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Response of The MITRE Corporation to the OSTP RFI on PFAS Research and Development

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For additional information about this response, please contact:

Duane Blackburn
Center for Data-Driven Policy
The MITRE Corporation
7596 Colshire Drive
McLean, VA 22102-7539

policy@mitre.org
(434) 964-5023

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About MITRE

MITRE is a not-for-profit company that works in the public interest to tackle difficult problems that challenge the safety, stability, security, and well-being of our nation. We operate multiple federally funded research and development centers (FFRDCs), participate in public-private partnerships across national security and civilian agency missions, and maintain an independent technology research program in areas such as artificial intelligence, intuitive data science, quantum information science, health informatics, policy and economic expertise, trustworthy autonomy, cyber threat sharing, and cyber resilience. MITRE's 9,000-plus employees work in the public interest to solve problems for a safer world, with scientific integrity being fundamental to our existence. We are prohibited from lobbying, do not develop or sell products, have no owners or shareholders, and do not compete with industry. Our multidisciplinary teams (including engineers, scientists, data analysts, organizational change specialists, policy professionals, and more) are thus free to dig into problems from all angles, with no political or commercial pressures to influence our decision-making, technical findings, or policy recommendations.

MITRE supports multiple federal agencies, ranging from defense- to health-focused, as they address challenges emerging from per- and polyfluoroalkyl substances (PFAS) contamination. We help provide a systems-level perspective by bringing together chemists, geospatial analysts, environmental epidemiologists, and water quality experts to collaboratively study issues and develop solutions. MITRE scientists explore ways to apply our capabilities to emerging challenges in key areas, such as the development of novel sensors, indicators and warnings, resilience, and mitigation capabilities, where we already have significant expertise. This includes developing rapid, real-time screening of PFAS in water, geospatial models to prioritize areas of increased PFAS vulnerability for continuous monitoring, and decision support tools to evaluate tradeoffs in remediation technologies. Our experts have also worked with state governments (e.g., Colorado, New Hampshire), industry (e.g., remediation companies, drinking water treatment plant operators) and academic institutions (e.g., University of Alabama, Clarkson University) to identify research gaps and develop capabilities and solutions that would enable more rapid, lower-cost detection and remediation of chemical contaminants across the defense and public sectors. As such, the MITRE team has gained insight into critical research and capability gaps, which informs the response to this RFI.

Questions Posed in the RFI

1. Should the USG consider identifying priority PFAS when developing a strategic plan for PFAS research and development? If so, what criteria should be used to identify priority PFAS for research and development (e.g., tonnage used per year; releases to the environment per year; toxicology or other human or environmental health concerns; national security or critical infrastructure uses)?

Priority PFAS species should be a combination of those species that have the highest tonnage usage per year in addition to high toxicity to human and environmental health. As toxicity profiles do not exist for all known PFAS species, priority should be given to classes with similar structures to known toxicants, like per-fluorinated carboxylic acids (PFCA) and per-fluorinated

sulfonic acids (PFSA). PFCA and PFSA are the most common breakdown products and are frequently found in contaminated water and soil. Additionally, a broad and simple definition for PFAS should be maintained and chemical providers should be required to report the amount of any PFAS chemical. This will keep a pulse on replacement molecules once other PFAS become regulated.

3. Based on the definition of PFAS in this RFI, what are the scientific, technological, and human challenges that must be addressed to understand and to significantly reduce the environmental and human impacts of PFAS and to identify cost-effective:

- a) Alternatives to PFAS that are designed to be safer and more environmentally friendly;
- b) Methods for removal of PFAS from the environment; and
- c) Methods to safely destroy or degrade PFAS?

3B: A vital consequence of any method used to remove PFAS is the generation of additional waste streams that will ultimately need to be destroyed. For example, granular Activated Carbon (GAC) and Ion-Exchange Resin (IX) currently stand as the two most common technologies for removing PFAS from water¹ and are used in wastewater treatment facilities and as part of remediation efforts. Both work by attractively adsorbing PFAS to their structure. As contaminants interact with the sorbents, sites get filled; full sites result in PFAS breakthroughs². This leads to filter replacement or regeneration, both of which produce additional waste streams for PFAS. Current sampling protocols for PFAS are not fast enough to detect breakthrough on a meaningful time scale. A filter could be failing for a week before an operator receives indication.

There are several promising emerging technologies for capturing PFAS. Surface-Activated Foam Fractionation (SAFF™) exploits PFAS' preference for the air-liquid interface to concentrate the chemicals in bubbles. These bubbles can be collected, removing the contaminant, but creating an additional waste stream. Several plant-based solutions are being tested as well. Cattails have been shown to act as water filters and will store PFAS. This acts to purify the water, but again produces an additional PFAS waste stream.³ When it comes to landfilling PFAS-contaminated waste, this may lead to leachate ending up back in the wastewater stream. Novel sorbents are being developed to bind PFAS more effectively, but all sorbents will eventually experience breakthrough. Rapid, on-site testing is needed to adequately manage PFAS contamination.

3C: There are several promising technologies that still require development and testing, but the field is rapidly expanding. Newly reported research in *Science* suggests a path towards low-temperature mineralization of specific PFAS species that leveraged computational power to identify effective degradation paths for perfluoroalkyl carboxylic acids.⁴ Most destructive technologies are not selective towards PFAS, but rather break down all organic substances. This

¹ H. Vo, et al. Poly- and perfluoroalkyl substances in water and wastewater: A comprehensive review from sources to remediation. 2020. *Journal of Water Process Engineering*

² R. Verma, et al. Remediation and mineralization processes for per- and polyfluoroalkyl substances (PFAS) in water: A review. 2021. *The Science of the Total Environment*

³ W. Zhang, et al. Destruction of Perfluoroalkyl Acids Accumulated in *Typha Latifolia* through Hydrothermal Liquefaction. 2020. *ACS Sustainable Chemistry & Engineering*.

⁴ B. Trang, et al. Low-temperature mineralization of perfluorocarboxylic acids. 2022. *Science*, 845(August), 839–845.

means that the efficiency of PFAS breakdown is impacted by the other substances found with it. A concentration of organic material will require more cycles to see the needed degradation of PFAS. This usually means additional filtering steps before destruction. Additionally, many destructive techniques show incomplete destruction of PFAS. True mineralization will reduce all fluorine to fluoride (F⁻), but the energy requirements needed to break down PFAS often yield small, usually volatile, PFAS compounds. These techniques are also limited in their throughput. Scaling up these technologies may be challenging. Energy costs should be considered as well.

For any PFAS remediation effort to be successful, it is critical that rapid, on-site detection occur to allow for the remediation conditions to be adjusted as the process is performed. As current laboratory methods are experiencing sometimes months of backlog, this gap poses a significant challenge.

6. What should be the research and development priorities for accelerating progress, improving efficiency, and reducing the cost of: analytical methods, detection limits, nontargeted detection?

Lack of accurate and rapid field-testing methods limits R&D breakthrough and our ability to make informed decisions in regard to contamination. Currently, samples are sent out to an EPA-accredited laboratory to perform LC-MS/MS analysis for a subset of PFAS compounds. This process can take 2-6 weeks, preventing site managers from making decisions in real-time. In the case of water treatment facilities, a breakthrough of PFAS could go unnoticed for a week and effect countless end users. It also limits understanding on how PFAS moves as a function of weather, natural disasters, or emergency action (like use of AFFF). The most significant analytical improvement would be developing a tool for on-site analysis of PFAS. This tool does not need to replace LC-MS/MS analysis or even compete with its accuracy. It needs to serve as a screening tool to provide rapid decision support. This would reduce the number of samples sent for testing and reduce the overall time requirement moving forward.

In the interim, focus should be on accelerating or optimizing current methods (e.g., increased preconcentration or sample preparation methods), focusing on sampling for not only bodies of water, but other media that contain PFAS (e.g., soil, air, biomass), and improving non-target methods. Non-target methods, like total organic fluorine (TOF), provide valuable information when assessing the scope of contamination, but heavily rely on thermal degradation of the sample which can be difficult to reproduce.

7. What studies would yield the most useful information and address the current gaps in understanding PFAS health effects in humans (e.g., in vitro, animal toxicological, and epidemiological studies)? Which health effects should be prioritized? What additional impacts beyond health should be prioritized? Social scientific approaches are welcome in addressing this question and any others, as appropriate.

To address the current gaps in understanding PFAS health effects in humans, additional health studies are needed to gather PFAS blood serum data for “low exposure” populations across a range of PFAS analytes. As part of the National Health and Nutrition Examination Survey (NHANES), data on PFAS blood serum levels for “low exposure” populations has been collected

for ~20,000 individuals, but additional cross-sectional and cohort studies are needed from diverse communities and geographies. PFAS exposure assessment via biomonitoring of blood and urine concentrations is critical to surveillance efforts, ideally, as part of a system integrating health outcome data from disease registries (cancer, birth defects, etc.). Adequate time series data of PFAS serum levels are also lacking. Consistent time series data (for example: weekly/daily data of PFAS blood serum levels versus weekly/daily data of individuals' blood glucose levels), would enable causal modeling and analysis (Bayesian networking, Granger, etc.) to examine health effects across different PFAS species beyond the correlational level.

The most studied health categories for their relationship with PFAS are developmental, bodyweight, and hepatic health categories. Based on the toxicological profile from the Agency for Toxic Substances and Disease Registry (ATSDR), there are a few health categories specifically that have conflicting studies on the health effects of PFAS:

- Immunological: Conflicting studies on associations between PFAS serum levels and asthma
- Hepatic: Conflicting studies on associations between PFAS serum levels and LDL cholesterol levels
- Cardiovascular: Potential, yet inconsistent associations between several PFAS serum levels and risk of pregnancy induced hypertension
- Reproductive: Inconsistent and few studies on associations between several PFAS serum levels and reproductive hormone levels
- Cancer: Inconsistent studies on associations between PFDA + FOSA serum levels and breast cancer risk

There are also little to no epidemiological health studies that have been conducted for the relationship between ocular and dermal health endpoints and PFAS, although some animal and mechanistic studies exist. These gaps and specific health effects could be prioritized for further research and health studies.

9. What goals, priorities, and performance metrics would be valuable in measuring the success of National, federally funded PFAS research and development initiatives relating to:
- a. The removal of PFAS from the environment;
 - b. Safely destroying or degrading PFAS; and
 - c. Developing safer and more environmentally-friendly alternatives to PFAS?
 - d. Mitigating negative human effects of PFAS, whether related to health or additional domains?

9A: Many promising technologies to remove and destroy PFAS from the environment are still in the development phase and are undergoing testing and pilot studies. Their scalability also remains unknown. While there are some technologies that are effective in destroying PFAS, there are many unknowns and still room for improvement. Specific metrics that would be helpful in assessing each technology's best use may include the durability of PFAS storage (How long will the technology sequester the PFAS before it begins leeching back into the environment? Under what conditions is it more likely to leech?), the amount of removal per unit of material (such as specific surface area or mass) and selectivity towards PFAS. Several materials interact with PFAS, but to increase durability and effectiveness, materials specifically designed to preferentially attract PFAS will be ideal.

Additionally, one goal should be ensuring that the concentration and removal of PFAS from drinking water through filtration processes occurring at water treatment plants does not end up back in the environment. For example, water treatment plants may install reverse osmosis (RO) systems to concentrate PFAS and other contaminants, but then release the concentrated waste downstream, which will negatively impact downstream communities. While removing all PFAS from all environments is not feasible, prioritizing those points in the system where human consumption is greater, such as at drinking water treatment plants, will have a greater impact in reducing exposure. Establishing a goal of removing PFAS *permanently* from the environment is therefore recommended. In addition, destruction technologies that can scale to large water treatment plants will assist in removing PFAS from the environment and prevent the reintroduction of contaminated waste back into the environment.

9B: As technologies become commercialized, it is important to continuously evaluate their effectiveness under different contaminated site considerations and conditions:

- *Destruction Percentage* – Essentially, its effectiveness. This would benefit from non-targeted measurement since several PFAS are uncharacterized.
- *By-Product Analysis* – What happens to the PFAS? Are other fluorinated compounds produced? What about volatiles?
- *Treatable Volume* – How much volume can be handled at a given time
- *Energy Cost* – How much energy is required to treat a given volume of contaminant?

9D: There are significant gaps in guidance on how to mitigate PFAS exposure as it related to health and other domains. For example, current blood testing solutions for PFAS are expensive and support limited analytes. Advances in affordable blood testing will help enable affected populations determine whether various PFAS are in their blood and at what levels.

Recent National Academies recommendations⁵ include clinicians encouraging “PFAS exposure reduction if a source of exposure is identified, especially for pregnant persons” for patients with serum PFAS concentration of 2 nanograms per milliliter (2 ng/mL) or higher.” Yet sources and levels of exposure are still not well understood (e.g., contaminated drinking water, consumption of contaminated fish or vegetables, etc.). As such, additional research and development is needed to rapidly assess possible sources for exposure. For example, low-cost, real-time detection capabilities to test for PFAS in water, blood and soil could advance efforts to rapidly detect PFAS and thus identify possible sources of exposure. Without these screening capabilities, it will be difficult for patients to follow clinician guidance on limiting PFAS exposure.

⁵ Guidance on PFAS Exposure, Testing, and Clinical Follow-Up. 2022. National Academies, <https://nap.nationalacademies.org/catalog/26156/guidance-on-pfas-exposure-testing-and-clinical-follow-up>. Last accessed August 25, 2022.