published a summary of the "SERDP and ESTCP Workshop on Research and Demonstration Needs for Management of AFFF-Impacted Sites." The critical priority needs described in that document informed the framework for our investments in PFAS, which continue today. Below I have provided a summary of the technologies we have developed to measure, sample, model, track, and treat PFAS. Each technology has a role in supporting current and future site investigation and remediation needs at both government and commercial sites. The technologies and methodologies include:

- Three offerings in advanced analytical techniques. These technological advances are critical to accurately identifying and/or quantifying PFAS in a variety of matrices.
    - Our DoD and state-accredited laboratory in Massachusetts has analyzed more than 42,000 samples for PFAS. In addition to traditional water and soil matrices, we work with complex matrices such as landfill leachate, environmental tissues, and vegetation.
    - We developed a totalorganofluorine method to assess total PFAS. Since only a limited number of PFAS analytes can be quantified using known analytical standards, there is a growing need for a holistic approach to quantify the total fluorine present in

environmental samples. Total PFAS measurements delineate the full inventory of PFAS at a site (e.g., perfluoroalkyl acids [PFAA] precursors, novel or unknown PFAS).

- Our most sophisticated analytical technique is a technology called PFAS Signature®, which combines high-resolution mass spectrometry with machine learning. PFAS Signature™ can determine if the site has been contaminated from Aqueous Film Forming Foam (AFFF) sources and non-AFFF sources such as landfills, wastewater effluent, and chemical manufacturing. The technology does this by looking for nearly 500 different PFAS through non-targeted suspect screening. Our innovation is in the data filtering and interpretation through advanced statistical techniques, which allow us to isolate the chemicals of interest from the tens of thousands of data points produced by the high-powered instrumentation. Application of this tool will better define and characterize source areas to improve the conceptual site model (CSM), fill data gaps, and provide a more robust picture of PFAS distribution beyond the targeted list of analytes and fate and transport of PFOA and PFOS.

- Because of the unique properties of PFAS chemicals, we also have developed sampling technologies to provide tools to characterize PFAS in a variety of matrices, including:
  - A passive sampler for surface and groundwater. As more detailed remedial investigations proceed, a significant amount of investigation-derived waste will be created. Passive samplers could help avoid this cost as waste is not generated. What makes passive sampling particularly beneficial in these applications is improved detection limits when compared to grab sampling, time-integrated results, and easy separation of only the most bioavailable, freely dissolved fraction of the contaminants. All these benefits translate into more reliable sampling at a reduced cost.

  - We also developed a sampler for ambient air to understand potential exposures and inform possible human and environmental health risks.
- Understanding the behavior of PFAS in groundwater has been identified as a key challenge in developing better knowledge about these chemicals of concern. Battelle created a tool called PFAS Predict™ that aims to help with that understanding. It is a tool that tracks and simulates PFAS transport in groundwater. It is capable of forward or backward tracking of the PFAS plume, and it can be used to predict future migration patterns over a span of time.
- Battelle has also pioneered a method of reactivating granular activated carbon (GAC) on-site. This innovative approach to GAC regeneration reduces operating costs and lengthens the life of a traditional GAC filtration system for drinking water treatment by allowing the GAC to be reused multiple times.

One of Battelle's most significant investments over the past two years is the development of a PFAS destruction technology. Our transformational innovation is powered by supercritical water oxidation (SCWO), which breaks the strong carbon-fluorine bonds within PFAS molecules and decomposes the material into a non-hazardous waste stream. SCWO is not a new technology, as it has been used since the 1980s to address difficult to treat compounds. What is new is the application and optimization of the technology for PFAS. In December 2020, the EPA issued interim guidance on suggested technologies for PFAS management. In addition to supercritical water oxidation, mechanochemical degradation, electrochemical oxidation and pyrolysis and gasification were highlighted as promising destruction solutions that merit further research and analysis. Others, like Allonnia, are attracting investment capital to innovate with synthetic biology. SCWO offers significant benefits for the environmental remediation and waste management industries. We call the technology "PFAS Annihilator" as it destroys PFAS in contaminated water to non-detect levels in seconds, leaving inert salts and PFAS-free water behind. Once the treated water has been tested to confirm that the PFAS have been destroyed, it can be safely discharged back into the environment. In addition to reducing liability, destroying PFAS to the lowest levels of detection ensures compliance, regardless of regulatory limits. Battelle's PFAS Annihilator system is housed in either fixed or mobile units that can be deployed to address on-site destruction needs. We have been testing the technology in the laboratory for more than two years. Battelle is preparing for field-testing a mobile SCWO system in January capable of treating up to 500 gallons per day of PFAS-contaminated liquids. We are also constructing a second mobile unit that will be able to treat up to 5,000 gallons per day. Because we are a non-profit, Battelle is able to collaboratively work with EPA on this important research. We have proposed demonstration projects to DoD's SERDP and ESTCP programs jointly with the U.S. EPA Office of Research and Development as a co-Principal Investigator. This enables EPA to actively contribute to the research and demonstrations needs, and stay current on technology improvements and progress.

DoD and EPA should be commended for their close collaboration on PFAS research. Considerable progress has been made through this collaboration. We would like to propose three additional opportunities to support the development of detection, monitoring, treatment, and destruction methods and technologies for PFAS.

1) Increasing the number of opportunities for field demonstrations of innovative technologies. Two weeks ago, EPA published a paper in the Journal of Environmental Engineering (Supercritical Water Oxidation as an Innovative Technology for PFAS Destruction | Journal of Environmental Engineering | Vol 148, No 2 (ascelibrary.org) describing the efficacy of SCWO systems, including Battelle's Annihilator, to reduce PFAS concentrations in AFFF. The findings showed "a greater than 99% reduction of the total PFAS identified", demonstrating the promise of this technology for PFAS destruction. The federal government can further support the development of detection, monitoring, treatment, and destruction methods and technologies for PFAS by increasing the number of on-site demonstrations for technologies that are showing promising results. Technologies that are proven in the laboratory may not be equally successful in the field, so it is imperative that field demonstrations are executed as early in the technology development lifecycle as possible. Taking an aggressive approach to field promising technologies will prove out those technologies which are fieldable solutions. Those that do not succeed in early attempts will 'fail fast' and have an opportunity to address shortcomings. It is important to test technologies under multiple site conditions as there can be significant variations in geology and contaminant composition from site to site, which can impact technology performance. More technology performance data will increase confidence in these new approaches and ultimately accelerate cleanup timelines . One of EPA's recommendations in its December 2020 guidance on Destruction and Disposal of waste materials was interim storage if immediate disposal was not imperative. Stored waste creates an opportunity for promising technologies to be tested for various volumes and a variety of waste streams.

2) **Utilize available advanced analytical techniques to increase known information early in the investigation process, which will ultimately reduce time and cost.** Battelle also supports the need for the objective described in EPA's PFAS Roadmap to develop and validate additional methods to detect and measure PFAS in the environment. By following the structure of the CERCLA/Superfund process for site clean-up, the federal government has made considerable progress using targeted PFAS methods to understand which federal sites have PFAS impacts to address. Unlike historical contaminants like chlorinated solvents, the level of PFAS characterization needed is greater than we have seen for past environmental contaminants because PFAS are a more complex class of chemicals. Enhanced site investigation will increase the understanding of background levels of PFAS, provide information on potential sources, and further define the plume of contamination. This includes the use of high-

resolution mass spectrometry, which can provide information on non-target PFAS, and "total PFAS" methods that can measure the sum without identifying specific PFAS through the measurement of total organic fluorine. Considering all of the CERCLA stages to achieve site closure, it is estimated that there will be a reduction in sampling and analytical costs by deploying more informative advanced analytical technologies earlier in the investigation process. In addition to cost savings, the application of such an integrated set of methods allows site owners to make better informed decisions and provide greater flexibility in determining the extent of PFAS contamination at the site.

3) Leverage federal and private-sector partnerships and collaboration to drive forward solutions.

More formal and deliberate federal government partnering with non-profit organizations (like Battelle) will be beneficial to achieve scale and accelerated action. For example, Battelle has demonstrated the ability to quickly test, finalize design and scale technology early in the pandemic when Battelle brought forward a technology that could decontaminate N-95 masks when these critical personal protective equipment were not available for front-line healthcare workers (Reference: Battelle CCDS Critical Care Decontamination System™ Services now Available at No Charge| Battelle Press Release). As a result, millions of masks were cleaned and reused at a time when N95 masks would otherwise not have been available. A similar model can be applied to PFAS for promising destruction technologies that are ready for scaling.

Battelle's development of technologies to monitor, sample, and destroy PFAS is indicative of the progress that can be made with focused commitment. Battelle and others are working relentlessly to bring these types of permanent solutions to life. Addressing these resilient and pervasive substances in our environment is not easy, but with more opportunities to test promising technologies in a real-world environment, an openness to utilizing new approaches, and enhancing collaboration opportunities, it can and will be done.

Amy Dindal – Bio

Amy Dindal is Battelle's Director of Environmental Research and Development. Ms. Dindal is currently leading Battelle's PFAS Program and is responsible for setting technical direction and oversight of a multidisciplinary team of more than 50 staff that includes scientists, engineers, chemists, biologists, toxicologists, and modelers. In this role, Ms. Dindal has applied her technical understanding of chemical processes and analytical chemistry to support development of innovative approaches and technologies to characterize, model, and destroy PFAS compounds.

Prior to joining Battelle in 2002, Ms. Dindal was a Research Scientist with Oak Ridge National Laboratory (ORNL) for 10 years. While at ORNL, she obtained a U.S Patent (No. 6,645,908) for a method for producing a sol-gel derived sorbent material and was an R&D 100 award winner in 1997.

Amy holds a Bachelor of Science degree in Chemistry from Penn State University and has been a certified Project Management Professional (PMP) since 2006.

Chairwoman SHERRILL. Thank you so much. And last, but not least, Dr. Jaffé.

TESTIMONY OF DR. PETER JAFFÉ, PROFESSOR, DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING, PRINCETON UNIVERSITY

Dr. JAFFÉ. Thank you. Chairs Sherrill and Stevens, Ranking Members Bice and Waltz, and Committee Members, thank you for inviting me today. It's an honor to appear before you. I'm the William Knapp Class of '47 Professor of Civil Engineering at Princeton University, and a member of Princeton's Andlinger Center for Energy and Environment, and the High Meadows Environmental Institute. The views expressed in this testimony are my own.

Unique challenges presented by PFAS include that there are over 4,700 PFAS compounds that have been synthesized, and the number is growing. PFAS have a wide range of molecular structures, varying carbon chain length, different functional groups such as acids, alcohols, sulfonates, and different ionic forms or charges. They can be amphoteric, with hydrophilic ends and hydrophobic tails, like soap molecules, all of which affects their transport in the environment. Hydrogen from their carbon skeleton may be either fully substituted with fluorine, perfluorinated, or partially substituted polyfluorinated compounds, which greatly affects their stability. This large variability in molecular structures and properties contrasts, for example, with other contaminants of major environmental and health concerns, such as polychlorinated biphenyls, PCBs, for which about 130 individual PCBs have been used in commercial products, and all of them are characterized by having a very low water solubility and relatively similar transport properties.

The key points I'd like to make today include that the large number of PFAS, and their wide range of properties, provide a unique challenge for conducting research on PFAS and regulating them, hence there's a need of moving toward identifying molecular properties that affect their toxicity, fate and transport in an environment, and potential treatment method, versus studying or regulating them individually. Analyzing PFAS is challenging and costly. There's a need to, one, develop new methods that are less costly, two, account for this cost in PFAS-related research, and/or three, establish facilities to analyze samples from federally funded research. DOE, with their Environmental Molecular Biology Laboratory at PNNL (Pacific Northwest National Laboratory), and a range of user facilities at various National Labs, may provide a model for such PFAS-dedicated analytical facilities.

All key PFAS sources need to be identified and characterized. This is needed to obtain a complete understanding of where they enter different environmental compartments, and where mitigation is needed, and/or most effective. A generalized understanding of biotic and abiotic reactions that can either partially transform PFAS, or degrade them completely, is needed for fate and transport assessment, and for development of PFAS treatment technologies. The mechanisms and limitations of biological transformations of PFAS is needed to be better understood. They should be environment specific, considering their chemical properties, and focus on the full range of redox conditions, ranging from aerobic to anaerobic. The microorganisms or microbial communities capable of transforming PFAS need to be identified and characterized. Knowing what genes are linked to the degradation or transformation of individual PFAS, or group of PFAS, and what conditions are needed for their expression, would allow to predict what PFAS transformations may take place in specific environmental settings where the presence of such genes has been detected.

In addition to DOD's AFFF contaminated sites, access to other PFAS contaminated sites is needed to validate laboratory results, transport models, and to test site remediation schemes. Many such sites are privately owned. Agencies such as EPA could catalog sites based on their prevailing PFAS through chemistry and accessibility or ownership. And finally, central data bases on what is known about these sites, including results of completed research or remediation projects, will be extremely valuable for researchers to model—for model testing, validation, or identification of new research directions.

Thank you for inviting me, and I look forward to your questions.

[The prepared statement of Dr. Jaffé follows:]

DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING
PRINCETON UNIVERSITY, PRINCETON, NEW JERSEY 08544

PETER R. JAFFÉ
WILLIAM L. KNAPP '47 PROFESSOR OF CIVIL ENGINEERING
PROFESSOR OF CIVIL AND ENVIRONMENTAL ENGINEERING

December 3, 2021

Chairs Sherrill and Stevens, Ranking Members Bice and Walzer, and committee Members:

Thank you for inviting me to testify today. It is an honor to appear before you.

I am the William L. Knapp '47 Professor of Civil Engineering in the Department of Civil and Environmental Engineering at Princeton University and a member of the faculty of Princeton's Andlinger Center for Energy and the Environment and High Meadows Environmental Institute. My research focuses on the physical, chemical, and biological processes that govern the transport and transformation of pollutants in the environment and their application toward the remediation of contaminated systems. The views expressed in this testimony are my own.

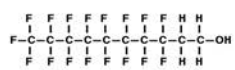
KEY POINTS

- A major challenge for conducting research on PFAS, and regulating them, is the large number of PFAS compounds (over 4700) that have been manufactured. This requires identifying molecular properties that affect their toxicity, fate and transport, reactions/transformations, etc., vs. studying/regulating them individually.
- The expense and challenges of identifying and analyzing PFAS requires (i) the development of new analytical techniques for PFAS detection and quantification that are less costly, (ii) an increased budget for PFAS related research as compared to research focusing on more traditional pollutants (i.e., trace metals, chlorinated solvents, etc.), and/or (iii) the establishment of government supported/operated facilities to analyze for PFAS in samples obtained from federally supported research projects.
- All key PFAS sources need to be identified and characterized to assess the fate and transport of PFAS in the environment.

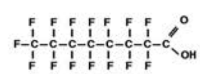
- The large number of PFAS, the diversity of their molecular structures (i.e., organic acids, alcohols, sulfonates), and their amphoteric properties which vary depending on the carbon chain length, make it both, challenging and prohibitively expensive to measure transport properties for each PFAS of interest. Therefore, there is a need to develop generalizable estimates of their transport properties. This includes parameters to quantify processes such as sorption/partitioning, volatilization, and bioaccumulation.
- Assessing PFAS fate and transport in the environment and developing novel PFAS destruction technologies also requires a thorough and predictable understanding of biotic and abiotic reactions that can either partially transform PFAS or degrade them completely.
- Laboratory studies have shown that under some conditions polyfluorinated compounds can be transformed biologically, but not fully degraded. A much more limited number of studies has shown that some perfluorinated compounds can be defluorinated biologically. The mechanisms and limitations of these biological transformations need to be better understood.
- Knowledge regarding what genes are expressed during the degradation/transformation of specific PFAS, in which environments organisms with these genes can be found, and under what environmental conditions these genes can be expressed, would allow for a more reliable prediction of PFAS transformations in the environment. This information is at present close to non-existent.
- Scientists/engineers need access to PFAS contaminated sites to validate results of fate and transport models, and to test site remediation schemes. AFFF contaminated sites from DoD are available to researchers, but there is also a need to access sites contaminated with other PFAS. Cataloging sites, with different geochemical characteristics and contaminated with different PFAS to which researchers could have potential access would be helpful to facilitate the transition from the laboratory to the field.

BACKGROUND

Per and polyfluorinated alkyl substances (PFAS) include thousands of chemicals that are present in many consumer and industrial products. According to the National Institute of Environmental Health Sciences, there are over 4,700 PFAS and the number is growing[1]. The fluorine-carbon bond is the strongest covalent bond in organic chemistry, which gives these compounds their high stability, even at high temperatures, and which makes it difficult for them to break down. Organic molecules are typically composed of a carbon (C) skeleton, made from carbon and hydrogen (H) atoms, and functional groups that give them their specific chemical properties. For PFAS, many of these hydrogen atoms have been substituted with fluorine (F) atoms. For polyfluorinated compounds, not all hydrogens from that carbon skeleton have been substituted with fluorine, whereas for perfluorinated compounds, all hydrogens of the carbon skeleton have been substituted with fluorine, making them even more stable. Pictured below are simple molecular representations of 8:2 fluorotelomer alcohol (8:2 FTOH), a polyfluorinated PFAS which has 8 fluorinated carbons and a 2-carbon ethyl alcohol group, and perfluorooctanoic acid (PFOA), which as the name implies, is a perfluorinated PFAS. Note the absence of C-H bonds in PFOA.



8:2 FTOH



PFOA

Note that for the above shown structures, the left side is a long symmetric carbon-fluorine chain, while the right end has a functional group (alcohol, -OH, for 8:2 FTOH), and (acid, -COOH, for PFOA). Hydrocarbons with long carbon chains usually have a low solubility in water, while small alcohols or organic acids are water soluble. This makes the above structures amphoteric, meaning one part of the molecule is not water soluble (hydrophobic) while one part is water soluble (hydrophilic), as is also the case for soap molecules. Like soap molecules, these PFAS tend to accumulate at the water/air interface, decreasing the surface tension and facilitating the formation of bubbles/foam, which makes them ideal for the manufacture of firefighting foam. The balance of hydrophobic vs. hydrophilic properties of a PFAS is greatly affected by the carbon chain length, for example, the hydrophobicity of PFOA (8 carbon chain length) is higher than that of perfluoropentanoic acid (PFPeA, 5 carbon chain length), and hence, their environmental fate and transport properties are expected to be different. Furthermore, organic acids such as PFOA can dissociate, forming a negatively charged ion, as shown below.

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[1] National Institute of Environmental Health Sciences (NIEHS), accessed 11/29/2021, https://www.niehs.nih.gov/health/topics/agents/pfc/index.cfm

The ionic species (negatively charged ion as shown above) has different transport properties (i.e., sorption and volatilization) than the non-ionic species. Negatively charged species are called anions, but other PFAS can also exist as positively charged species (cations) and there can even be PFAS molecules with both, positive and negative charges (zwitterions). The large number of different PFAS, their widespread use, their amphoteric properties, and their dissociation into ionic forms make it a challenge to assess and generalize their fate and transport in the environment.

This contrasts with other contaminants of major environmental/health concerns. For example, for polychlorinated biphenyls (PCBs), there are only 209 possible structures, and of those, about 130 individual PCBs were used in various commercial products. PCBs are neutral and very insoluble in water and are therefore mostly found in sediments such as those of the Hudson River, which differentiates them from PFAS. Therefore, assessing the fate and transport of PFAS is significantly more complex than that of pollutants such as PCBs.

Much is known about the fate and transport in ground and surface waters of hydrophilic (water soluble) compounds, such as trace metals, radionuclides, and ionic organic compounds, as well as the transport of hydrophobic (low solubility) organic compounds such as PCBs and chlorinated solvents. Building on this knowledge, researchers are actively investigating the fate and transport of PFAS in the environment, considering the above-mentioned properties, and many of these studies have been summarized in several recent reviews.[2, 3, 4]

RESEARCH CHALLENGES AND NEEDS

Listed below are research needs and challenges which need to be addressed if we are to better understand and predict the fate and transport of PFAS in the environment, and ultimately the treatment (remediation/destruction) of PFAS.

The reason to focus on fate and transport of PFAS is to allow assessment on how they move from a source to a receptor. One such receptor could be humans ingesting PFAS contaminated water, food

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[2] Interstate Technology & Regulatory Council (ITRC), 2020. PFAS Technical and Regulatory Guidance Document and Fact Sheets PFAS-1. Washington, DC. Interstate Technology & Regulatory Council, PFAS Team. https//pfas-1itrcweb.org/.

[3] Sima, M., and P.R. Jaffé, 2021. A Critical Review of Modeling Poly- and Perfluoroalkyl Substances (PFAS) in the Soil-Water Environment. *Science of the Total Environment*, Vol. 757, 143793.

[4] Sharifan et al., 2021. Fate and transport of per- and polyfluoroalkyl substances (PFASs) in the vadose zone. *Science of the Total Environment*, Vol. 771, 145427.

(crops, fish, etc.), or exposure to PFAS via air inhalation or skin contact. The focus of this discussion is on waterborne pathways. A thorough understanding of PFAS fate and transport is also required to engineer schemes to remediate PFAS contaminated sites.

PFAS Analyses. Challenges remain, although significant progress is being made by analytical and environmental chemists in the analyses of PFAS. Analyzing even the more common PFAS is expensive, requiring state of the art liquid chromatography-mass spectrometry methods, equipment, as well as operators that are trained in conducting these analyses. Lack of access to this equipment and analytical techniques may prevent some scientists from conducting research on PFAS. Alternatively, it requires them to either build up expensive analytical facilities, conduct research in close collaboration with scientists that have access to such facilities, or have samples analyzed commercially. All these options are expensive, with the result that PFAS focused research is significantly costlier than research focused on more conventional pollutants. Short of developing novel analytical methods for quantifying and/or identifying PFAS that are less costly, or the availability of regional/national facilities that are dedicated to analyzing PFAS from federally funded research projects (i.e., EPA, USDA, NSF), PFAS related research budgets need to account for the high analytical expense. A possible model for a PFAS analytical facility is the Environmental Molecular Science Laboratory (EMSL)) at Pacific Northwest National Laboratory (PNNL), which is equipped to make a wide range of very specialized analytical measurements, and researchers can submit proposals to have a specific set of samples analyzed. In addition to EMSL, DoD has many user facilities where scientists can conduct experiments and measurements using very specialized and expensive facilities. The number of samples that might have to be processed at a PFAS-dedicated facility would certainly be larger than samples being processed currently at government-owned laboratories such as EMSL. There are some university laboratories that specialize in PFAS analysis; however, for the reasons given above, not many of those exist, and their objective is not to provide broad analytical support to multiple investigators conducting independent PFAS research and who are not working in close collaboration with scientists associated with these laboratories.

How to determine which PFAS to focus on? As stated above, while there are thousands of PFAS, most knowledge about their impact on human health, and therefore also fate and transport, as well as remediation, is limited to a few [i.e., perfluorooctanoic acid (PFOA), perfluorooctane sulfonate (PFOS), perfluorononanoic acid (PFNA)], or those with a very similar molecular structure. A more systematic understanding is needed regarding which PFAS have significant human health- and/or ecotoxicological effects, how the molecular structure of specific PFAS drives these effects, and the frequency and concentrations with which they are detected in the environment. Such insights will help prioritize which PFAS researchers need to focus on. Research should also focus on the precursors of these PFAS. Identification of these precursors necessarily requires understanding their biotic/abiotic transformations, as discussed below. Such a systematic understanding should also inform the establishment of environmental regulations and standards.

PFAS Sources. Assessment of fate and transport requires characterization of the sources. There is a good understanding of sources such as from airports or hydrocarbon processing facilities where Aqueous Film Forming Foam (AFFF) has been used to extinguish fires or where AFFF has been used at firefighting training sites. Other PFAS sources that have been identified and/or are being studied include PFAS manufacturing facilities and landfills. Landfills are especially challenging, since many PFAS containing consumer products might have been disposed in them, and current landfill leachate treatment does not address the removal of PFAS. Studies funded by the US EPA have shown variability in PFAS composition between landfills. Other sources are less understood and/or studied. Wastewater treatment plants, for example, treat millions of gallons of wastewater per day. If that wastewater contains traces of PFAS, some of the more volatile PFAS might become airborne due to the intense aeration systems used in these plants, while other PFAS will concentrate in the biosolids. Some polyfluorinated compounds may be converted into shorter polyfluorinated compounds or into perfluoroalkyl acids (PFAAs), hence there could be differences in the composition of PFAS between the inflow and outflow of wastewater treatment plants. In wastewater treatment plants, a significant fraction of the biodegradable organic compounds (referred to as BOD or biochemical oxygen demand) is converted into bacterial mass while bacteria use these organic compounds as a growth substrate. The bacterial mass that is produced in these treatment plants is referred to as biosolids, which needs to be disposed of. It is very common to apply biosolids from wastewater treatment plants to agricultural lands, and at this point it is not clear if there are circumstances where biosolids are a significant PFAS source that might be taken up by crops. Like wastewater treatment plants, which for justifiable reasons have not received the attention of AFFF sites, there may be other PFAS sources that need to be identified and characterized to obtain a complete picture on where these compounds enter the environment, and where PFAS sources can be most effectively abated.

PFAS Transport. Because of the sheer number of different PFAS chemical structures, the most efficient approach is to develop detailed chemical models for the fate of PFAS in the environment. As mentioned above, their amphoteric properties result in PFAS accumulation at the air/water interface which can significantly slow their migration in unsaturated soils. Sorption onto soil components, both organic and inorganic, will further slow their migration in the subsurface or sediments. Sorption to soils is driven by both, their hydrophobic properties, which results into partitioning into soil organic carbon (typical for compounds such as PCBs), and sorption to the mineral structure of soils (typical for ionic species such as trace metals). The partitioning of these compounds at the water/air interface as well as the partitioning into soil organic carbon is strongly affected by the compounds carbon chain length. The sorption onto the mineral fraction of soils is affected by the functional group of the specific PFAS molecule. This sorption depends on the PFAS ionic state, pH (of the soil), the presence of other ions especially with more than one charge (i.e., calcium and magnesium), and the mineral characteristics of the soil. It is just not practical to quantify these processes for every PFAS and soil of interest when an assessment of their transport needs to be conducted. Scientists know how changes in the PFAS molecular structure (carbon chain length, functional group, ionic form) affect sorption and partitioning, and how to estimate volatilization rates based on their Henry's law constant (ratio of compound's concentration in gas phase to liquid phase at equilibrium). Hence, research needs to focus on obtaining generalizable sorption/partitioning models and means to estimate and verify thermodynamic parameters of individual PFAS based on their individual chemical structure.

Limited studies are available focusing on the kinetics (or the rate) of sorption/desorption as well as hysteresis during desorption. Hysteresis is attributed to the presence of a fraction of PFAS that might be sorbed irreversibly, or due to very slow desorption kinetics. Understanding this hysteresis and/or slow desorption kinetics is important in the assessment of fate and transport of PFAS, especially for "pump-and-treat" remediation schemes, where rate limiting desorption will result in a longer time to achieve a desired remediation endpoint. Again, research is needed to characterize this process in terms of PFAS structures and soil/water properties.

Application of biosolids to agricultural land was discussed above, and this practice might be a pathway which could result in PFAS contaminated crops. Other sources such as atmospheric wet and dry deposition might also result in agricultural soil and crop contamination. Bioconcentration factors (the ratio of PFAS concentration in plant tissue compared to the concentration in solution) have been reported in the literature for several PFAS and specific crops, including fruits, grains, and leafy greens. Translocation factors (the ratio of PFAS concentrations in shoots of the plants compared to that in root matter) have also been reported for several PFAS. To complicate the matter, to account for different climatological conditions and/or duration over which a plant was exposed to PFAS, a transpiration concentration factor (the concentration in foliage compared to foliage weight divided by the concentration in solution times the volume of water transpired) needs to be determined. All these factors can be used to estimate the concentration of PFAS in crops based on their concentration in the soil pore water, although different methods will yield different results and these methods need refinement to estimate plant uptake of PFAS more accurately in terms of the PFAS chemistry, concentration, soil/water properties, climate, as well as plant growth and type. Furthermore, there is a lack of data on PFAS transformations (change in chemical structure) in plants, which could result in an underestimation of the biological concentration factors.

Biological concentration factors are also used and have been measured to estimate PFAS concentrations in organisms such as shellfish, fish, etc. Relationships between biological concentration factors and exposure time have been established and have shown that for specific organisms and PFAS the biological concentration factors are also a function of the exposure time, showing that the use of a biological concentration factor is only a simple means of estimating PFAS concentrations in organisms, requiring more refinement to link fate and transport processes to accurate PFAS concentrations in foods.

As already mentioned above, PFAS specific thermodynamic parameters are needed to estimate volatilization rates. Fluorotelomer alcohols (FTOHs), for example, which are PFAA precursors, are volatile, while PFAAs are much less volatile. Accurate assessment of volatilization is needed to assess their fate in settings where volatilization could be important, such as in wastewater treatment plants, surface waters, and shallow soils.

Reactions. Understanding transformations of PFAS has multiple critical applications. Under environmental conditions, polyfluorinated PFAS can be partially degraded/transformed, resulting in

the production of PFAAs. There are multiple studies that have reported the appearance or increase of a PFAA that was not present at the onset/source, or that was not expected to be present at a specific location/time at the observed concentration. These effects are usually attributed to the degradation of polyfluorinated compounds, hence referred to as PFAA precursors. These reactions need to be understood and be predictable to accurately assess the fate and transport of selected PFAS.
Given the extremely large number of polyfluorinated compounds, a systematic approach is needed to understand the transformations in molecular structure under various environmental conditions.

Abiotic reactions. This includes possible, but likely only a very small number of PFAS transformations under environmental conditions, as well as reactions that may result in PFAS destruction under "harsher" conditions in terms of temperature, pH, or oxidizing conditions, such as may be applied for PFAS treatment/destruction technologies.

Under environmental conditions, it is thought that PFAAs do not undergo abiotic reactions and that most transformations are limited to polyfluorinated compounds. These transformations of polyfluorinated compounds do not result in the complete degradation (mineralization) of PFAS and result in the production of smaller PFAS molecules including PFAAs.

Biodegradation. Biodegradation of organic pollutants is in general among the most effective pathways to eliminate them from the environment. Furthermore, if a compound is biodegradable, biological treatment methods are usually the most cost-effective treatment technologies. Biodegradation of organic compounds can occur either in the presence of oxygen (aerobic) or its absence (anaerobic). There are many different anaerobic conditions to be considered, which are characterized by a redox state, ranging from more oxidized to more reduced. Usually aerobic processes are faster, but the removal of halogens (i.e., chlorine, fluorine) from an organic molecule, specifically for highly halogenated compounds, is often achieved under anaerobic conditions by a process referred to as reductive dehalogenation. A well-drained soil, for example, is typically aerobic, while a waterlogged soil might be anaerobic. Similarly, there are aerobic and anaerobic river/lake sediments and groundwaters. For site remediation, if a specific aerobic or anaerobic pathway is desired, a contaminated site can be manipulated to obtain the required redox conditions. Hence, we need to understand PFAS biotransformations under the full possible range of redox conditions, since it is possible that some biotransformations are favored under aerobic conditions while others require anaerobic conditions.

There is evidence from field observations, and many laboratory studies that polyfluorinated compounds can be transformed biologically. Most of these efforts have focused on aerobic conditions and have shown that polyfluorinated compounds can be transformed biologically into smaller poly or perfluorinated compounds. Laboratory studies are often conducted at concentrations that might be different than what is found in the environment, and usually at conditions that favor the growth of a specific organism which may not necessarily be representative of the natural environment. Hence, research is needed to obtain a general understanding on the biodegradation of polyfluorinated compounds, focusing on groups of PFAS and systematically studying the effect of their structure on the biotransformation process. Studies should focus on biotransformations in different environments (including soils, wetlands, waste treatment plants), redox conditions, what end products are being produced, which specific organisms (and/or bacterial communities) are responsible for these transformations, and what are possible thresholds if any, for biotransfomations.

Although until recently, perfluorinated compounds such as PFOA and POFOS were considered to be non-degradable, some recent laboratory studies have shown that perfluorinated compounds can be defluorinated. However mechanistic insights into this degradation process are needed, identifying the key enzymes responsible for this defluorination as well as the genes that encode these enzymes. This will aid in the search for other organisms that might be capable of degrading perfluorinated compounds and help to understand the limitations (threshold concentrations if any), the degree to which a PFAAs can be defluorinated (completely vs. partially). Although these initial findings are exciting and may at some point lead to PFAS bioremediation schemes, the reason PFAAs have been dubbed "forever chemicals" is because they are so stable in the environment, undergoing little if any biodegradation. It is unclear at this point what the potential is for biodegradation of PFAAs, even in environmental settings that favor the growth of organisms that have been shown to defluorinate PFAAs in laboratory experiments.

Linking degradation pathways to the expression of specific genes, and determining what genes are present in a specific environment, and under what environmental conditions they might be expressed, should aid in predicting what transformations might occur to specific PFAS molecules in specific environments. Such information would be valuable for potential bioremediation schemes, where environmental conditions can be manipulated. A significant effort is needed to reach this point, but once such information is available, predictions of the fate of PFAS would be improved, and the implementation of potential site bioremediation schemes could be examined.

While identifying conditions or organisms that can transform PFAS requires less specific PFAS related methodologies, except for analyzing decreases in PFAS concentrations and tracking the production of intermediates, including fluoride, gaining insights into PFAS degradation mechanisms will be more complex and costly. Such efforts may require, for example, synthesizing PFAS for which specific carbons are labeled, or the study of a partially defluorinated intermediate that is not commercially available.

Access to PFAS contaminated sites to verify fate and transport models and test remediation schemes. Although much research can be done at the laboratory scale and via modeling, eventually laboratory and model findings and proposed remediation schemes need to be verified and tested at the field scale. DoD sites, which are relatively accessible to PFAS researchers, have been contaminated mainly with AFFF. There are many other sites contaminated with specific PFAS, that would be valuable for field testing, but where access is difficult. These would include mostly privately owned sites. Although government may not be able to facilitate access to such sites, there may be sites under government control that are different than AFFF contaminated sites to which researchers may be able to get access. Hence, it would be helpful if an agency such as EPA could catalogue PFAS contaminated sites that are under government control where field testing might possible be conducted.

Treatment. A common method to treat PFAS-contaminated water is based on PFAS removal via sorption onto sorbents such as granular activated carbon (GAC) or ion exchangers. It is important to point out that this technology does not destroy the PFAS but just removes them from water. The large range of PFAS properties affects, as was discussed above, the sorption process, and hence the effectiveness of this removal process for different PFAS. Therefore, gaining a generalizable understanding of sorption processes that is needed for assessing PFAS fate and transport, is also useful for the design of sorption-based treatment systems. A major challenge of PFAS removal via sorbents is the regeneration of the sorbent after the sorption capacity has been exhausted, followed by the proper treatment/disposal for the PFAS laden regeneration stream.

Other PFAS treatments include, but are not limited to, combustion, chemical oxidation, treatment using plasmas, or perhaps at some point biodegradation, all of which require an understanding of the reaction pathway. There is a need to conduct research to develop novel and cost-effective technologies for PFAS destruction for a variety of PFAS contaminated matrices (soils, biosolids, sorbent regeneration stream, etc.).

END

Thank you again for inviting me. I look forward to your questions.

Sincerely,

Peter R. Jaffé

Technical abbreviations used

AFFF	aqueous film forming foam
GAC	granular activated carbon
FTOHs	fluorotelomer alcohols, which are named based on the relative number of fluorinated to hydrogenated carbons, see 8:2 FTOH, shown in the text
PCBs	polychlorinated biphenyls
PFAS	per and polyfluorinated alkyl acids
PFAA	perfluoalkyl acids
PFNA	perfluorononanoic acid
PFOA	perfluoroalkyl acid
PFOS	perfluorooctane sulfonate, also referred to as perfluorooctanesulfonic acid
PFPeA	perfluoropentanoic acid
8:2 FTOH	8:2 fluorotelomer alcohol

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Peter R. Jaffé, the William L. Knapp '47 Professor of Civil Engineering, is a Professor in the Department of Civil and Environmental Engineering. His background is in chemical engineering, and he obtained a Ph.D. in Environmental and Water Resources Engineering from Vanderbilt University in 1981. He was chair of the Department of Civil and Environmental Engineering from 1999 to 2005 and was the Associate Director for Research at the Andlinger Center for Energy and the Environment from 2012 to 2019. He held the position of Research Associate in the Department of Civil Engineering at Princeton University from 1982 to 1983 and was a faculty member at the Universidad Simón Bolívar in Venezuela from 1983 to 1985. He joined the faculty of the Department of Civil Engineering at Princeton University in 1985. He held visiting positions at the Venezuelan Research Institute, the International Institute for Applied Systems Analysis in Austria, the University of Auckland, and the Ecole des Mines D'Albi, and was an AT&T Industrial Ecology Fellow. He has served on numerous committees and panels, including the National Research Council, EPA, NIH, NSF, DOE, the Singapore Expert Panel of The Environment and Water Industry Development Council, the Korean Institute of Geoscience and Mineral Resources, and others. He is an Elected Fellow of the American Geophysical Union and was appointed as Board Certified Environmental Engineering Member of the American Academy of Environmental Engineers by Eminence.

His research interests relate to the physical, chemical, and biological processes that govern the transport and transformation of pollutants in the environment, and their application towards the remediation of contaminated systems. His research has focused extensively on biological and chemical pollutant dynamics in porous media; simulation and analysis at the watershed scale of soil contamination processes and nutrient cycling; nitrogen cycling at the watershed scale; and dynamics of trace metals and radionuclides in sediments, wetland soils, and groundwater. Areas of current emphasis include biological defluorination of per- and polyfluorinated alkyl substances (PFAS); and understanding novel biological processes for anaerobic ammonium oxidation, focusing from field-scale transformations to applications for wastewater treatment.

Chairwoman SHERRILL. Thank you so much. At this point we'll begin our first round of questions. I now recognize myself for five minutes.

Currently there are no federally enforceable standards for PFAS. This can often lead to confusion for municipalities, with some States setting more stringent standards for PFAS in drinking water. Dr. Jaffé, how could addressing gaps in PFAS science better inform the standards, and can you detail the state of the science for current PFAS standards at the State level?

Dr. JAFFÉ. Standards are set by the prevalence of PFAS and their health effects, a combination of both. And New Jersey, for example, has added perfluorononanoic acid that is being regulated because it is more prevalent in New Jersey than other places. So, I'm not a toxicologist, but I think what we need to have a combination of what is the health impact of specific PFAS, and how prevalent they are to come up with specific standards.

Right now EPA is focusing mostly on PFOA and PFOS, which have been manufactured specifically by manufacturers, and less of an emphasis is on PFAS that are out in nature. Many of the polyfluorinated compounds in, let's say AFFF, can be transformed to perfluoro alkyl acids. They are not necessarily PFOS. They can be perfluoro hexanoic acid, and we don't fully understand the toxicity of all of them. So I think there is a need to understand structurally what PFAS should be regulated, instead of just looking at individual PFAS in a family, one by one.

Chairwoman SHERRILL. Thank you so much. And, Ms. Hendershott, would uniform PFAS standards be helpful to States that are working to address contamination, and what is the role of Federal agencies like the EPA in this work?

Ms. HENDERSHOTT. Absolutely. So uniform standards would definitely help our entire country. Michigan has had to come up with our own standards for water quality values for surface water, drinking water standard, and groundwater cleanup criterias, and having uniform settings across our country would certainly make a better consistent message, make us all work toward a collaboration, and really coalesce the science around all of our uniform angle of drinking water protection. So I think that's the first thing that's absolutely necessary.

The role of EPA, then, is obviously, you know, having that national standard, having EPA take that lead for development of a State—or a national drinking water standard through the MCLs for the *Safe Drinking Water Act* is absolutely essential, and I encourage—I'm very thrilled that they're taking those first steps, and will be making efforts to have MCLs in place within the next 18 months, because that's absolutely necessary for all of our Nation's public water supplies, to have safe drinking water standards.

Chairwoman SHERRILL. Thank you. And for all the witness—witnesses, what is the importance of Federal research and development activities in developing uniform science-based PFAS standards across the country?

Dr. SUNDERLAND. I can comment on that quickly. So I think uniform standards are very helpful for avoiding confusion among the public. I guess one challenge for developing these uniform standards, and one thing that we see leading to the diversity of drinking water standards right now is the fact that different agencies are picking different health outcomes to develop these risk-based limits, so agreeing on which health effect, and perhaps focusing on the most sensitive health effects for protecting the most vulnerable populations, such as children, is very important, and with these compounds, the most sensitive health endpoint that we see does relate to immune function in children. A number of European regulatory agencies are using that immune outcome to develop more uniform and consistent guidelines, and I would encourage the agencies to think about using that in the development of more uniform guidelines.

And the second point Dr. Jaffé touched on already, which is, you know, how many compounds are we regulating when we develop these standards? So it's difficult to have a uniform standard if there are different numbers of PFAS compounds or different types of compounds, being considered in the regulation. And one point that I think perhaps hasn't become clear yet is that—and I touched on it very briefly in my statement, but the majority of compounds in the environment now, and most of the PFAS compounds in our products, are ones that we're not measuring with our standard methods, and they're not being regulated, and they're not included in our standards. Some of them—some of those compounds that we're not measuring actually degrade into compounds that have already been associated with negative health impacts.

So as we think about developing uniform standards, I would put out there that I think we need to think about, you know, a screen for total organofluorine compounds, and then think about some of these compounds that we're missing, and their health impacts after that. So thank you for the opportunity to comment.

Chairwoman SHERRILL. Thank you so much. And my time has expired, so I'll now recognize Ranking Member Bice, Ranking Member of the Environment Subcommittee, for five minutes.

Mrs. BICE. Thank you so much. My first question is to Ms. Dindal. It is my understanding that the majority of your work is funded or done in collaboration with the DOD. PFAS contamination on military complexes is a high profile issue, and three Air Force bases in Oklahoma, Vance, Tinker, and Altus, are in need of cleanup. In addition to this Committee, I also serve on the House Armed Services Committee, so I'd like to dive deeper into how DOD projects are coordinated or utilized by non-defense research that fall under the jurisdiction of the Science Committee.

Ms. DINDAL. Yes, ma'am, thank you for the question. We looked at DOD's critical needs, which were identified in the SERDP-ESTCP September 2017 workshop of where to inform our investments. All of the developmental work that we have done has been self-funded by Battelle. EPA performed an evaluation of our technology for destroying AFFF, and released a journal publication, and we've also been awarded, and have contracts pending, where EPA is a co-principal investigator with us on DOD projects. So the performance results are definitely transferable to other agencies, and to others that are dealing with commercial sites as well.

Mrs. BICE. Excellent. What is your level of interaction, then, with the agencies, namely the EPA and the DOE, when you successfully demonstrate a technology like the PFAS Annihilator? Are the results and the data sort of easily transferable to those agencies?

Ms. DINDAL. Yes, they are. They are—it is information that has been generated—as I said, the EPA has just released a journal publication on supercritical water oxidation and the effectiveness for AFFF. Our interaction with EPA has been as a co-principal investigator on our DOD projects so that we can engage with them as we are progressing with the technology.

Mrs. BICE. Thank you for that. Can you talk a little bit about the pros and cons of PFAS incineration, and how your research involves methods for removing PFAS from GAC (granular activated carbon)?

Ms. DINDAL. So that is correct, GAC, or granulated activated carbon, will remove the PFAS from the water, but it won't destroy it. The GAC filters are typically sent back to the vendor for thermal reactivation. One of our early investments was in a process for regenerating GAC that was a non-thermal process. We have a liquid regenerant that we use, and we've developed a system so that the GAC can be regenerated without the use of thermal processes. And so once that GAC is treated with our GAC regeneration, the GAC can be re-used, and the regenerate can be destroyed by the Annihilator technology.

Mrs. BICE. Thank you for that. And my last question, Ms. Sunderland, you mentioned earlier that we're, you know, utilizing PFAS in a variety of areas, including in packaging, particularly in the food area. What is the suggestion for moving away from that?

Dr. SUNDERLAND. My suggestion would be to follow the lead of the European Union, and counties like Denmark, which is to phaseout these products in our food packaging. There's a lot of discussion in the academic community right now on essential uses of PFAS, so where do they really convey a benefit to the product, or where can they be replaced by less toxic alternatives? And certainly there are many non-PFAS-based alternatives to food packaging. The—a few of the States are already looking at banning PFAS in food packaging, and I think it's something that could be done with a little support quite easily on a Federal level.

Mrs. BICE. OK. That's the extent of my questions. Madam Chair, I yield back.

Chairwoman SHERRILL. Thank you. The Chair now recognizes Ms. Stevens, Chairwoman of the Research and Technology Subcommittee, for five minutes.

Ms. STEVENS. You know, it's absolutely fascinating, as we talk about the cleanup, and the complex technologies and processes that go into it, and yet we've got to devote energy and time to thinking about prevention. And certainly we're doing both today, but the enormity of the cleanup is just astonishing. And, Ms. Hendershott, I'm just wondering if you could give us the Michigan perspective of the cleanup, particularly, you know, costs, manpower, how far we can go? You know, listening to Ms. Dindal, and reading through her testimony, and this Annihilator technology, and the supercritical water infrastructure that they're putting into place, it's absolutely incredible, but then I start to think about the actual infrastructure, and how far we can actually go with this. So—yes.

Ms. HENDERSHOTT. Great question. The amount of PFAS in our site—so I—as I said before, we have 193, 94, MPART—or PFAS sites recognized currently in our State, and we're still identifying PFAS sites every day, additional ways at which a PFAS concentration in groundwater exceeds the State standard, and then it becomes officially an MPART site, but a lot of these are legacy issues in large, large areas.

Our—we've been investigating all of our commercial airports. Almost all of our airports have significant issues. We've gone offsite to look at doing precautionary drinking water sampling around the airports because many of these are in and surrounded by residential areas, serviced by groundwater for drinking water, so it's really important to understand that, because fully identifying a site that is a mile, two miles, three miles large, because of the AFFF use on these airports, is really quite difficult, time consuming, and very, very costly.

So when you talk about what does it take to clean up an airport, a military site, a large tannery, or a large industry, you're talking about huge investments. And while, you know, a PFAS Annihilator is a great first step, I'm very excited to see that, we need something that can go—we're looking at really a combination of technologies. How do we cleanup the groundwater? How do we cleanup those soils? How do we cleanup surface water? And it's usually a combination of technologies. There's not one technology that can do all of the things that we'd need necessary for cleanup, and so we're looking for—is there a way to—like Dr. Jaffé's research on degradation of PFAS in the soils or in groundwater, can we do that? Can we do—use the PFAS Annihilator in maybe foreign landfill leachate, another huge issue? What do we do with our wastewater treatment biosolids?

So it's not just cleanup of individual sites, but all these processes where PFAS are coming out, or are in some sort of a waste stream that need to be addressed. All of those need some sort of PFAS treatment, and technology to go with it.

Ms. STEVENS. Well, we have also on the Committee another Michigander, the Dean of the Michigan Democratic Delegation, Congressman Dan Kildee, who leads our bipartisan task force on PFAS and PFAS remediation, and we spend a lot of time talking about cost, you know, and who's going to pay for it? And so you look at the cost spectrum here, we've got the identification of PFAS, and in itself is a complex endeavor, and I want to salute every single one of you, you know, who are involved with this effort. You know, academic, you know, we've got industry here, as well as State actors. That in and of itself is a complicated effort.

Then we've got this—you know, the cleanup, the handling, the dealing, and it—you know, we can look at what gets shouldered on the taxpayers. You know, we can recruit a fund, certainly, and then we've got this last component, which is on prevention. And so, you know, as we look to identify our scope going forward, absolutely applauding the R&D efforts that are taking place, but also recognizing that the continuity of investment that needs to get made going forward.

So, with that, what I'm going to do is I'll pause on the time. Ms. Hendershott, we'll come back to you on questions for the record, particularly on, you know, what EPA should be replicating. I know you've utilized the National Pollutant Discharge Elimination System, and how best we can continue to serve all of you at the local level. And with that, Madam Chair, perfectly on time, I yield back.

Chairwoman SHERRILL. Well, thank you. Thank you, Ms. Stevens. I now recognize Research and Technology Subcommittee Ranking Member Waltz for five minutes. And he might have stepped away. All right. I am going to turn it over to the Committee Counsel for the order of recognition.

STAFF. Recognize Mr. Ellzey.

Mr. ELLZEY. Well, thank you, Madam Chair, and I appreciate everybody coming in to—today to discuss this very important issue. I have a quick question for Ms. Dindal. As a Naval aviator, I'm very familiar with AFFF, and what it does, and—as well, in the news recently, in Hawai'i, the water system for numerous families has been polluted by some leaking fuel that got into their water system. My question to you is at what point would your Annihilator be able to be used, and how scalable is it? And finally, real quickly, how much power does that thing use? It sounds like an exciting technology. I'd be hopeful that that could be used on the water system in Hawai'i, but, you know, is it—is—in the next couple years, is it going to be largely scalable? And thank you for your time.

Ms. DINDAL. Thank you, sir, for that wonderful question. It's scalable today. We have a mobile unit that is capable of destroying up to 500 gallons per day. We will be deploying that starting in January. We are also constructing a larger scale system that is capable of up to 5,000 gallons per day. So it is scalable today, and I'm—and I am very happy to, you know, talk further about how that could be scaled, you know, especially when it would—comes to, you know, drinking water systems. When you talk about impacts due to AFFF, there are some existing systems that are in place treating that drinking water now, so that GAC can be used to treat, for example, the drinking water, and then Annihilator can be couple with that. So when we're talking about scaling, it can either be scaled by itself, or in combination with other technologies to perform more of a treatment train approach.

Mr. ELLZEY. Thank you. And is the power requirement for that fairly large?

Ms. DINDAL. Sir, thank you for repeating the question. I knew there was another important point we wanted to cover. It is not. We can do it with a generator in the field, or we can plug it in to house power. It is not energy intensive.

Mr. ELLZEY. OK. Fantastic. And finally, I know Battelle does a lot of important work, one of which is near and dear to me as—and I'm sure it is to Mike Waltz, as those of us who deployed in combat. You do a lot of work with—at Battelle with correcting nerve damage from traumatic brain injury and explosions in combat, so thank you for the work Battelle does. I look forward to seeing more important and scalable issues from Battelle. Thank you for your time today, and, ahead of time, Madam Chair, I yield back.

STAFF. Ms. Bonamici is recognized.

Ms. BONAMICI. Thank you so much to our Subcommittee Chairs Sherrill and Stevens, and Ranking Members Bice and Waltz, and especially to our witnesses for your expertise, and your testimony. And I note that our Subcommittee Chairs are from New Jersey and Michigan, two of the States that are really leading the way at the State level on addressing PFAS. But, as we've already discussed this morning, we really do need a Federal standard so everyone is protected, not just those in States that have made the issue a priority. And I note that in my home State of Oregon we have not detected as much PFAS in drinking water, but we are—our Department of Environmental Quality is doing a lot of testing.

So I want to ask Ms. Hendershott, because—your experience in Michigan implementing the enforceable drinking water standards, which I know New Jersey has done as well—so can you tell us what went well in the collaboration between Michigan State experts and national experts, what could've been improved, and what lessons can we at the Federal level learn from Michigan's efforts over the past few years?

Ms. HENDERSHOTT. A fantastic question. Thank you. So when we went to look for the enforceable standards for what we set as the State MCLs, or the maximum contaminant levels for the *Safe Drinking Water Act,* for Michigan, we first started with—consulting with our internal experts at the State level for health, and setting what—we came up with advisory levels for what we thought was appropriate based on the best available science, the research at the time, and our understanding.

Then we went to the national experts, and asked them, and created a Science Advisory Board, similar to what EPA is doing, and actually some of those same experts were on our Science Advisory Board as well, to get their input on whether they agreed with our assessment, did they agree with the science, did they have anything else—I think that was absolutely important. The next step that we did was then go to the public, talk to the public, get their input, held a number of different public hearings and events on sharing that science, that information, with the public to get their input, and went through that—what is really pretty standard MCL development process for EPA.

But I think the things that went very well were obviously getting the input of the Science Advisory Board, double checking our science, making sure we had the best available information, and incorporating the public input into this, because I think, if we don't hear anything else from our public, they want us to be transparent. They want to know what's going on, they want to hear, and have a voice at the table.

Ms. BONAMICI. OK.

Ms. HENDERSHOTT. So I——

Ms. BONAMICI. And I don't want to cut you off, but I want to get to another question for everyone.

Ms. HENDERSHOTT. Sure.

Ms. BONAMICI. And I just want to note, I appreciate the public input part, and I think the more public knowledge there is, and the—public education efforts, you know—I know that a lot of food packaging, as we were talking about—I just learned that a lot of dental floss contains PFAS. I think the more public knows about this, the more they're going to be engaged.

So, for each of you, you know, our underserved communities, and communities of color, have suffered disproportionately from exposure to a wide range of toxins, including PFAS, and so I'm encouraged by the EPA's October release of the PFAS Roadmap, which is establishing the plan to research, restrict, and remediate. So I want to ask each of you, the plan directs agencies to incorporate environmental justice considerations into programs and policies, so what opportunities do you see for the Federal Government to further engage on the environmental justice as it relates to PFAS research and development, prevention, and mitigation? And if you could keep your answers brief, that would be helpful. And I'll start with you, Dr. Sunderland.

Dr. SUNDERLAND. Sure. Thank you for that very important question. I think our first task is to understand the communities that are disproportionately affected by PFAS. I have several graduate students working on this subject right now, and there are many broader tools that we can leverage to look at that. And then I think the point touched on earlier, with, you know, which—are communities equally able to afford the risk mitigation that's needed if they contaminated drinking water, things like this. So this——

Ms. BONAMICI. And I'll go to Dr. Jaffé before I run out of time. I'm going to try to get quick responses from—Dr. Jaffé, please?

Dr. JAFFÉ. Yes. One important thing is to identify the sources, and typically we have more contaminated sources in those close to disadvantaged communities. They need to be identified, and addressed, and contained.

Ms. BONAMICI. Thank you. Ms. Hendershott? I think you're muted.

Ms. HENDERSHOTT. Sorry. Just for the EJ communities, I think that they have a disproportionate amount of storage and disposal facilities that end up in their communities, and so not just looking at the contamination sites, but how the PFAS would flow through their communities would be very important.

Ms. BONAMICI. Thank you. And Ms. Dindal?

Ms. DINDAL. We need to ensure that the technologies that are brought forward are cost-effective to be able to be deployed in every community.

Ms. BONAMICI. Terrific. Thank you very much. I yield back. Thank you, Madam Chairs.

STAFF. Ranking Member Waltz is recognized.

Mr. WALTZ. Thank you, and thank you, Madam Chairman, for your indulgence. Ms. Dindal, I'd like to hear about the PFAS Signature Advanced Analytics Tool, which I understand identifies specific signatures of PFAS in areas of comingled sources. Specifically, how does this tool incorporate any machine learning (ML) AI (artificial intelligence) technologies, and do you think this tool will be upgraded and improved as we advance our understanding and use of AI and ML?

Ms. DINDAL. Thank you, sir, for that excellent question. Certainly happy to share about our PFAS Signature Tool, and excited to tell you about its capabilities. So PFAS Signature combines analytical chemistry and data science. We use high resolution mass spectrometry, where we'll do non-targeted analysis which generates thousands of mass spectral data. We can then, from there, use a filtering process that we developed. That's really where our innovation is. And from that we can also using a suspect screening tool look for up to 496 different PFAS compounds.

So, as I said, our innovation is around really the data filtering process, but it's also key to reducing it so that we can utilize those AI/ML techniques, which are used to train the tool on different sources and signatures of PFAS.

Mr. WALTZ. That's great. And—so do you see—well, can we just get—can you rewind the clock a little bit, and just tell us a little bit more about kind of how it was developed, and what went into that? Because I think it's just a—just as a process and an approach, something that I would hope to see replicated across the board. And what kind of collaboration did you have as you developed the tool?

Ms. DINDAL. Thank you for the question. We had a cross-disciplinary research approach when developing this tool. It involved analytical chemists, modelers, subject matter experts in a number of different areas in order to bring the tool. As I said, data science is really where this tool is enabled. The power comes from our ability to filter the tool. So it was a strong internal collaboration, and it is one that has significant impacts.

As we look at site investigation, where there is the need for more data, the ability to deploy a tool like PFAS Signature allows more information to be learned about that site early in the investigation process, which can really improve the approach we take—and really better inform those approaches that we take to remediating the site.

Mr. WALTZ. So how do we—Ms. Dindal, how do we—I don't know how to say this. What's needed to ramp up the use of tools like these, right? I mean—such as the signature, and the—and your predict tool. You know, how do we get them more widely adopted, and then how can government, you know, how can government coordinate, and to ensure that these types of tools are utilized, but I think importantly how do they—you know, to help make sure that they're accessible?

Ms. DINDAL. Thank you. That's a great question as well. Increasing the number of opportunities for demonstrations of these technologies is key to getting them more widely used and accepted. More technology performance data will increase the confidence in these new approaches, and ultimately accelerate cleanup times when those technologies are utilized. So right now we have a proposal pending with DOD to utilize a technology toolbox approach, where we have Signature, our Predict tool, which is a groundwater fate and transport modeling tool, and our PFAS Insight, which is a passive sampling tool. We have a proposal to demonstrate all three of those technologies working in combination to support additional site investigation.

So that will be key for us—if that proposal is funded, and we move forward with demonstrating this under the ESTCP Program, that will be critical in terms of getting it widely, or more adopted, within the DOD.

Mr. WALTZ. OK, great, thank you. And just in the, you know, 30 seconds or so I have remaining, can you just speak briefly to the—

what you see is the current state of PFAS alternatives research, and the viability of any alternatives that we know of?

Ms. DINDAL. Yes, sir. I can speak from it from the perspective that Battelle is supporting DOD, through the ESTCP Program, evaluating non-fluorine forms of AFFF, and that research is still ongoing. We are doing the test and evaluation, and to this point there has not been a PFAS-free foam that has been identified that meets the military specifications, but that research is continuing.

Mr. WALTZ. Great. Thank you so much, and I yield.

STAFF. Mr. Tonko is recognized. You're on mute, Mr. Tonko.

Mr. TONKO. Sorry about that. Can you hear me?

STAFF. Yes.

Mr. TONKO. I believe Representative Stansbury needed to go before me, unless that's changed?

STAFF. Yes, sir. Are you yielding time?

Mr. TONKO. Yes, I am, to Representative Stansbury.

Ms. STANSBURY. Thank you, Mr. Tonko, and thank you, Madam Chairwoman, for convening today's panel. Given the impacts of PFAS in our communities, and communities across the country, and particularly in New Mexico, it's vital that we advance coordination and advanced science and research on the impacts, cleanup, and alternatives to PFAS in order to address these issues.

In New Mexico we have had devastating impacts from PFAS contamination, especially in Curry and Otero Counties in the eastern side of our State, where PFAS was used as—in firefighting foams at Cannon Air Force Base that has led to contaminated drinking water supplies, private wells, and wells that supply dairies in the Ogallala Aquifer, and also contamination at Holloman Air Force Base, which has led to extensive groundwater contamination.

PFAS has also been detected in water bodies throughout our State, and we are just beginning to scratch the surface in understanding the full picture of this contamination, the fate and transport of the contaminants within our communities, and the impacts on environmental and human health. Our dairies in particular, and the dairy industry, as one of our leading agricultural industries, has been just devastated. Thousands of gallons of milk have been dumped, and people's livelihoods have been destroyed by this contamination.

So my question is really to Doctors Jaffé and Sunderland, which is how can we expedite and increase the speed of our understanding and our ability to measure these contaminants, and to do remediation, especially in areas where there's been large-scale spills?

Dr. SUNDERLAND. I'll start with how can we detect them, and perhaps Dr. Jaffé can take how can we remediate them? I think—so in terms of understanding and detecting PFAS, I think support for joint collaboration between EPA and NIST is essential, so we need standard methods that fully capture all of the compounds that we know are used in commerce, and we're innovating on those detection methods, and making sure they're usable in the field.

And I think another component of this that you touched on is just understanding all the different types of PFAS sources, so there are efforts underway, you know, to integrate PFAS accounting into the Toxic Release Inventory, and other data bases. And those—I think, with support from all of you, those efforts could be accelerated. I'll yield to Dr. Jaffé now.

Dr. JAFFÉ. Thank you for the question. So when we look at PFAS remediation, right now most of our efforts are site specific, where we have high concentrations of PFAS. When you're concerned about agricultural processes, dairy farms, we probably have very dispersed, very low concentration of PFAS. They may have been applied with sewage sludge, and that's much, much more challenging to remediate these large, large sites. We need to have more focused research. It could be the Department of Agriculture that focuses on that, on how to make these PFAS leach so they don't go back into the food chain, and how we may be able to sequester them. And there could be methods, depending on which one that you could mobilize the PFAS a little bit more, so that they get out of the root zone. We don't have a good methodology to address that right now.

Ms. STANSBURY. Thank you to both of the doctors. It's just so urgent that expedite this research and development, and then expedite the cleanup of these communities. As I said, it's been economically devastating, and also just devastating to these communities, so I appreciate the work that you all do. I'm heartened to see that the administration is helping to coordinate this work through the Office of Science and Technology Policy, and I look forward to getting *NDAA* passed, and advancing and supporting this Committee's work on this effort. So thank you very much, and thank you to Representative Tonko for yielding, and I yield back.

STAFF. Mr. Gonzalez is recognized.

Mr. GONZALEZ. Thank you. Thank you to the Chairs and Ranking Members for holding this hearing today, and to our distinguished witnesses for joining us. While the science of PFAS continues to evolve, a couple things I think are clear. First, given the wide use of PFAS in so many products, these chemicals have found their way into the soil, and in many cases our drinking water. That's obvious. Second, with a growing body of evidence directly linking PFAS to adverse health effects, we need to be doing more to improve our R&D efforts in surveillance, rapid testing, and treatment technologies. I want to particularly emphasize the importance of treatment technologies, because, regardless of any action taken by Congress or the EPA to regulate PFAS, many Americans could be drinking contaminated water for years if we don't identify and support solutions that will destroy these forever chemicals.

Ms. Dindal, I appreciated your testimony, particularly your comments and recommendations on how we continue to make advances in these PFAS destruction technologies. I actually had the opportunity to visit one of Battelle's environmental labs back in 2019 in Columbus, Ohio, and it's extraordinary to see the progress that your organization has made with the Annihilator technology in such a short period of time. Also, it has an awesome name, so, you know, congrats on that.

I think, you know, one thing we can take away from all the testimony we've heard is that total destruction of these chemicals is of the utmost importance, and the technologies at Battelle sound very promising. Could you please describe how you believe the Annihilator would work to remediate sites that are currently contaminated with PFAS in the groundwater, and does it work for contaminated soil?

Ms. DINDAL. Yes, sir, thank you for the question. PFAS Annihilator is very applicable to groundwater treatment. It can be done in a number of scenarios. It can be used directly to treat that groundwater. In some sites there are existing remediation systems that are in place, like granulated activated carbon or ion exchange, that are already pumping and treating at different sites. As opposed to replacing that with a new technology, we can work in augmentation with that technology, so that's another opportunity to scale quickly, and not have to completely change to a new solution, but rather augment the solution that is there.

You asked a question about soil as well. That is——

Mr. GONZALEZ. Yes.

Ms. DINDAL.[continuing]. Another area where we are focusing. We have an active DOD SERDP contact to develop the technology further for soil. Currently the process to get it in an aqueous state, where we would remove the PFAS from the soil through a soil washing technique, and then we would destroy it with Annihilator, but we are working now on treating the solid material directly.

Mr. GONZALEZ. Great. How far along is that technology? It sounds like that's more in development than the other. How close are you all, do you think, to really——

Ms. DINDAL. It is. It's—the soil directly is in early stage, but, as I said, we do have a solution to wash the soil, and then destroy that. It would just be a two step process.

Mr. GONZALEZ. Great. And sort of related to that, could you share how your conversations have been going with Federal agencies, and how they want to use this technology at their waste sites? And then, if there's barriers that the Federal agencies are throwing up, I'd certainly love to hear about that as well.

Ms. DINDAL. We have been having a lot of conversations about this technology, particularly as we have begun to scale it and put it on this mobile platform. The conversations with DOD and EPA in particular, and the focus on a mobile technology that we can take the solution to the waste, and not move the waste around the Nation has been positively received, and that is why we've built our second larger unit also on a mobile platform. There's encouragement and engagement to utilize this technology. We do have a couple of current contracts with DOD to deploy the technology in the next year.

Mr. GONZALEZ. Great. Well, that's great to hear. Congratulations on all the progress. I know this Committee's very excited to see what you all can do in this space. Thank you to the Ranking Members and the Chairs, and I yield back.

STAFF. Mr. Casten is recognized.

Mr. CASTEN. Thank you so much, and thanks to our witnesses. I want to dive sort of straight into questions, and I'm—I really just have some basic science questions, and I'm hoping you can help me, Dr. Sunderland. I'm proud to have supported the *PFAS Action Act* to designate PFAS as a hazardous substance under *CERCLA,* and direct EPA to study whether it should be designated as a toxic pollutant, but I'm scratching my head a little bit, because there was this FDA analysis about a year ago that, if I'm reading it right, suggests that food, rather than water, is the primary source of PFAS contamination for most Americans. And, as I've gone through, that looks to be a measure of the number of people who are—have PFAS in their system, not necessarily the dosage.

So, Dr. Sunderland, I wonder if you can give us a little bit of an overview, do we have a good sort of dose response data for PFAS? Is there such a thing as a safe level? Do we know? Give us a little bit of an overview, if you could, on where the—what the status of that science is.

Dr. SUNDERLAND. Sure. Thank you very much for the question. For the—on the health side, there are many different health outcomes, and so, in terms of establishing a dose response relationship, it would depend on the specific compound being considered, and the types of effects that have been investigated. Certainly we've seen, for things like immune toxicity, and we've seen effects at high levels, we've seen effects in adults, so we've seen an association between PFAS exposure, for example, in severity of COVID–19 in adult populations, and then we've seen effects in terms of antibody production following routine vaccination in children. So for those types of effects—and I would say there's a whole suite of effects on the metabolic system, so human metabolism, which relate to things like diabetes and cardiovascular disease. So for those kinds of outcomes, we do have fairly well established dose response relationships. There are many, many new types of impacts being discovered all the time.

You commented on this difference between—and very astutely, you know, we have high dose communities, so some of these contaminated communities that have—water exposures versus the general population, and I think it's worth noting that exposures in the general population are still of concern. And for those populations it's true that we would think that diet is very important. And I guess one thing I really want to highlight for this Committee is we have almost no data to characterize what are the most important exposure sources for the U.S. general population. We should be concerned about everybody. We're most concerned about risk mitigation for those contaminated communities, but as soon as we get that under control, I think it's really important to also think about the whole population. And, until we identify those predominant exposure sources, it's very difficult to identify the most appropriate risk mitigation options. And our food supply has been systematically understudied, so most of our knowledge is from European data. And I don't want to be long-winded, so I'll stop there.

Mr. CASTEN. So—well, so—and I don't want to misunderstand that. Are you suggesting that the highly exposed populations are more likely for water-based exposure, or——can you answer that?

Dr. SUNDERLAND. Yes. So we have highly exposed populations from a—like, it is possible to get highly exposed populations from a variety of—in a variety of ways. The ones that we've looked at most closely are these contaminated communities, but we also have data on population level exposures from CDC, and there are—you know, there are ways that people in the general population can also be highly exposed, through use of products, through dietary ingestion, and other sources. And we simply don't have enough data on those—you know, the—what we would call the U.S. general population outside of these contaminated communities to really have an informed response right now, and I think that's a really big gap in our knowledge that needs to be addressed.

Mr. CASTEN. All right. So, with the little time I have left, I have a dumb and sort of selfish question. I represent a fairly affluent district in the Chicago suburbs that doesn't have a military base, and it—we certainly have our, you know, our pockets of inequality, but I think we're generally more fortunate than most. But on the other hand, last time I did a poll, 100 percent of my constituents eat food. The—can you just tell us what—how do you personally, in your expertise, think about nonstick cookware? Is it a thing we should be concerned about? How do you—what would you advise people who eat and cook to do, given what you know as a scientist?

Dr. SUNDERLAND. I mean, I'm a strong believer in the—cast iron pans, and not using nonstick cookware, but, you know, I rely a lot on my husband for cooking, so—what can I say? They're—these are personal choices, right? And I think that, you know, there's a variety of advice we can give to people to mitigate their personal exposures to PFAS in products. That is one of the handles that we could use to reduce exposures for the general population, by phasing out the nonessential uses in some of those products.

Mr. CASTEN. Well, thank you very much. I'm out of time. I may follow up on the record to see if your husband's got some good records—good recipes for us. But thank you, and I yield back.

STAFF. Ms. Ross is recognized.

Ms. ROSS. Thank you. Thank you very much to our Subcommittee Chairwomen, and also to the Ranking Members, for holding this very important hearing. I've been doing a lot of work on PFAS issues, bipartisan work, because of all the contamination in North Carolina (NC). My home State of North Carolina knows PFAS issues too well. Chemical companies have polluted the Cape Fear River with PFAS for years, and I've worked on these issues both with Congressman Hudson and Congressman Rouzer, so I appreciate Representative Bice's emphasis on the bipartisan work that we're doing on this.

But tests of drinking water in my district, including Raleigh and Cary, have also detected PFAS. Fortunately, though, my district also includes NC State University, home to researchers and scientists who've dedicated their time and expertise to assessing PFAS exposure, bioaccumulation, and remediation, as well as the harmful health effects that can result from exposures to these forever chemicals. And in October I had the privilege of touring NC State's Center for Environmental Health and Effects of PFAS, where I witnessed the incredible work our scientists are undertaking to learn more about these chemicals.

That same day I joined EPA Administrator Michael Regan in North Carolina to announce the Biden Administration's plan to combat PFAS pollution in a governmentwide effort with eight Federal agencies, and several people have referenced this plan. I understand that it had its first meeting to discuss coordination, and, Ms. Hendershott, I don't know if you followed that meeting, but recognizing that these initiatives are in their early stages, can you speak to what you've seen so far? And, if you don't know what's happened in that meeting, I'd love to hear from our other experts here.

Ms. HENDERSHOTT. Yes. Thank you for that great question. I'm not sure exactly which meeting you're talking about, but if you're referring to the EPA PFAS Roadmap, I am very encouraged by the coordinated actions that EPA's going to be taking. I would further request that all of the Federal agencies coordinate at an—at the national level, at a very high level, to strategize on PFAS response, because I don't think one agency, or one department, has all the answers. And so I think, as we learned in Michigan, that a coordinated response, all the way, you know, from the low levels of field work, up to the strategic decisions for implementation and process are really, really important, including our general public, so—not wanting to leave the public out of it. But I think the Roadmap is a great first step, but there are many, many more steps to take.

Ms. ROSS. And, do be clear, that meeting was a meeting of the joint Subcommittee on Environment, Innovation, and Public Health. Did anybody else follow that meeting, and have any reactions to the first steps? Maybe not. OK. Then, for all of the witnesses, what do you hope the—this inter-agency coordinating body will accomplish as it relates to our R&D needs? Maybe Dr. Sunderland? Do you have any comment on that?

Dr. SUNDERLAND. So the body that recently met? What——

Ms. ROSS. The inter-agency coordinating body, yes, where—with the eight different agencies.

Dr. SUNDERLAND. Yes. Well, I think we've heard many different ideas for what we hope the—this body accomplishes, and they broadly fall within the areas of exposure and risk mitigation, comprehensively identifying the health outcomes associated with these compounds, thinking about the remediation techniques, making them available, and then source—you know, comprehensive source identification across the country. So—and I think it was highlighted a moment ago as well, you know, there are many steps that we need to take. So if others want to comment as well, I'd welcome their input.

Ms. ROSS. Well, let me shift, because I only have twenty-six seconds left. One of the efforts that we've taken in North Carolina with advocates is to get Chemours, which has done most of the PFAS contamination, to bear some of the financial responsibilities for research. And so do you agree that the Federal Government and academic research institutions should not have to bear the full cost of needed PFAS research, and that industry should be required to chip in, particularly when they were part of the cause?

Dr. SUNDERLAND. I absolutely agree.

Ms. ROSS. Thank you very much, and I yield back.

STAFF. Mr. Gimenez is recognized.

Mr. GIMENEZ. Thank you, Mr. Chairman. I have no questions at this time. Thank you.

STAFF. Thank you. Mr. Kildee is recognized.

Mr. KILDEE. Thank you very much to the two Chairs for holding this really important hearing. This is a subject that I've spent a lot of time on, so, for Chairwoman Stevens and Chairwoman Sherrill, thank you. I've been working on these issues ever since I learned about the people that I represent in Oscoda having been exposed to PFAS. And, you know, we know, from this testimony and from research, that these chemicals are linked to health issues, thyroid disease, cancer, et cetera. The people of Oscoda have been dealing with this because the military used firefighting foam containing PFAS that has leached into the former Wurtsmith Air Force Base, and into their drinking water. And even though the base has been closed for thirty years, the people of Oscoda are still dealing with these impacts.

But, of course, it's not the only community dealing with PFAS contamination. In fact, a couple years ago, when Congressman Brian Fitzpatrick and I, my Republican colleague, founded the bipartisan congressional PFAS Task Force, we didn't have that many Members involved because people didn't know about it. This task force now has more than sixty Members, and it's because, as we discover the extent of PFAS contamination, Members of Congress understand that we have this responsibility to step up and defend the people that we work for. And that's why I'm so happy that this continues to be a—very much a bipartisan effort.

One of the ways that people are exposed through—to PFAS is through drinking water when firefighting foam containing PFAS leaches into the groundwater. This affects those folks, but also particularly affects firefighters, who are posed to—exposed to PFAS when they use this foam. And obviously firefighters have a much higher rate of cancer, and so we have this obligation to protect communities, and especially to protect those firefighters. We were able, through this Committee, to pass legislation that would require both military and civilian airports to find alternatives to PFAS containing firefighting foam, and to help with the transition. Again, through this Committee, I was able to secure $95 million in the *Build Back Better Act,* which hopefully will come to the President's desk in the not too distant future, to replace firefighting foam containing PFAS. So this is an are I'm really curious about.

And I want to start with Ms. Hendershott. If you might address how—assuming the *Build Back Better* dollars are delivered, how this would help you, and sort of what the state of play is in terms of being able to remove PFAS firefighting foam from the environment?

Ms. HENDERSHOTT. Absolutely. Great question. Thank you, Representative Kildee. So, you know, as I said, Michigan's been collecting—we've collected over 51,000 gallons of PFAS containing AFFF. But, as Ms. Dindal said, you know, the research on a fluorine-free—truly fluorine free foam is still in the process, so we need to do better than what we've got right now for Class B while the research continues. I think there needs to be measures to look at what is truly fluorine-free, what's the next best thing until we can get that research. It's unfair for us to collect the Class B firefighting foam, and then not give additional—or additional options to our firefighters that are out there on the first lines, and it's really—my thoughts are to make sure that they're, one, protected, that we're not exposing them to the Class B AFFF anymore, but also that they have appropriate measures for replacement.

And I don't know that we're quite there yet, but there are best management practices that we can put in place so that when they do have to use it, environmental cleanup is done quickly, it's contained, and we want to minimalize the use of it as much as possible.

Mr. KILDEE. Well, thank you so much, Ms. Hendershott for your testimony, for the answer, but especially for the great work you're doing. I'm proud of the way the State of Michigan has taken this challenge on.

I want to quickly turn, if I could, back to—Dindal. I was really taken by your testimony, and particularly Mr. Gonzalez's questions, about the use of this technology that you've been developing when it comes to treatment of groundwater, particularly as it might work in concert with GAC filtration. Can you help me understand sort of the cost and scalability? I know you've mentioned the scalability to be able to get to, say, a 5,000 gallon per day threshold, but help me understand what the all-in costs of this might be once taken to scale, as compared to the cost of implementing GAC filtration, which has been a limitation in some—and I know this is the case in Oscoda, in our ability to sort of take this on at scale. Could you address that?

Ms. DINDAL. Yes, I can, and thank you for your leadership with the bipartisan PFAS Task Force. It certainly has been impactful. And I appreciate your question. We are certainly focused on bringing forward an economically viable solution, because we know that if the technology is not affordable, it won't be adopted. And we have been evaluating costs of current demonstration projects. We will be doing that as part of our current demonstration projects with DOD as we look at the scale, and what the costs will be involved. That will provide cost data on the implementation in a real world scenario, as the cost could vary from site to site, depending on the site conditions.

I will say that EPA did cite some costs to dispose of AFFF in a recent publication, and it was on the order of $28 per gallon, so we certainly understand that that's an unsustainable cost, and we want to be able to provide the most cost-effective solution possible.

Mr. KILDEE. Well, thank you for that. Thank you all for your work. An excellent hearing, with excellent witnesses. I yield back.

STAFF. Mr. Foster is recognized.

Mr. FOSTER. Thank you. Am I audible and visible here?

The STAFF. You are, sir.

Mr. FOSTER. OK. Well, first off, of immediate concern here, for I guess Ms. Dindal, is water-borne PFAS destroyed by putting it through a coffee machine?

Ms. DINDAL. By putting it through a coffee machine?

Mr. FOSTER. Coffee machine, yes. Yes, I mean—or do you need the supercritical pressure, as—and the other additives to actually destroy the chemical, in addition to the heat and boiling temperatures?

Ms. DINDAL. Yes, sir, the technology is based on supercritical water oxidation, which indicates that it is—at a certain pressure and temperature it becomes in the supercritical state——

Mr. FOSTER. Sure, yes.

Ms. DINDAL [continuing]. And then an oxidant is added in order to break the C-F (carbon-fluorine) bond.

Mr. FOSTER. OK. All right. Now, you know, I'm struggling with the biotoxicity thresholds for all these things. We had an issue in my district having to do with ethylene oxide, where it—there was a huge amount of uncertainty about what the safe concentration is. And, you know, there's obviously a wide variety of PFAS compounds, and I would not be surprised to find orders of magnitude differences in the safe concentrations of those different compounds. And—so my question, I guess, to Dr. Jaffé, or whoever wants to handle it, what would a systematic program to actually identify the biotoxicity thresholds of all the different compounds, or at least the most important ones, what would that look like, and the rough time scale and dollar cost? Whoops, I think you're muted, if you're——

Dr. JAFFÉ. Sorry, thank you. Thank you for the question, and I was saying I'm probably the least qualified to answer this question because I'm not a toxicologist, but what we need to understand is how toxicology is linked to molecular structures. Instead of looking at a molecule at a time, how can we sort of find groups that are toxic, and which ones we have to be concerned about that? As I mentioned earlier, there are 4,700 PFAS, and it's hard to look at them one by one. So look at the molecular structure, see what part is of concern, what part is toxic. And I——

Mr. FOSTER. Ms. Sunderland, do you want a——

Dr. JAFFÉ. Yes.

Mr. FOSTER [continuing]. Shot at that?

Dr. JAFFÉ. Thank you.

Dr. SUNDERLAND. Thank you. That's an excellent question. I think the first point I would make is that we actually don't have any kind of health information available for the majority of these compounds. And Dr. Jaffé mentioned the 4,600 plus, which has recently been upgraded to 9,000 plus potential structures, so there's a big challenge here where we only have actual data for a few of these compounds, and certainly the health outcomes associated with exposures to those compounds are quite different. So we have a few well studied PFAS, we have many that we need to consider. There are programs at EPA which are looking at this, so things like the ToxCast Program, high throughput screening, linking some of these detection methods to toxicological assays. These show a lot of promise, and I think we could leverage from these. There are some great people at EPA working on these programs.

I also think we have to think about this idea of mixtures. So the—you know, do we want to think about health impacts associated with PFAS one by one, or do we want to think about it in the way that's relevant to how we're exposed to these compounds? So we may get a certain mixture of PFAS through AFFF exposure, we're going to get a different mixture of PFAS compounds through consumer products, and diet, and other pathways, so this kind of research is really important. NIH has some important research going on in this area. It's an area, I think, that research needs to be supported to get some of those answers to that important question you just asked.

Mr. FOSTER. Yes. I—has anyone gone through and tried to generate a scope—a project scope and estimate for really nailing this? Or is it simply impossible, because ultimately what you need are long-term human exposures, which is not something that we're willing or eager to do?

Dr. SUNDERLAND. Certainly there's some data. I think that part of the limitation right now on the health side is actually detection, so characterizing—you know, the chemistry is so interwoven with understanding the health outcomes that, until we know what, you know, what the exposure vector is, it's difficult to say, you know, comprehensively an answer to your question. I think there certainly are preliminary data on this that provide a partial answer to your question, but we haven't nailed it, as you say, so it's something that we need to keep looking at. There's some great work going on at NIH right now also with animal models, looking at some of these——

Mr. FOSTER. Yes. But those are limited to short term, very high concentrations, and I know in the ethylene oxide thing, you know, what we were interested in is long term, very low concentration exposures, and the important question of is there an—actually a biologically safe dosage of this which completely controls the cost of mitigation that you get to? So it's a—anyway, thank you, and I yield back.

STAFF. Ms. Wild is recognized.

Ms. WILD. Thank you so much, and thank you, Madam Chair. I appreciate the testimony of our witnesses today to illustrate the work that we still need to do to understand and address PFAS risk. Earlier this year the Pennsylvania Department of Environmental Protection conducted surveys of more than 400 sites across the Commonwealth of Pennsylvania suspected to have PFAS contamination, and found at least one PFAS chemical in a third of those tested sites. The State is now moving forward to protect our drinking water with a limit on PFOA and PFOS, two common types of PFAS, to ensure that the more than 3,000 water systems across Pennsylvania measure and limit the—these chemicals to no more than 14 or 18 parts per trillion, respectively. But, as our witnesses have noted, there are so many more research questions, including how we can also assess our air quality, understand impact on our health, or detect any kind of PFAS chemical.

So I'd like to start—Ms. Hendershott, in your testimony you mentioned that Michigan developed water quality standards for PFOA and PFOS, using both expertise in the State, and with support from national experts. And, of course, as a representative in Pennsylvania, where we are taking these initiatives, where our Governor and his administration are taking these initiatives, I'd love to know what went well, in terms of the collaboration between State experts in Michigan and those at the national level, and any recommendations that you might give to leaders in my State as they move forward with a similar standard?

Ms. HENDERSHOTT. I think the recommend—the biggest recommendation would be to continue to collaborate, gather the best available science, and make sure we're making the right assumptions. You know, we did a great job of communicating both with our internal experts and the external national experts, but even in two years the science is rapidly changing. There's so much more that we know today than we did two years ago, when we started that process. And so I think gathering as many of the national experts together, to really give you the best available science—because once these things are set, obviously, it takes a lot longer for us to change MCLs than the science does to improve our understanding and knowledge. So just making sure we're working with the best available modeling, and the best available human health outcomes, as Dr. Sunderland was talking about, is really, really important for us.

Ms. WILD. Well, thank you. And I will tell you, and this is for the whole panel, when I started running for Congress, before I was even elected, one of the very first community groups I met with were from a region in my district with—that has very serious PFAS concerns and contaminants, and so this is something I've been hearing about from the beginning. I've—you know, and it continues that I hear about this from my constituents. And—so I really appreciate the testimony today.

I want to make sure that I have good context for my constituents, and anyone else learning about this topic, to understand the current science. And so, Dr. Sunderland, and then any body else who would like to answer, how should we, as Members, talk about this issue in our districts with concerned constituents, and perhaps with constituents who don't—have never heard of PFAS, don't know what it is, and don't know what the possible impact could be? That was for Dr. Sunderland, as——

Dr. SUNDERLAND. Yes. Thank you for the question. And I think, you know, the way I approach interactions with communities is to first ask them, I guess, what they're concerned about most. And you've mentioned that there are community members who've already expressed concerns, so I think listening to the things that people are concerned about. In my experience, you know, the general population is concerned about ways that they were exposed through consumer products, and providing helpful tips on how to reduce their personal exposures, if they're concerned about it.

I think balancing these risk messages is really important, so we, you know—and there's been a lot of concern among the Federal agencies about creating a sort of frenzied climate of fear around these chemicals, and what we're instead trying to do is say, OK, well, you know, if this is something of personal concern, here are ways that you can reduce exposures. And then, for those populations that we know are already at risk, we're doing our best to find some of the technologies and some of the solutions for reducing those exposures in the very short term. So that's, I guess, where I'd start. I'd welcome input from others on that conversation as well. Thank you.

Ms. WILD. Well, thank you, I appreciate that. I'd love their input too, but, unfortunately my time is up, as is so often the case in these hearings. But thank you very much, Dr. Sunderland. Thank you to the entire panel.

Chairwoman SHERRILL. I just want to echo that. Thank you so much to our witnesses for testifying before the Committee today. Unfortunately, I need to step away, so Representative Stevens will be taking the Chair for the remainder of the hearing. Thanks so much.

Ms. STEVENS. So be it. Now we'll recognize our next witness. Who do we have in the queue, please?

STAFF. Mrs. Fletcher is recognized.

Ms. STEVENS. Ms. Fletcher.

Mrs. FLETCHER. Thank you so much, Chairwoman Stevens, and, of course, to Chairwoman Sherrill, who just left, as well as to everyone who's here today. Really grateful that you're holding this important hearing, and very grateful to our witnesses for taking the time to testify on this important topic today. Some of my questions relate to things that I have already heard some of my colleagues ask, which I think, to me, just underscores the importance of some of the issues that we've been focused on in our Committee. And, of course, want to thank my colleague Dan Kildee for his work on the PFAS Task Force, which I'm very glad to be a part of as well.

And some of his questions about the firefighting foam relate directly to some of my concerns that got me involved and interested in this topic when we had a very large chemical fire in the Houston Ship Channel, right outside of my district, and we were very focused on the PFAS in the firefighting foam used to fight those very difficult fires to put out, and the resulting PFAS contamination that we found down into Galveston Bay. So a lot of concerns in my community, as are people across the country concerned with these issues, and so I'm really grateful for your insights today.

Last year I introduced a bill, in the last Congress, and it's the *Federal PFAS Research Evaluation Act,* and that will direct EPA to work with the National Academies to conduct a series of research studies on PFAS. The studies in my bill would advance the research on human exposure and toxicity hazard estimation, as well as the environmental hazards and treatment of PFAS contamination. So I really appreciate the insights that I've already heard from our witnesses on these issues, and—to help us really further refine this bill, and this effort, before reintroducing it in this Congress.

So I guess maybe, with the time I have, I'd love to just put this question generally out to all of you to weigh in on how comprehensive studies to identify research gaps, and help advance the field of PFAS research and development, could be useful. And maybe if you could just share your thoughts on the types of questions you think that these kind of studies should tackle? Maybe I'll just start—I'd love to hear from all of you. Maybe I'll start with Dr. Sunderland, since you mentioned in your testimony that threat exposure research falls under the mandate of the EPA. Could you elaborate on the type of exposure research EPA should conduct, and then, again, what kinds of questions you think studies about the gaps could tackle?

Dr. SUNDERLAND. Yes. Thank you very much for that important question, and for asking that. I think for EPA, and for this general theme of exposure research, we just—you know, we basically need studies that systematically look in a representative way for different populations across the country at what the exposure sources and pathways are. And, believe it or not, that is missing for the majority of individuals.

So we have—you know, we've talked a lot about contaminated drinking water, and I think because we've recognized that as a problem, and because the States have been so proactive about that, we've made a lot of progress on both understanding concentrations in drinking water across the country, and also understanding, you know, who's exposed and who's at risk. So that's wonderful, that's a great success. Unfortunately, we don't have a comparable research program for things like dietary exposure. There's, you know, some preliminary work from FDA, but it's not statistically representative of the U.S. population and different demographic groups.

And this is where EPA really has a specialty, so, if given the mandate to do that kind of work in a—you know, the key here is in a representative way for the whole—you know, for different demographic groups in the population. So I'm thinking of something analogous to what the CDC does with NHANES (National Health and Nutrition Examination Survey), but from the exposure perspective for PFAS. So I would love to see that kind of work. It's not inexpensive, so it would have to be a partnership, probably, with CDC, ATSDR, and EPA, but it would fill, in my mind, a big gap in knowledge that's so important for really taking those risk mitigation actions now, and that's really ultimately what people are most concerned about, because they're asking all of you, you know, what should I do, how do I reduce my exposure? And we can tell people in contaminated communities we can provide an answer, but not elsewhere. So thank you for that question.

Ms. STEVENS. Congresswoman Fletcher, we're losing you. You've got to unmute.

Mrs. FLETCHER. Well, I used up my time, so thank you, Chairwoman Stevens. I was going to say, since I was coming to the end of my time, I would love it if any of our other witnesses would submit an answer to that question for the record after the conclusion of the hearing. I——

Ms. STEVENS. Fabulous.

Mrs. FLETCHER [continuing]. Appreciate it, and I appreciate all of your testimony. Thank you again, Chairwoman Stevens. I yield back.

Ms. STEVENS. Fabulous. And, for the good of the order, do we have anyone else in the queue for questions right now, Members for questions?

STAFF. No, we do not, Ms. Stevens.

Ms. STEVENS. OK. I thought we had that accurately. Well, thank you so much to our witnesses for your expert testimony. Several Members have already recognized that they'll be submitting questions for the record. Clearly PFAS remains a topic of the day, a topic of our time, and this Committee will remain very dedicated to the R&D efforts, as well as the environmental implications, in terms of how we remediate PFAS, how we identify PFAS, and how we prevent the worst of its impacts.

And certainly we are one exclusive Committee in the Congress, but you can—when we talk about a whole of government approach, and you talk about the multitude of agencies that will involve this work, we also recognize that we've got to take an all of Congress approach, and that we will have this Committee, and Energy and Commerce, and certainly some of the other regulatory effects that need to be addressed here. And we're always in favor of, you know, the agencies that we have direct oversight over, particularly NIST, in terms of their public/private partnership and advisory approach.

The EPA as well is going to play, you know, obviously an oversized role, so we look forward to the dialog. We salute your work.

And, with that, the record's going to remain open for two weeks for these questions for the record, all right? So Members are going to have time to submit those, and we'll get back to you—or look forward to hearing back from you. But, with that, the Committee will be adjourned, and thank you all so much.

[Whereupon, at 12:01 p.m., the Subcommittees were adjourned.]

Appendix

ANSWERS TO POST-HEARING QUESTIONS

ANSWERS TO POST-HEARING QUESTIONS

Responses by Dr. Elsie Sunderland

Questions for the Record to:
Elsie M. Sunderland
Gordon McKay Professor of Environmental Chemistry
Harvard John A. Paulson School of Engineering and Applied Sciences
Harvard T.H. Chan School of Public Health
Submitted by Chairwoman Eddie Bernice Johnson

Dr. Sunderland, in your testimony, you discussed the concept of essential uses of PFAS. You also mentioned there are areas where PFAS can be phased out, and you gave the examples that some countries are phasing out the use of PFAS in food packaging.

1. Can you explain the concept of essential uses of PFAS? What is the importance of such a standard/definition? What PFAS are considered to be of essential use today?

The concept of essential uses of PFAS argues that we should stop using these chemicals when they are not essential to the function of a product or when safer alternatives exist.[1] This approach draws from the example set by the Montreal Protocol, where CFCs were eliminated due to their harmful impacts on the ozone layer, except in cases where they were "necessary for the health, safety or functioning of society" and where "no technically and economically feasible alternatives" existed. This definition is important for PFAS because it provides a framework for reducing uses, environmental releases, and exposures to protect public health. Members of the research community have defined three essentiality categories for PFAS to aid in decisions regarding their phase-out. These are: "non-essential" uses that are not necessary for the health, safety and functioning of society and are driven primarily by market opportunity. The second category is "substitutable" uses, where safer alternatives with the same functionality are available. The final category is "essential" uses that cannot be phased-out at this time. Essential uses of PFAS include things like medical devices, occupational protective clothing, and certain uses of aqueous film forming foams (AFFF).

2. In addition to food packaging, where else do you believe we could reasonably phase-out the use of PFAS-containing products in favor of suitable alternatives?

Safer alternatives to PFAS can be found for almost all consumer applications such as dental floss, cosmetics, outdoor gear, carpets, furniture coatings, ski waxes, and others.

3. Are any PFAS safe? How do we know?

In my opinion, "safe" is a bit of a misnomer because almost every activity we undertake, such as driving our car to work, carries some risk. With the use of PFAS in products, we must decide whether the benefits of their use outweigh any risks incurred. I think for well-studied PFAS, it is becoming clear that most uses cannot be justified in this way and are not "essential" as discussed above. Further, we have little to no information on the majority of PFAS in our products today and presently the burden of proof is on affected individuals, communities, and regulators to show

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[1] Definition and response paraphrased from the article by Cousins, IT et al.: The concept of essential use for determining when uses of PFASs can be phased out.

that they cause harm. I believe a better public health protection strategy would be to use the precautionary approach and regulate these chemicals as a class, leaving it to industry to prove that certain PFAS do not cause appreciable risks to public health, thereby reversing the burden of proof. Their persistence alone is cause for concern.

Questions for the Record to:
Elsie M. Sunderland
Gordon McKay Professor of Environmental Chemistry
Harvard John A. Paulson School of Engineering and Applied Sciences
Harvard T.H. Chan School of Public Health
Submitted by Representative Bill Foster

Dr. Sunderland, In your testimony before the committee, we discussed some of the research that's already looking into biotoxicity threshold of the different PFAS compounds. Due to the sheer number of PFAS compounds and differences in their biotoxicity, the reality that we only have this data for a few of these compounds, and our need to also look at how we are exposed to combinations of PFAS in the environment, you highlighted the need for further research to address all of these issues.

1. If you were to design a program to actually define the biotoxicity thresholds of all PFAS compounds, what would that program look like?

This is a difficult question. Analytical standards are needed for such studies and they are not presently available for the majority of PFAS used in products and by industry. Indeed, many of the PFAS in use are considered "confidential business information" and can only be detected by forensic chemistry studies that use sophisticated mass-spectrometry methods so this would be a key starting point. For example, information on PFAS used in manufacturing for DOD is difficult to obtain.

There are a growing amount of epidemiological and animal data that could be used to rank PFAS with analytical standards by their relative toxicity, similar to the "toxic-equivalency factor (TEF)" approaches used for some other chemicals like dioxins. A priority list of additional actions could include indentifying unknown individual PFAS in samples, high throughput toxicity testing of more PFAS, read-across and other methods to estimate toxicity of compounds with little or no data, and guidance on how to apply these methods.

2. Would it include systematic research such as automatic screening, cell culture and organoid studies, community exposure, health databases like national cancer and birth defect registries, and programs allowing people to contribute their electronic health records to science postmortem?

High-throughput screening using cell-based assays (e.g., activation of key cellular receptors) and organoids would make a lot of sense. Some of this would need to be reinforced by whole animal testing but again none of this is possible without reference standards. Systematic research only works for well-researched PFAS, which are only a small fraction of the thousands potentially out there. We need toxicity testing of not just individual PFAS but mixtures as well. But as the number of possible mixtures is astronomical, research should focus on methods for predicting the biological effects of PFAS mixtures along with validation studies: TEF systems are one possible example but there are other approaches that should be considered as well.

Epidemiological data are needed to determine the impact on human health in the long run, but they are very expensive and take a long time to develop. Information is thus available after the fact and less preventative as a result. Epidemiological data on both the general population and at contaminated sites would be needed for such an analysis.

3. What would the rough price scale of such a program be, and what would be an achievable timeline to get it done?

I think the first question might be how expensive it is not to do this. Fixing things after the fact is likely to be more expensive than preventative actions. For timeline, I think this is an urgent issue that needs to be addressed as quickly as possible. We have taken definitive actions for a few legacy compounds and seen rapid declines in environmental concentrations and human exposures. Unfortunately, these declines also resulted in replacement in product streams with other PFAS with unknown health impacts. We need to end this regrettable substitution cycle.

4. Are there existing federal programs that are already attempting to do all or part of this, and could their input be combined to help achieve this goal faster?

Absolutely. EPA's Center for Computational Toxicology and Exposure is an excellent resource as well as NIH's effort on toxicity testing. However, both efforts could use additional support. On the analytical chemistry and standards side, EPA, CDC, and NIST are well-positioned to provide support and could partner with NIH if the political support and other resources were in place.

5. If it is within your area of expertise, have efforts been made to implement this kind of effort to chemicals outside of PFAS?

The present challenges we face with PFAS in society are a microcosm of those faced by the chemical industry as a whole. There are substantial efforts underway at EPA and NIEHS to screen and rank chemicals based on their potential for adverse exposures and toxicity. These efforts can be leveraged here.

Questions for the Record to:
Elsie M. Sunderland
Gordon McKay Professor of Environmental Chemistry
Harvard John A. Paulson School of Engineering and Applied Sciences
Harvard T.H. Chan School of Public Health
Submitted by Representative Deborah Ross

1. **Dr. Sunderland,** do you believe granular activated carbon is an effective control technology for PFAS contamination? If so, what impediments prevent it from being implemented on a broad scale?

My understanding is that granular activated carbon (GAC) is effective for treating PFAS with more than four perfluorinated carbons but that it does not capture some of the shortest chain PFAS and some of the novel compounds. Some of the impediments for implementation on a broad scale include slow adsorption of PFAS so large quantities of GAC are needed to treat substantial water flows. For maintenance, GAC needs to be regenerated approximately twice a year, which can be labor intensive and costly. GAC is also very temperature sensitive, which can result in less effective treatment at higher temperatures. Overall, I think GAC is one of the best options for PFAS treatment at AFFF contaminated sites but it is very expensive and the costs of treatment are being passed on to consumers rather than the polluting industry. This does not seem appropriate to me.

2. **Dr. Sunderland**, Section 4 of the Toxic Substances Control Act (TSCA) gives EPA broad authority to require industry to fund health and environmental effects studies on chemicals they have manufactured and introduced into the environment. EPA's TSCA Section 4 authority includes the express authority to order PFAS manufacturers to conduct studies on chemical mixtures and to order funding of epidemiological studies of exposed communities. In October 2020, several North Carolina groups filed a TSCA petition with EPA to require Chemours to fund health studies on 54 PFAS released for decades from its facility in Fayetteville. The petition also seeks to have Chemours fund studies of the mixture of PFAS chemicals that Cape Fear communities have been exposed to in their drinking water and to fund animal studies that would provide the needed answers to the potential human health effects of exposure to these PFAS chemicals.

    a. How will the EPA using its TSCA Section 4 authority to order Chemours to fund studies on the unique mixture of PFAS chemicals from its Fayetteville facility and to fund an epidemiological study and exposed communities provide invaluable information to the exposed communities and their doctors help fill data gaps in PFAS research?

These data will be essential for understanding the public health impacts of PFAS releases from the Chemours facility and will hopefully result in some further ideas for risk-mitigation in affected communities.

b. Why is it important for EPA to have epidemiological data from communities that have been exposed to PFAS for decades, such as the Cape Fear Communities in North Carolina?

It is essential that we understand the impacts of chronic exposures to PFAS over different life stages rather than just cross-sectional studies that capture a particular point in time. Some of the health endpoints associated with PFAS exposure, such as cancer, have a long latency period between exposures and observed impacts so if we truly want to understand the public health effects of exposure these studies are essential.

c. Why is it important for EPA to have information on the human health effects of PFAS mixtures, especially mixtures that reflect the mix of PFAS that a community has been exposed to in their drinking water for decades?

Exposures to PFAS occur as mixtures rather than individually. We currently have very little data on the toxicological impacts of PFAS mixtures and it is an essential area for further research. It is possible for mixtures to have measurable biological effects even if individual compounds do not at the same concentrations, a phenomenon some called "Something from Nothing." Presently, we typically assume impacts are additive but for other chemicals we have noted synergistic effects that result in greater harm than the sum of individual exposures. Therefore I believe such research is essential.

<u>Questions for the Record to</u>:
Elsie M. Sunderland
Gordon McKay Professor of Environmental Chemistry
Harvard John A. Paulson School of Engineering and Applied Sciences
Harvard T.H. Chan School of Public Health
Submitted by Representative Paul Tonko

Earlier this year, I was incredibly pleased to see the strong action taken by Administrator Regan and the EPA on PFAS, including the establishment of the PFAS Strategic Roadmap. The Roadmap, as you know, is built on three principles - research, restrict, and remediate.

1. **Dr. Sunderland**, are there any unappreciated sources of exposure to PFAS that the EPA should be addressing?

I believe a collaboration between EPA and FDA in the area of dietary PFAS exposure in the U.S. food supply would be very fruitful. Such joint efforts have been very effective for disseminating consistent advice to the public on things like fish consumption advisories so I believe such a collaboration would be very effective here as well. I also think further research on dermal absorption of PFAS is needed given their prevalence in consumer products such as cosmetics. Further, we have preliminary data on PFAS in the indoor environment and dust suggesting this is a substantial source of PFAS exposure for the general public, yet we lack systematic data in this area. We need studies of total exposure to PFAS in general populations examining the relative importance of these pathways. Again, EPA would be ideal to lead such research.

2. You spoke to the complexity of considering each PFAS chemical individually. I believe it is necessary to regulate these chemicals by class or by category. What are the primary R&D investments needed to figure out how to evaluate, monitor and regulate PFAS chemicals in classes or groups?

I think some of the current challenges to regulating PFAS as a class are grouping them into different toxicological and physical/chemical categories when basic information is missing for so many of the ones in our product stream. Further, there is ongoing debate about how to define PFAS as a class of chemicals - which has implications for developing such regulations. So, most importantly, I think political leadership and direction is needed for pursuing the class approach to these chemicals. The research community has already developed a range of analytical methods for measuring total organofluorine in consumer products and these could be used to support such efforts. Some standardization and intercomparison of these methods by NIST, in partnership with the EPA, would be very helpful. For aquatic systems, this approach is more difficult given high concentrations of fluorinated pharmaceuticals from wastewater streams in many surface waters. Here, a definition of what constitutes a PFAS is needed and perhaps some sort of toxic equivalency conversion relative to the PFAS we have studied intensively like PFOS and PFOA for the remaining organofluorine compounds. This could be established conservatively with a margin of safety and a stipulation for more detailed analysis of the composition of samples if high concentrations were detected.

3. I understand that even when PFAS contamination is identified, addressing it is difficult and expensive. What are some of the main barriers to effective remediation of PFAS contamination?

I think the greatest challenge to PFAS remediation occurs when contaminated sites are left untreated for decades. When this happens, the impacted area becomes much more diffuse and difficult to treat so the first practical thing would be to treat newly affected areas right away. For legacy PFAS contamination, a lot of the research is showing that most of the chemical mass still resides in contaminated soils and sediment that serve as source to groundwater - thereby affecting drinking water supplies. Although it is very expensive, I believe the best option in this case is to treat and remediate the affected soils directly. R&D efforts underway to support such efforts are commendable and should continue to be supported.

Responses by Ms. Abigail Hendershott

WRITTEN TESTIMONY

OF

Abigail Hendershott
Executive Director, Michigan PFAS Action Response Team (MPART)

HEARING ON

"Forever Chemicals: Research and Development for Addressing the PFAS Problem"

Committee on Science, Space & Technology
Subcommittee on Environment & Subcommittee on Research and Technology
U.S. House of Representatives

December 7, 2021

ADDENDUM

Questions for the Record to:

Abigail Hendershott
Executive Director
Michigan PFAS Action Response Team (MPART)
Submitted by Representative Deborah Ross

1. ***Ms. Hendershott**, EPA recently issued its toxicity assessment for GenX, which concludes that these PFAS chemicals cause serious liver and other adverse health effects and sets a Reference Dose for chronic exposure that is well below GenX levels in many samples of drinking water downstream of the Chemours plant in North Carolina. In the GenX assessment, EPA underscored the lack of data on several critical end-points necessary to determine their health impacts on exposed communities. These GenX chemicals are included the October 2020 North Carolina PFAS Testing Petition, which asks EPA to require Chemours to conduct the very studies that the GenX assessment finds are essential for public health protection. Do you agree that EPA should exercise its TSCA authority to order Chemours to fill the data gaps identified in the GenX toxicity assessment?*

Answer:

The EPA should be encouraged to use all appropriate regulatory authorities to obtain the necessary toxicological data needed to fully understand the effects of GenX on public health and the environment.

Questions for the Record to:

Abigail Hendershott
Executive Director
Michigan PFAS Action Response Team (MPART)
Submitted by Representative Paul Tonko

Earlier this year, I was incredibly pleased to see the strong action taken by Administrator Regan and the EPA on PFAS, including the establishment of the PFAS Strategic Roadmap. The Roadmap, as you know, is built on three principles - research, restrict, and remediate.

1. ***Ms. Hendershott**, what kinds of collaborations or research might be helpful to prevent PFAS from polluting our land, water, and air in the first place?*

Answer:

MPART is encouraged by the actions laid out in the EPA PFAS Roadmap and the goals for coordinated and cooperative cross-agency efforts to develop improved tools to address PFAS as announced by the Biden Administration in October. A national, science-driven effort to support states and communities dealing with PFAS contamination will help to bring additional knowledge and support to PFAS investigations and cleanups and will ease the burden on states to develop state standards for drinking water and groundwater, as Michigan has done. Expanded, cross-agency research into PFAS remediation and treatment technologies, as well as investigation and guidance regarding PFAS in the food supply, will also help states better protect residents, consumers, and producers.

The announcements regarding federal efforts to improve the understanding of how PFAS impacts the environment and human health are encouraging for states like Michigan and our fellow Great Lakes States that are already hard at work to conduct needed research with limited resources. Michigan urges all federal agencies working on furthering the understanding of PFAS to coordinate with states to maximize the impact and utility of federal PFAS research and synergize the response actions across our country. Michigan also urges federal agencies that have PFAS-contaminated properties to be leaders for the nation by expeditiously cleaning up these sites – even in the absence of perfect science. We cannot let imperfect information hold up the responsibility of protecting our citizens and natural resources today.

While there are numerous research and development areas where federal funding and studies will be helpful, I want to highlight a few examples of real-world areas where focused research and development can have a real benefit in Michigan and all states.

First, there is a real need for additional studies of PFAS in the food supply to understand how PFAS enters and affects the food supply and potential health risks from PFAS in food. Standardized testing methods are needed for crops, livestock, and food products to provide producers and consumers with useful and consistent information and to build the data set needed to begin establishing health-based standards for food.

Second, the use of PFAS-containing firefighting foam, also known as aqueous film forming foam, or AFFF, results in dispersal of PFAS into the air, surface waters, soil, and groundwater. As long as military, airport, and civilian fire departments use PFAS-containing AFFF, these negative consequences will continue to impact surrounding communities, particularly in areas where residents rely on groundwater as a source of drinking water.

As Michigan tackles the job of identifying sites of PFAS contamination, the even larger challenge is identifying a cost-effective way of remediating the PFAS-impacted groundwater, soils, and sediments in place without large removal efforts.

While these studies are expected to yield important data, additional federal support is needed to further expand on our knowledge of the toxic effects of more of the thousands of PFAS in the environment.

Finally, to help predict how PFAS will impact people and resources after being released into the environment, scientists need to know more about the unique ways that PFAS behave in the environment.

2. *I understand that even when PFAS contamination is identified, addressing it is difficult and expensive. What are some of the main barriers to effective remediation of PFAS contamination?*

Answer:

Michigan supports development of new and improved remediation techniques to enable long-term, cost-effective treatment of PFAS, including sequestration, foam fractionation, and destruction technologies. For our Great Lakes State, the remediation of our water is critical to the well-being of our ecosystem and the well-being of our communities and economy.

Barriers to effective remediation may include treatment technology that is economically feasible; scalable for large areas; effective for full defluorination of all PFAS; and practical to implement, design, and operate.

WRITTEN TESTIMONY

OF

Abigail Hendershott
Executive Director, Michigan PFAS Action Response Team (MPART)

HEARING ON

"Forever Chemicals: Research and Development for Addressing the PFAS Problem"

Committee on Science, Space & Technology
Subcommittee on Environment & Subcommittee on Research and Technology
U.S. House of Representatives

December 7, 2021

ADDENDUM #2

June 30, 2022

Questions for the Record to:

Abigail Hendershott
Executive Director
Michigan PFAS Action Response Team (MPART)
Submitted by Representative Bill Posey – 6/26/2022

1. **What are the most critical research needs that will help advance the treatment and remediation of PFAS contamination at DOD facilities like Patrick Air Force Base in my district?**

   Answer: Michigan has a number of DOD facilities that have been actively involved in PFAS investigation and characterization of their groundwater, soils and surface water. MPART would encourage the committee to talk directly to the DOD project staff to determine the most critical needs for the PFAS mitigation and remediation.

2. **The U.S. Geological Survey (USGS) has played a pivotal role in water resources research throughout their history. Can you please tell the committee what you know about USGS efforts to study PFAS presence and transport in surface and ground waters and what more we might ask them to do to contribute to closing gaps in PFAS R&D?**

   Answer: USGS worked with MPART on smelt sampling and provided input on our passive surface water sampler studies. USGS is currently conducting a study in Lake Superior and select tributaries to assess contaminants of mutual concern, including PFAS, in surface water and sediment. MPART provided comments on that draft work plan and suggested sampling locations. We anticipate implementing additional projects with USGS in the future.

3. **Some of the testimony provided today suggests that recent scientific research may offer some hope for developing successful biodegradation strategies for treating and remediating PFAS contamination. Can each of you please evaluate this possibility and comment on whether Congress should work toward providing a priority and more resources for such research?**

   Answer: Michigan supports development of new and improved remediation techniques to enable long-term, cost-effective treatment of PFAS, including sequestration, foam fractionation, and destruction technologies. For our Great Lakes State, the remediation of our water is critical to the well-being of our ecosystem and the well-being of our communities and economy.

4. **Please provide a brief description of a science-based strategy for remediating PFAS at DOD facilities like Patrick Air Force Base. In your statement, please include a short-term response to expedite near term remediation based on available technologies and a longer-term strategy that will depend on improved techniques that are developed by the scientific community. In short, how should remediation best proceed in the short and long-term and provide for expedited treatment and remediation?**

   Answer: A defensible, science-based approach for all facilities with PFAS contamination starts with robust characterization and a clear understanding of current site conditions, including groundwater, surface water, sediment, and soils concentrations. Once characterization is understood, then an evaluation of all available remedial technologies can be made to determine the appropriate remedy for short- and longer-term response actions. Most DOD facilities have multiple source areas over many acres that require rigorous investigation to fully characterize the complexities of the fate and transport of PFAS across the facilities.

Responses by Ms. Amy Dindal

Questions for the Record to:
Amy Dindal
Director of Environmental Research and Development,
Battelle Memorial Institute
Submitted by Representative Deborah Ross

1. **Ms. Dindal**, as we consider how to further control PFAS, one question that has arisen involves how different technologies work on different PFAS. Are there technologies available or in development that work on a broad spectrum of PFAS?

Ms. Ross, supercritical water oxidation (SCWO) is a technology that breaks the C-F bond and works well for a broad spectrum on PFAS. SCWO is not a new technology, as it has been used since the 1980s to address difficult to treat compounds. What is new is the application and optimization of the technology for PFAS. Battelle's technology based on SCWO is called "PFAS Annihilator™," as it destroys PFAS in contaminated water to non-detect levels in seconds, leaving inert salts and PFAS-free water behind. Once the treated water has been tested to confirm that the PFAS have been destroyed, it can be safely discharged back into the environment. The PFAS Annihilator™ is ready for deployment today and is effective on the broad spectrum of PFAS and other co-contaminants. In addition to reducing liability, destroying PFAS to the lowest levels of detection ensures compliance, regardless of regulatory limits.

Questions for the Record to:
Amy Dindal
Director of Environmental Research and Development,
Battelle Memorial Institute
Submitted by Representative Paul Tonko

Earlier this year, I was incredibly pleased to see the strong action taken by Administrator Regan and the EPA on PFAS, including the establishment of the PFAS Strategic Roadmap. The Roadmap, as you know, is built on three principles - research, restrict, and remediate.

1. **Ms. Dindal**, what are some of the main barriers to effective remediation of PFAS contaminants?

Mr. Tonko, PFAS chemicals are mobile, bioaccumulative, and persistent. Large contamination areas, coupled with the recalcitrant nature of the C-F bond, adds technical challenges and potentially high cost for approaches to treating entire plumes. Environmental behaviors for PFAS are not consistent with other organic contaminants, which means they are likely to require new technologies for effective site characterization and treatment. The presence of co-contaminants also can complicate fate and transport behavior. In addition, past treatments at a site may have unknowingly negatively impacted the PFAS contamination. Taking an aggressive approach to field promising technologies will prove those technologies that are fieldable solutions. Those that do not succeed in early attempts will 'fail fast' and have an opportunity to address shortcomings. It is essential to test technologies under multiple site conditions as there can be significant variations in geology and contaminant composition from site to site, which can impact technology performance. Comprehensive technology performance data will increase confidence in these new approaches and ultimately accelerate cleanup timelines.

Questions for the Record to:
Amy Dindal
Director of Environmental Research and Development,
Battelle Memorial Institute
Submitted by Representative Randy Feenstra

1. **Ms. Dindal**: The State of Iowa's Department of Natural Resources has been active in staying on top of the PFAS issue. They put together an action plan for the issue two years ago, and in recent months have done sampling for PFAS in public drinking water at sites across the state using current technologies. I have been told that the results coming back from public sites are reassuring, and PFOS and PFOA have only been detected in one location. And those concentrations are well below the EPA's health concern threshold of 70 parts per trillion.

Mr. Feenstra, thank you for sharing this information. Please let me know if Battelle can be of assistance to the Iowa's DNR.

2. Much of the responsibilities of tracking and containing PFAS contamination could likely fall on state government, local governments, and municipal utilities as more is learned. Cost-effectiveness is a large concern for these types of organizations. What current and future technologies being researched at Battelle, or other organizations, do you see that could increase cost-effectiveness of these types of undertakings in the future?

Mr. Feenstra, unlike historical contaminants like chlorinated solvents, the level of PFAS characterization needed is greater because PFAS are a more complex class of chemicals. One example of this complexity is the need to identify PFAS at very low concentrations (parts per trillion). Enhanced site investigation will increase the understanding of background levels of PFAS, provide information on potential sources, and further define the plume of contamination. This includes the use of high-resolution mass spectrometry, which can provide information on non-target PFAS, and "total PFAS" methods that can measure the sum without identifying specific PFAS through the measurement of total organic fluorine. Considering all of the stages to achieve site closure, it is estimated that there will be a reduction in sampling and analytical costs by deploying more informative advanced analytical technologies earlier in the investigation process. In addition to cost savings, the application of such an integrated set of methods allows site owners to make better-informed decisions and provide greater flexibility in determining the extent of PFAS contamination at the site. Battelle has invested in the development of several monitoring and characterization tools, such as PFAS Signature®, PFAS Insight™, and PFAS Predict™, that are examples of technologies that can be used to increase site characterization information that will also increase the cost effectiveness of site investigations.

Questions for the Record
Submitted by Representative Bill Posey
Response by: Amy Dindal
Director of Environmental Research and Development,
Battelle Memorial Institute

1. What are the most critical research needs that will help advance the treatment and remediation of PFAS contamination at DOD facilities like Patrick Air Force Base in my district?

Mr. Posey, unlike historical contaminants like chlorinated solvents, the level of PFAS characterization needed is greater because PFAS are a more complex class of chemicals. One example of this complexity is the need to identify PFAS at very low concentrations (parts per trillion). Research in site investigation technologies will increase the understanding of background levels of PFAS, provide information on potential sources, and further define the plume of contamination. This includes the use of high-resolution mass spectrometry, which can provide information on non-target PFAS, and "total PFAS" methods that can measure the sum without identifying specific PFAS through the measurement of total organic fluorine. Considering all of the stages to achieve site closure, it is estimated that there will be a reduction in sampling and analytical costs by deploying more informative advanced analytical technologies earlier in the investigation process. In addition to cost savings, the application of such an integrated set of methods allows site owners to make better-informed decisions and provide greater flexibility in determining the extent of PFAS contamination at the site. My organization, Battelle, has invested in the development of several monitoring and characterization tools, such as PFAS Signature®, PFAS Insight™, and PFAS Predict™, that are examples of technologies that can be used to increase site characterization information that will also increase the cost effectiveness of site investigations.

2. The U.S. Geological Survey (USGS) has played a pivotal role in water resources research throughout their history. Can you please tell the committee what you know about USGS efforts to study PFAS presence and transport in surface and ground waters and what more we might ask them to do to contribute to closing gaps in PFAS R&D?

Mr. Posey, I am not familiar with the USGS's study.

3. Some of the testimony provided today suggests that recent scientific research may offer some hope for developing successful biodegradation strategies for treating and remediating PFAS contamination. Can each of you please evaluate this possibility and comment on whether Congress should work toward providing a priority and more resources for such research?

Mr. Posey, recent advances in both fungal and bacterial biodegradation of PFAS compounds is showing promise as both types of microorganisms have been shown to degrade, and specifically to defluorinate polyfluorinated alkyl substances. Some enzymes have also been shown to degrade perfluorinated compounds, albeit not yet with the desired efficiency. Continued research and development around both of these potential pathways will likely result in the discovery of novel biodegradation strategies that will reduce the cost of PFAS remediation either alone or in combination with other technologies. It is worth remembering that in 1980, chlorinated solvents were considered non-biodegradable, and by 2010 bioremediation was by far the most common site cleanup remedy. An area with especially high potential is synthetic biology. With the tremendous advances in DNA and protein synthesis and computing capacity in the last 10 years, together with dramatic decreases in cost, the possibility of developing novel enzymes for PFAS degradation is very real within the next one to two years. Commercialization of such bioremediation technologies will greatly reduce the financial burden of remediating contaminated sites, which will mean sites are cleaned up faster and people are safer.

4. Please provide a brief description of a science-based strategy for remediating PFAS at DOD facilities like Patrick Air Force Base. In your statement, please include a short-term response to expedite near term remediation based on available technologies and a longer-term strategy that will depend on improved techniques that are developed by the scientific community. In short, how should remediation best proceed in the short and long-term and provide for expedited treatment and remediation?

Mr. Posey, large contamination areas, coupled with the recalcitrant nature of the C-F bond, adds technical challenges and potentially high cost for approaches to treating entire plumes. Environmental behaviors for PFAS are not consistent with other organic contaminants, which means they are likely to require new technologies for effective site characterization and treatment. The presence of co-contaminants also can complicate fate and transport behavior. In addition, past treatments at a site may have unknowingly negatively impacted the PFAS contamination.

In the short-term, taking an aggressive approach to field promising technologies will prove those technologies that are fieldable solutions. Those that do not succeed in early attempts will 'fail fast' and have an opportunity to address shortcomings. It is essential to test technologies under multiple site conditions as there can be significant variations in geology and contaminant composition from site to site, which can impact technology performance. Comprehensive technology performance data will increase confidence in these new approaches and ultimately accelerate cleanup timelines. One of the innovative new technologies that has demonstrated effectiveness for PFAS destruction is based on supercritical water oxidation (SCWO). SCWO is a technology that breaks the C-F bond and works well for a broad spectrum on PFAS. SCWO is not a new technology, as it has been used since the 1980s to address difficult to treat compounds. What is new is the application and optimization of the technology for PFAS. Battelle's technology based on SCWO is called "PFAS Annihilator™," as it destroys PFAS in contaminated water to non-detect levels in seconds, leaving inert salts and PFAS-free water behind. Once the treated water has been tested to confirm that the PFAS have been destroyed, it can be safely discharged back into the environment. The PFAS Annihilator™ is ready for deployment today to destroy PFAS in contaminated waste streams, such as the investigation derived waste (IDW) that is being generated during remedial investigations at DoD sites like Patrick Air Force Base. In addition to reducing liability, destroying PFAS to the lowest levels of detection ensures compliance, regardless of regulatory levels. It will also help sites to prepare for the long-term remediation strategies by identifying and deploying technologies in the short-term which are successful for smaller volumes of PFAS-impacted media such as IDW.

Responses by Dr. Peter Jaffé

DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING

PRINCETON UNIVERSITY, PRINCETON, NEW JERSEY 08544

PETER R. JAFFÉ
WILLIAM L. KNAPP '47 PROFESSOR OF CIVIL ENGINEERING
PROFESSOR OF CIVIL AND ENVIRONMENTAL ENGINEERING

January 19, 2022

Chairwoman Johnson, Ranking Member Lucas, Subcommittee Chairs Sherrill and Stevens, Ranking Subcommittee Members Bice and Walz:

Thank you again for having invited me to testify at the hearing titled *"Forever Chemicals: Research and Development for Addressing the PFAS Problem,"* held December 7, 2021.

Attached are responses to questions submitted by Chairwoman Eddie Bernice Johnson, Representative Deborah Ross, and Representative Paul Tonko. Some of these questions were addressed in my letter dated December 15, 2021, focusing on questions that were raised during the hearing, for which we did run out of time before I could address them, and they are included here, where appropriate.

Thank you again for inviting me. If you have any further questions, please feel free to contact me.

Sincerely,

Peter R. Jaffé

Submitted by Chairwoman Eddie Bernice Johnson

1. **Dr. Jaffé,** several research gaps were highlighted during the hearing and in written testimony submitted by the witnesses. Are there any additional research gaps you feel are important to be highlighted for the Committee?

   Much of the current PFAS fate, transport, and remediation research focuses on the more contaminated sites (firefighting/training sites, landfills, etc.), but large challenges on understanding diffused PFAS pollution like contaminated farmland or river sediments remain. How long does such contamination last? What are methods to flush PFAS from the surface soil to below the root zone? Exactly what is the PFAS pathway from soils to crops or food sources, and can we predict it?

   Better and/or more cost-effective treatment technologies need to be developed, especially for operations where large volumes of water need to be treated. Municipal drinking water treatment plants, for example, might have to treat millions of gallons of water per day to bring PFAS concentrations to drinking-water levels. This is currently done either via ion exchangers, where typically the resins are not regenerated after they have been exhausted and are disposed of as hazardous waste, or via granular activated carbon (GAC). The sorption capacity of GAC for small carbon-chain PFAS is limited, and they might break through much sooner than larger PFAS molecules, resulting in that either smaller unregulated PFAS, if present, do end up in the drinking water, which is undesirable, or that GAC must be replaced much sooner. Currently GAC is often regenerated and then used for other purposes than potable water treatment, but only virgin GAC is used to treat drinking water, which also adds to the cost. Either option, ion exchanger or GAC, is therefore expensive, which calls for the development of new or significantly improved technologies.

   In contrast to drinking water treatment plants, in wastewater treatment plants PFAS, especially the longer carbon-chain PFAAs, may end up in the biosolids produced by these plants. These biosolids must be disposed of, often by applying them to agricultural lands, which may result in the pollution of food sources (i.e., crops, livestock). Hence, technologies to either treat PFAS contaminated biosolids or prevent the biosolids from becoming polluted in the first place need to be developed.

   And, although this is out of my area of expertise, given the large number of PFAS, there are significant knowledge gaps regarding health effects of the less common PFAS, or shorter carbon chain PFAAs (perfluoroalkyl acids) as well as exposure to PFAS via water, food, air, dermal contact, etc.

2. Do you believe that industry responsible for the PFAS problem should play a role in supporting research addressing the PFAS problem? If so, how?

   Industry seems to be genuinely interested in understanding the fate and transformations of PFAS in the environment and developing effective treatment technologies. Industry (PFAS producers and consumers) are already funding scientists/engineers directly to conduct basic research on the fate, transport, and remediation of PFAS and have been willing to provide PFAS contaminated soil or biosolid samples to be used in laboratory experiments. Still, these interactions are somewhat limited when compared to Federally funded PFAS research.

   NSF's ERASE-PFAS program is funded by an unrestricted gift from DuPont. This results in peer-reviewed research grants for which NSF makes the funding decisions based on the merits of the proposed research, without input from DuPont. This program provides an excellent model on how industry can contribute to funding PFAS-related research.

3. The risks presented by PFAS can seem, to many, to be overwhelming and complicated. Do you have thoughts about how officials should effectively communicate with the public about PFAS and their risks?

   This is a challenging but very important topic. Many citizens have heard of PFAS only recently and assume it is a new problem. They need to understand that exposure to PFAS has occurred for a long time and that measurements are taken to decrease this exposure, and that exposure comes from many sources and not just drinking water.

   If drinking water is above standards, water must be either treated or other water sources need to be procured. If traces of PFAS below drinking water standards are detected, which is likely going to be very common, assurances must be given to the public that the water is safe for consumption. From a public health perspective, we want to avoid that consumers switch needlessly from safe and monitored public water sources to unmonitored sources.

   The public should be given information on exposure. Are there PFAS-containing products that should be used cautiously, while others might be safe? For example, applying PFAS containing sprays to make cloth or leather water repellent should be done outdoors, if at all, and the individual applying these products should remain upwind. Whereas it is currently believed that the use of Teflon frying pans is relatively safe if they are not scratched or used under excessive heat. Products need to be labeled and information on which products might result in PFAS exposure, as well as their safe handling and disposal, should be readily available. Unfortunately, much of this information is at this point rather incomplete and requires further study.

Submitted by Representative Deborah Ross

1. **Dr. Jaffe**, one method of detecting all PFAS in water is using a total organic fluorine method. Will you please discuss the context in which you would use this method, whether you think it is appropriate, and what impediments prevent use of a total organic fluorine method?

   Targeted PFAS analyses (those that focus on a specific PFAS compound) may miss many fluorinated compounds that can be present in soil or water, and which are not being targeted by the analytical method. Hence, a combination of targeted PFAS analyses and analyses of total fluorinated organics will give the most complete insights into the degree of contamination with organofluorine compounds. Such a combined use of targeted and non-targeted methods will allow to determine if there is a significant presence of PFAS that has not been identified via the targeted methods.

   A challenge with total organic fluorine methods is their detection limit. Perhaps the most common methods to quantify total organic fluorine include the extractable organic fluorine assay (EOF) and adsorbable organic fluorine (AOF) assay. Both of which are based on combustion ion chromatography and have typical detection limits ≤ 1 µg F/L[1]. To put this in context, EPA's drinking water health advisory for PFOA is 70 ng/l, which would have a total organic fluorine concentration of 0.048 µg F/L, showing that we can't fully rely on total organic fluorine methods to determine if PFAS concentrations are below acceptable drinking water levels.

   Another method that is useful to complement targeted PFAS analyses is the total oxidizable precursor (TOP) assay, which quantifies perfluoroalkyl acids (PFAAs) and their precursors, and has been reported as the most sensitive among surrogate methods (0.1 – 0.5 ng/L for individual PFAS)[1]. The TOP assay is therefore sensitive enough to detect PFAAs (which at this point are of most health concern) and their precursors at below EPA's drinking water advisory levels.

   To summarize, a combination of targeted and non-targeted methods would give the most complete insights into PFAS contamination at various environmental settings and should be used for site characterization and to monitor drinking water quality.

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[1] McDonough et al., 2018, https://doi.org/10.1016/j.coesh.2018.08.005

Submitted by Representative Paul Tonko

Earlier this year, I was incredibly pleased to see the strong action taken by Administrator Regan and the EPA on PFAS, including the establishment of the PFAS Strategic Roadmap. The Roadmap, as you know, is built on three principles - research, restrict, and remediate.

1. **Dr. Jaffe**, with regard to the second principle, proactively restricting PFAS releases, what kinds of technology could be deployed today to reduce the release of PFAS into the environment?

   One of the most significant sources of PFAS to the environment is the use of AFFF (aqueous film forming foam) in firefighting, including its use during training. Although alternate formulations are being pursued, it is likely that AFFF will be used for the foreseeable future. Therefore, training with AFFF should only be done at properly prepared sites (e.g., lined) where the runoff AFFF can be captured and treated. When AFFF has been used to suppress an actual fire, when possible, the topsoil should be covered, removed, and treated as soon as feasible, and/or other means of isolating the AFFF and preventing it from migrating to groundwater should be implemented.

   Other major sources of PFAS to the environment include landfills and possibly wastewater treatment plants. Landfills typically treat their leachate before discharging it to the environment, but these treatments do not remove PFAS. There are many methods that could be implemented to remove PFAS from the treated leachate, such as sorption to granular activated carbon, or ion exchangers. Needless to say, that this would add significantly to the operational cost and research and testing is needed to make such treatment efficient and cost-effective.

   If PFAS enter wastewater treatment plants, it is thought that most PFAS will sorb to the biosolids or sludge that is produced in these plants. If the sludge is incinerated, and PFAS are present, one will have to be certain that the temperature is sufficiently high to destroy the PFAS. Sludges are often applied to agricultural lands, where PFAS contamination becomes especially challenging, and so far, no technology has been developed or implemented to remove PFAS from sludges/biosolids. Hence, the best alternative is to prevent PFAS from entering the wastewater, requiring treatment at the source of PFAS discharge to the wastewater. This approach has been successfully implemented for heavy metals and it is worthwhile to investigate if it can be replicated for PFAS. There is ongoing research focusing on, for example, PFAS biodegradation in sludges, but such technologies, although promising, are at best years from being implementable and also require further R&D.

   Finally, it is possible to ban the use of PFAS for selected applications. For example, the country of Denmark recently banned the use of PFAS in food packaging products.

2. You spoke to the complexity of considering each PFAS chemical individually. I believe it is necessary to regulate these chemicals by class or by category. What are the primary R&D investments needed to figure out how to evaluate, monitor, and regulate PFAS chemicals in classes or groups?

   To evaluate PFAS by group would require doing systematic studies for each group, starting with toxicity, transport properties (sorption, volatilization, bioaccumulation, etc.), biodegradation/biotransformations, reactivity, etc. For example, for the case of perfluoroalkyl acids (PFAAs), one should systematically study the effect of the carbon chain length as well as branching. This will give insights into how the above mentioned characteristics vary within a given group of PFAS. The most studied PFAAs are PFOA (perfluorooctanoic acid) and PFOS (perfluorooctane sulfonic acid), for which EPA has advisory level concentrations. These compounds have been manufactured widely and are therefore more common at contaminated sites, specially where they have been manufactured or used to produce other goods. Perfluorononanoic acid (PFNA) has been used in New Jersey in manufacturing processes and is regulated in NJ. We know that compounds in AFFF can be transformed to shorter PFAAs, and we have evidence that larger PFAAs can be degraded to shorter, more mobile ones, hence it is imperative to understand these compounds as a group vs. just focusing on an individual one.

3. I understand that even when PFAS contamination is identified, addressing it is difficult and expensive. What are some of the main barriers to effective remediation of PFAS contamination?

The very large number of different PFAS compounds with a range of different properties affecting their fate and transport makes it a special challenge to develop remediation technologies that are broadly applicable. Furthermore, PFAS are present in a wide range of environmental settings of concern (i.e., contaminated sites, river sediments, agricultural soils, etc.), requiring different approaches for their remediation.

For example, PFAS removal via sorption might be effective for longer carbon chain PFAS while it is less effective for shorter carbon chain PFAS. Therefore, PFOA (8 carbons) might be removed effectively via sorption while PFBA (4 carbons) might break through activated carbon filters much sooner. If only the larger carbon chain PFAS (i.e., PFOA, PFOS) for which EPA has set advisory levels, are monitored in the effluent of the activated carbon filter to determine when the filter needs to be replaced, it is possible that smaller carbon-chain PFAS might have broken trough much earlier and are not removed. Hence, it is important to focus on multiple PFAS with multiple properties in the implementation and operation of remediation schemes. This also points to the need to develop sorbents or more likely a combination of sorbents that result in a more uniform PFAS removal.

To date, PFAS remediation has mainly focused on sites where AFFF was used or at PFAS manufacturing sites, and even for these sites, remediation technology is in its infancy. Since most PFAS sorb strongly onto solid surfaces and in unsaturated soils to the air-water interface, conventional pump-and-treat methods, that are usually applied for compounds that are more mobile, are not very efficient. Therefore, remediation at such sites has typically focused on either the addition of amendments to immobilize PFAS, which includes injecting sorbents (e.g., microscale activated carbon) into the soil to sorb and immobilize PFAS, preventing them for migrating further and contaminating groundwater. Alternatively, it is also possible to add amendments to mobilize PFAS (e.g., surfactants) to enhance pump and treat schemes and then treat the extracted PFAS contaminated water on site via a variety of available technologies (i.e., sorption, chemical oxidation, etc.).

The concern with using immobilization amendments, which probably have been used to date most successfully, is that they do not remove PFAS from the soil, nor do they destroy them. Other available techniques, like thermal treatment are both expensive and very energy intensive and may not be practical except at small areas with highly concentrated PFAS. In situ chemical oxidation techniques have been tested at the laboratory scale, but to my knowledge have not been applied for in situ site remediation to date. Bioremediation, if possible, is usually considered one of the least expensive methods to treat sites contaminated with organic compounds that can be biodegraded (either mineralized or dehalogenated), but the science of PFAS bioremediation is in its infancy and it is not clear to what degree and how soon PFAS bioremediation techniques might be applicable.

To my knowledge, there has been no successful PFAS remediation scheme implemented to treat much more diffused and large-scale contaminated settings, like river sediments or agricultural/pasture soils.

For all the above reasons, more basic and applied research into PFAS remediation of different environmental settings and a range of PFAS is needed.

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June 23, 2022

Chairwoman Johnson, Ranking Member Lucas, Subcommittee Chairs Sherrill and Stevens, Ranking Subcommittee Members Bice and Walz, and Representative Bill Posey:

Attached are responses to questions submitted by Representative Bill Posey as a follow-up to the hearing "*Forever Chemicals: Research and Development for Addressing the PFAS Problem,*" held December 7, 2021, which I received on June 22, 2022.

Please let me know if you have any further questions.

Sincerely,

Peter R. Jaffé

[Submitted by Representative Bill Posey]

1. What are the most critical research needs that will help advance the treatment and remediation of PFAS contamination at DOD facilities like Patrick Air Force Base in my district?

   I am not familiar with the particulars of the PFAS contamination at the Patrick Air Force Base, nor with the site hydrology and biogeochemistry, hence I do not have any site-specific recommendations. I would say that many of the overall research needs that have been discussed during this hearing will also apply to a site like the Patrick Air Force Base.

2. The U.S. Geological Survey (USGS) has played a pivotal role in water resources research throughout their history. Can you please tell the committee what you know about USGS efforts to study PFAS presence and transport in surface and ground waters and what more we might ask them to do to contribute to closing gaps in PFAS R&D?

   One of the many tasks of the he USGS is to track the Nation's water quantity and quality as well as the trends of these parameters over time. The USGS also has a strong track record on conducting excellent work focusing on the fate and transport of various pollutants in the environment. I am aware, although not firsthand, that the USGS is planning on implementing a National-scale program to study the prevalence of PFAS in waterbodies and in fish, and to focus on PFAS fate and transport as well as the effects of PFAS on ecosystems. I understand that their efforts will also include the development of environmental sampling methods for PFAS. The USGS is the proper organization to conduct this research, given their existing sampling network, expertise in sampling and in environmental processes, including contaminant fate and transport and exposure assessment. Given the growing concerns about PFAS, it is important to understand what the prevalence of PFAS is in Nation's different water bodies and ecosystems, and the USGS should be given the resources to conduct this challenging and important task.

3. Some of the testimony provided today suggests that recent scientific research may offer some hope for developing successful biodegradation strategies for treating and remediating PFAS contamination. Can each of you please evaluate this possibility and comment on whether Congress should work toward providing a priority and more resources for such research?

   About 40 years ago it was believed that chlorinated organic compounds could not be degraded. Significant progress has been made since then in our understanding of the mechanism of biodegradation of chlorinated compounds, and there are many sites, contaminated with chlorinated compounds, where bioremediation has been and is being used effectively.

   PFAS, specially the perfluorinated compounds (where all carbons except the functional carbon are fully saturated with fluorine) are thought to be more stable and more difficult to biodegrade than chlorinated compounds, hence the label "forever chemicals". Recently, exciting laboratory results have been obtained showing that fluorinated compounds, including perfluorinated ones like PFOA and PFOS (perfluorooctanoic acid and perfluorooctanesulfonic acid, respectively), can be degraded by certain bacteria and/or fungi. It is likely that there are more organisms yet to be discovered that can do so too and perhaps even more efficiently than those that are currently being studied. We may be at a point where our understanding of PFAS biodegradation is like where we were with biodegradation of chlorinated compounds a few decades ago. The availability of powerful new molecular biology tools, and knowledge gained from the bioremediation of sites contaminated with chlorinated compounds, should facilitate gaining new insights into PFAS biodegradation and ways to implement it for site treatment purposes more effectively.

Many researchers have shown in laboratory experiments and in the field that polyfluorinated compounds (not fully saturated with fluorine) can be partially degraded and be converted into perfluorinated compounds. Biodegradation of these perfluorinated compounds is considered much more challenging and the microorganisms and mechanisms resulting in their degradation need to be elucidated.

A general truism is that if a contaminant can be biodegraded, biodegradation is the most cost-effective manner to achieve its breakdown. For various reasons, it might often not be possible to achieve drinking water levels of a specific contaminant via biodegradation, but the goal is often to reducing the overall mass of a contaminant at a source area, and hence reducing the overall risk that the contaminant presents. Biodegradation can be very effective to achieve such reduction in contaminant mass.

Therefore, funding work on PFAS biodegradation should be a priority for Congress (risky but with high rewards) in the development of methods to treat PFAS contaminated sites, and to better understand their fate and transport in different environmental settings. More needs to be understood about the biotransformations of the polyfluorinated compounds, specially to assess their fate and transport in different environmental settings, but much of the research effort on PFAS biodegradation should be directed towards studying the biodegradation of perfluorinated compounds, and how to enhance it at contaminated sites/environmental settings for bioremediation purposes.

4. Please provide a brief description of a science-based strategy for remediating PFAS at DOD facilities like Patrick Air Force Base. In your statement, please include a short-term response to expedite near term remediation based on available technologies and a longer-term strategy that will depend on improved techniques that are developed by the scientific community. In short, how should remediation best proceed in the short and long-term and provide for expedited treatment and remediation?

   In the short term it is always important to isolate pollutants at a site, so they do not spread and contaminate a larger volume of water, contaminate biota (e.g., being taken up by plants and enter the food chain), become airborne (e.g., associated with dust), and most importantly prevent human exposure to such pollutants. This applies also to PFAS, and mighty include caping sites, hydrologic isolation via the strategic placement of pumps that extract and/or inject water, or placement of barriers, which could include physical barriers or injection of sorbents such as activated charcoal. Once the pollutant has been isolated and is no longer spreading, there is less urgency for immediate treatment, allowing for time to evaluate newer technologies that might or might not be ready for field deployment. Some of the above-mentioned isolation techniques can be coupled with treatment, like 'pump and treat' which is not as effective for PFAS as for other contaminants such as chlorinated solvents, for example.

   Given the rapidly decreasing levels of PFAS concentrations that are considered "safe", and the large number of contaminated sites that have PFAS above these levels, technologies that can destroy PFAS and reach these low levels will, if available at all, be very limited and difficult/expensive to implement, hence, a combination of treatments focusing on source-reduction and long-term isolation of PFAS at contaminated sites might be required.