PER- AND POLYFLUOROALKYL SUBSTANCES (PFAS) IN AN OCCUPATIONAL COHORT: FINDINGS FROM A PILOT PROGRAM AMONG INDIANA FIREFIGHTERS

Indiana Department of Homeland Security

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EXECUTIVE SUMMARY

The Indiana Department of Homeland Security's (IDHS) voluntary pilot program marks Indiana's first step toward proactively assessing and addressing the occupational PFAS exposure risks faced by its first responders – specifically current and retired firefighters. This initiative is being guided by the established research and clinical frameworks developed at the federal level, ensuring Indiana's actions are aligned with national best practices for testing and patient care. As a foundational effort, the pilot program established a preliminary exposure baseline for Hoosier firefighters. While it is too early to definitively pinpoint specific causal factors for the elevated PFAS levels observed, this finding highlights the critical need for continued, expanded research and testing to fully map the specific exposure pathways and implement evidence-based protective protocols statewide to protect our first responders.

The program tested 316 firefighters from across Indiana (career, volunteer/combination, municipal, airport and industrial departments) and paired blood testing with an exposure survey covering foam use, gear handling, station practices, incident tasks and decontamination behaviors.

What we found

- **PFAS levels may be elevated relative to the U.S. general population.** Using the National Academies' recommended sum of seven PFAS to inform clinical care, 88% of Indiana firefighters fell in the "potential for adverse effects", 3% were "increased risk" and only 9% were "low risk". These bands help orient follow-up but are not diagnoses.
- **Foam use shows a potential dose–response pattern.** Self-reported frequency of using PFAS-containing foams was significantly associated with higher PFAS risk categories. Firefighters who reported daily, weekly, or monthly AFFF use had a notably higher share of elevated results than those who used foam rarely or never.
- **Decontamination of gear and self-appear protective.** Cleaning PPE after exposure was linked to lower PFAS categories. Personal decontamination trended in the same protective direction.
- **Gear and station contact matter.** High gear-contact frequency was associated with higher averages of PFAS biomarkers, consistent with contact and dust pathways observed in the fire service literature.
- **Task patterns are consistent with incremental exposure.** Participation in hazardous materials and water-emergency responses showed small, positive correlations with higher PFAS burdens (statistically significant for hazmat), with suggestive trends for airport crash rescue/ARFF.

What this means for Indiana: Recommended actions guided by federal initiatives

This preliminary data establishes a necessary research foundation for Indiana, highlighting the immediate need for expanded testing and data collection to fully inform protective action aligned with the national EPA's PFAS Strategic Roadmap goals: research, restrict and remediate.

1. **Advance future testing and research.** Research is essential in understanding and combat PFAS. This continued collection of variable exposure data is important to better understand occupational exposure pathways and the long-term health implications for the fire service. This effort is complimented by a national push to measure and monitor PFAS in humans.
2. **Protect.** PFAS are believed to reach firefighters mainly through ingestion (e.g., hand-to-mouth transfer of residues and dust, drinking-water contributions) and occupational inhalation of aerosols and dust. These exposure routes underpin the observed patterns in Indiana's data and point to consideration of practical controls, including implementing foam transition control, on-scene and post-incident decontamination and establishment of separated clean gear and clean quarters with separate ventilation from contaminated gear.
3. **Inform.** Implement a standardized biomonitoring program. PFAS blood tests are exposure measurements, not disease tests. While they cannot pinpoint a specific source, determine causation for an individual or predict a person's future health, testing can nonetheless guide exposure-reduction counseling and align follow-up with widely used clinical frameworks. A biomonitoring program could offer voluntary no-cost testing with targeted outreach, provide each participant with a plain-language results sheet, a clinician letter aligned with CDC/ATSDR and NASEM guidance and integrate PFAS exposure history into surveillance for continuous monitoring and improvement.

BACKGROUND

LEGISLATIVE DIRECTION AND PILOT PROGRAM

In 2023, the Indiana General Assembly appropriated $200,000 to the Indiana Department of Homeland Security (IDHS) to establish a pilot program to determine whether firefighters in Indiana have measurable levels of per- and polyfluoroalkyl substances (PFAS) in their blood. IDHS designed a voluntary program that offers PFAS blood testing at no cost to Indiana firefighters. Individual results are returned to each participant and the analysis in this report relies on de-identified data to characterize statewide patterns and inform public policy. The pilot was designed to be informative and establish a baseline understanding of PFAS among Hoosier firefighters, not a clinical diagnosis program, and complements federal guidance on how PFAS testing can be used to support exposure reduction and routine preventive care.

WHAT ARE PFAS AND WHY THEY MATTER

PFAS are a large family of synthetic chemicals used since the 1940s to impart oil-, water-, and stain-resistance and to reduce friction in industrial processes. Major historical applications include firefighting foams, surface treatments for textiles and paper and numerous consumer and industrial products. The carbon-fluorine bond that defines PFAS is one of the strongest in organic chemistry, which makes many PFAS highly persistent in people and the environment. As a result, they are termed "forever chemicals" and are pervasive in the environment and humans.

PFAS has been linked to a range of health effects in laboratory animal studies, human epidemiological studies and occupational studies. The affected body systems include developmental, endocrine, reproductive, cardiovascular, hepatic and immune systems, as well as potential increased risk of cancer.

HOW PEOPLE ARE EXPOSED

For the general population, ingestion is typically the most common exposure route, often through contaminated drinking water and certain foods. PFAS can also be ingested via household dust and contact with some treated consumer products. Inhalation is a lesser route for the public but can be important where emissions or incineration occur. Absorption through the skin (dermal) appears limited for most PFAS in community settings. Additionally, some PFAS can cross the placenta and are present in breast milk.

WHY FIREFIGHTERS WARRANT PARTICULAR ATTENTION

Firefighters can face additional PFAS exposure beyond community sources:

- **Aqueous Film-Forming Foam (AFFF):** Class B foams historically used for flammable-liquid fires (and in some training contexts) contain or degrade to PFAS, creating inhalation and incidental ingestion risks during use and contributing to site contamination (e.g., training grounds, airports).
- **Turnout gear:** Fluorinated treatments used to impart water resistance have been documented in new and used turnout materials; federal researchers have measured PFAS in gear textiles and investigated potential transfer and release.
- **Fire stations and settled dust:** Peer-reviewed environmental sampling in 15 Massachusetts fire stations found multiple PFAS in dust, especially in gear locker rooms, even at stations that had stopped using PFAS-containing AFFF, indicating indirect and ongoing exposure pathways.
- **Occupational settings generally:** The National Institute for Occupational Safety and Health (NIOSH) identifies firefighters among worker groups with potential for higher PFAS exposure.

Consistent with these exposure pathways, biomonitoring has documented elevated PFAS in some firefighter cohorts. In a controlled study of Finnish firefighters, serum PFAS increased following AFFF-based training exercises, especially PFHxS and PFOS. In Australian firefighters with historical AFFF use, PFOS and PFHxS concentrations in some individuals were up to an order of magnitude higher than levels observed in the general population. U.S. studies (including California and multi-department cohorts) have also reported higher levels of certain PFAS in firefighters relative to U.S. reference values.

HOW PFAS BEHAVE IN THE BODY

Many well-studied PFAS are absorbed through the intestines and lungs, bind to proteins in the blood, distribute to tissues such as the liver and kidneys and are eliminated primarily via urine (with some loss through feces, menstruation, breastfeeding and placental transfer). Biological half-lives vary markedly, from days for some replacement PFAS to years for legacy compounds like PFOS and PFOA. As such, measured blood levels may reflect both recent and past exposures.

WHAT IS KNOWN ABOUT HEALTH EFFECTS

While the strength of evidence varies by outcome and compound, federal government and scientific reviews conclude that PFAS exposure is associated with several health endpoints. These associations are based on epidemiological findings and should not be considered causal. While associations between PFAS and health endpoints show the two are more likely to occur together, it does not necessarily mean PFAS causes the health endpoint. Continued study of causal mechanisms remains underway. The most consistently supported associations include increased total cholesterol, small decreases in birth weight, decreased antibody response to vaccines, elevated risk of kidney cancer and testicular cancer, pregnancy-induced hypertension or preeclampsia and liver-enzyme changes. Evidence is limited or mixed for other outcomes, including thyroid disease, ulcerative colitis and breast cancer.

HOW BLOOD TESTING FITS IN

PFAS blood testing is the accepted biomarker to identify people or groups with elevated levels, inform exposure-reduction actions and support public-health responses. However, results do not identify the exposure source, predict future illness or by themselves change clinical treatment. Furthermore, there are no approved medical treatments to remove PFAS from the body.

Nearly all U.S. residents have detectable PFAS in blood. In 2017–2018 NHANES data, geometric means were approximately 4.25 ng/mL (PFOS), 1.42 ng/mL (PFOA), 1.08 ng/mL (PFHxS) and 0.41 ng/mL (PFNA), with 95th-percentile values substantially higher. These national reference values help interpret Indiana results relative to the U.S. population.

However, the current study and NHANES are not directly comparable and thus are not examined beyond overall statements of higher vs. lower.

PURPOSE OF THIS REPORT

Given firefighters' potential for additional occupational exposure and the evolving scientific guidance, at the direction of the Indiana General Assembly, IDHS assessed PFAS blood levels among Hoosier firefighters to (1) characterize current exposure patterns; (2) help identify practical exposure-reduction opportunities; and (3) provide lawmakers, public-safety leaders and clinicians with robust, transparent information to guide resource allocation and testing recommendations. This report analyzes de-identified pilot data against national reference ranges and National Academies' interpretive bands and discusses implications for training, equipment and environmental management.

Findings here describe population-level exposure patterns. Individual medical decisions should continue to follow routine standards of care, informed by personal risk factors and shared decision-making with a clinician. Because measured PFAS represent exposure at the time of sampling and some PFAS have long half-lives, values may reflect past as well as current exposures.

METHODOLOGY

The PFAS Pilot Program was a two-phase project conducted to investigate the exposure of Indiana firefighters to PFAS. Phase 1 of this project involved an online survey to assess demographics, occupational history, potential exposure history and PFAS-related knowledge and behaviors. Phase 2 consisted of the collection and analysis of blood samples from a subset of participants to analyze their PFAS levels. This pilot was a collaborative effort between IDHS and an external diagnostic laboratory, Eurofins Scientific, to ensure the secure and accurate collection and analysis of biological data.

STUDY DESIGN, SAMPLE RECRUITMENT AND SURVEY DATA COLLECTION

This pilot included a cross-section of active and retired Indiana firefighters. The first phase involved a self-administered, web-based survey administered using Qualtrics. The survey was developed with input from IDHS stakeholders and included five key sections: (1) demographics, (2) fire department affiliation and experience, (3) exposure assessment, (4) PFAS-specific exposure assessment and (5) health and safety behaviors, awareness and knowledge. The full survey is provided in Appendix A. This survey instrument was designed to take approximately 10-15 minutes and was a critical tool for capturing potential exposure history and identifying participants for the subsequent blood sample collection phase.

The survey was launched on August 13, 2024, yielding a total of 927 respondents. Following the survey, participants were required to reconsent to the pilot program and acknowledge modifications to the process for providing blood sample test results. The reconsent period was open from March 18, 2025, to March 28, 2025, and resulted in 485 reconsenting participants.

A total of 380 participants were selected using stratified random sampling. This approach balanced participants according to the size of their emergency preparedness districts, preventing over- or under-representation of certain geographies and providing a clearer picture of the statewide experience. Those selected proceeded to Phase 2 of the pilot for blood sample collection.

Procedure summary

1. **Eligibility and survey completion**: To be eligible for participation, individuals were required to be active or retired firefighters from the state of Indiana. Completion of the online survey was a prerequisite for potential selection into the second phase of the pilot, but completion did not guarantee an individual would receive a blood test.
2. **Blood sampling collection and testing process:** Participants who were randomly selected for the second phase were notified via email.
    a. Self-collection PFAS blood testing kits were supplied by Eurofins Scientific.
    b. Participants were instructed to collect a small blood sample using a finger prick lancet, following the detailed instructions provided in the kit.
    c. To ensure proper processing, samples were required to be postmarked for return no later than fourteen (14) days after delivery.
3. **Laboratory analysis and results**: Upon receipt, Eurofins Scientific processed the anonymized blood samples. The laboratory analyzed the samples to quantify the levels of 46 different PFAS analytes.
4. **Data handling and security of PHI:** After the analysis was completed, Eurofins uploaded the results to a secure portal. From this portal, the analysis team downloaded the test results and applied password encryption to ensure data security and protect participant privacy.
5. **Communication and participant support:** A secure email inbox was set up to manage all communications with participants throughout the pilot program. This centralized inbox was used to send status updates, selection notifications and consent forms, as well as to securely share test results. Participants were directed to this inbox for any questions or concerns. Following the distribution of results, the inbox remained active for approximately two weeks to address any immediate questions or technical issues participants might have had with accessing their documents.

BLOOD SAMPLE DATA COLLECTION

For Phase 2 of the pilot, a total of 380 blood sample collection kits were mailed to participants by Eurofins Scientific. Of those, a total of 316 were returned by participants, while 64 were never returned, resulting in an 83.12% response rate. Reminder emails were periodically sent to boost participation and keep selected participants informed on the pilot's status.

Participants were instructed to collect a small blood sample via a finger prick using a lancet provided in the kit. The kits contained four tips, and to ensure appropriate analysis, at least two of the tips needed to be filled to the recommended saturation level. While most participants successfully returned all four filled tips, nine samples were initially canceled because they were under-saturated. All nine of these participants were contacted and offered a replacement kit. From this group, eight responded and all successfully returned a re-sampled kit, which was then included in the analysis. The complete instructions for the process are detailed in Appendix B.

LABORATORY ANALYSIS

All samples were tested for 45 different PFAS analytes. Appendix C includes a full list of these analytes. The thresholds used for interpreting the results were based on established guidelines from the Centers for Disease Control and Prevention (CDC) and the National Academies of Science, Engineering and Medicine (NASEM). Supplemental information about NASEM thresholds can be found in Appendices B and D.

RESULTS & KEY FINDINGS

PARTICIPANT CHARACTERISTICS

Most participants were currently employed as firefighters or fire officers (90.5%). Retirees comprised 6.6% of participants, and 1.6% were previously employed. Paramedic/EMT credentials were common, including among 64.2% currently employed, 1.9% previously employed and 3.2% retired. The tenure of the cohort was skewed towards more experienced, with the majority of participants serving for more than 15 years.

Table 1. Participant current Firefighter, Paramedic, and EMT status.

Firefighter/Fire Officer Status	Paramedic/EMT Status
Currently employed - 286 (90.5%)	Currently employed - 203 (64.2%)
Previously employed - 5 (1.6%)	Retired - 10 (3.2%)
Retired - 21 (6.6%)	Previously employed - 6 (1.9%)
Did not answer - 4 (1.3%)	Did not answer - 97 (30.7%)

Respondents primarily served municipal departments (70.3%), with 25.3% stationed in volunteer or combination departments, 2.5% at airports and 1.9% in industry. Service areas were largely suburban (46.8%) and urban (44.6%), with only 4.1% of participants primarily serving rural communities.

Table 2. Participant current department and community type.

Department Type	Community Type (residents)
Airport - 8 (2.5%)	Rural (less than 2,500) - 13 (4.1%)
Municipal - 222 (70.3%)	Suburban (2,600 – 49,999) - 148 (46.8%)
Volunteer/Combination – 80 (25.3%)	Urban (greater than 50,000) - 141 (44.6%)
Industrial - 6 (1.9%)	Did not answer - 14 (4.4%)

EXPOSURE ASSESSMENT

PFAS biomonitoring summary

PFAS exposures for firefighters come from both intentional activities (e.g., using foams on fuel fires) and incidental pathways (e.g., handling turnout gear, station dust). In occupational settings, inhalation of PFAS-containing aerosols and dust is a recognized route of exposure, where skin (dermal) uptake is believed to be limited but can occur and ingestion (e.g., hand-to-mouth, dust) contributes as well. At airports, historical training and response with PFAS foams, combined with PFAS-treated gear, create multiple and overlapping exposure pathways.

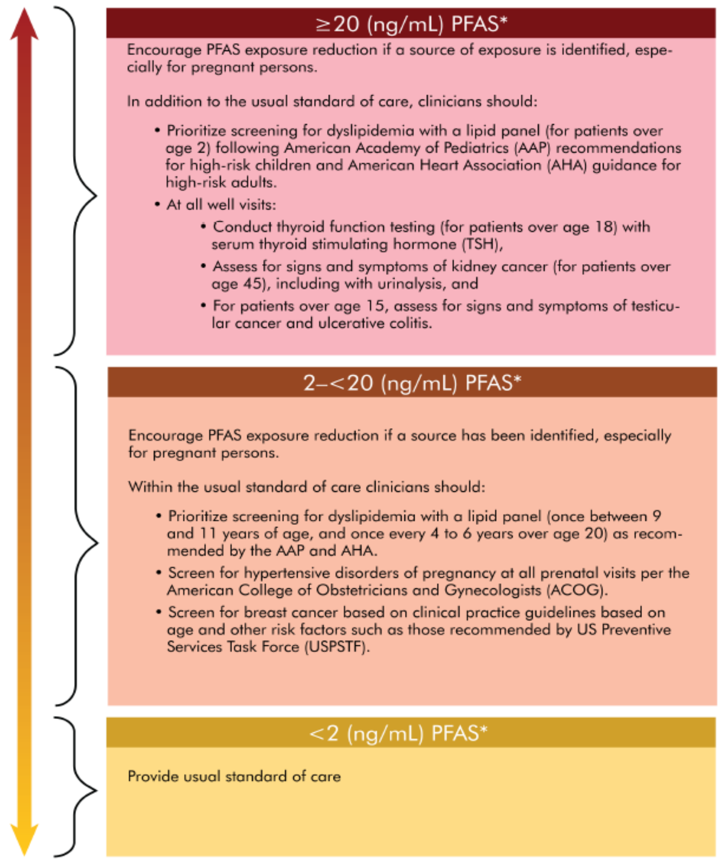
The Centers for Disease Control and Prevention (CDC) and the National Institute of Environmental Health Sciences (NIEHS) tasked the National Academies of Sciences, Engineering and Medicine (NASEM) to form a committee to advise on PFAS testing and clinical care for patients exposed to PFAS. In 2022, the committee published guidance on PFAS exposure, testing and clinical follow-up.

A key recommendation directs clinicians to use the sum of seven PFAS (MeFOSAA, PFHxS, Total PFOA, PFDA, PFUnDA, Total PFOS and PFNA) detected in serum to inform clinical care of exposed patients. The sum of these PFAS can be compared to risk thresholds established by the committee to categorize potential risk of health effects. This is known as the “NASEM Total Value to Inform Clinical Care”, abbreviated throughout this report as NASEM.

Interpreting PFAS blood results in this report

PFAS blood measurements are the accepted biomarker of exposure, but results do not identify the specific source of exposure for an individual. Throughout this report, we present both average PFAS blood concentration values as well as categorizing blood testing using the NASEM sum-of-PFAS approach to summarize potential exposure sources without direct attribution:

- **< 2 ng/mL:** routine standard of care; reinforce exposure-reduction practices.
- **2–< 20 ng/mL:** encourage exposure reduction and prioritize routine screenings already recommended in primary care (e.g., dyslipidemia per age-appropriate guidance; close blood-pressure monitoring in pregnancy).
- **≥ 20 ng/mL:** in addition to the above, clinicians should add thyroid-stimulating hormone testing (>18 y), assess for signs/symptoms of kidney cancer (>45 y, including urinalysis) and assess for signs/symptoms of testicular cancer and ulcerative colitis (>15 y).



* Simple additive sum of MeFOSAA, PFHxS, PFOA (linear and branched isomers), PFDA, PFUnDA, PFOS (linear and branched isomers), and PFNA in serum or plasma

FIGURE 2 Clinical guidance for follow-up with patients after PFAS testing.

Figure 1 compares the Indiana Firefighter sample to the NASEM categories established by the committee. We observed most of the Indiana Firefighter sample to present with a medium risk for adverse health events (88%), with 3.5% living under high risk. The majority of respondents had more than 15 years of experience (Table 3). Analysis of NASEM threshold classifications across years of firefighting experience suggested a cumulative exposure effect over time. All high-risk NASEM observations were among those with more than 15 years of experience.

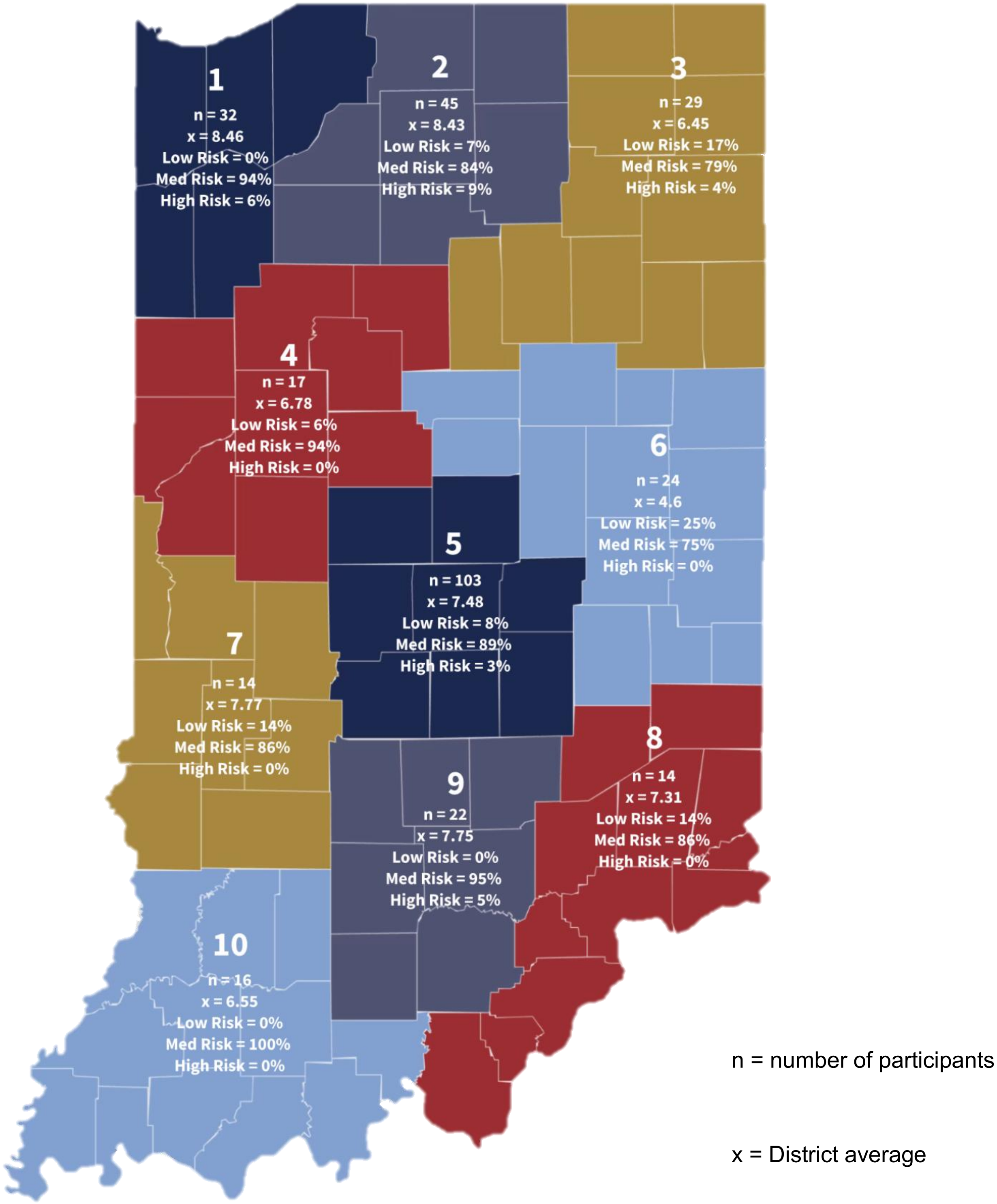
Figure 1. Distribution of NASEM categories (Low/Medium/High) for all participants (n = 316).

Table 3. Total years of participant experience by NASEM category

	Low Risk	Medium Risk	High Risk	Overall
0-5 Years	1 (9.1%)	10 (90.8%)	-	11 (3.5%)
6-10 Years	4 (10.5%)	34 (89.5%)	-	38 (12.0%)
11-15 Years	5 (12.2%)	36 (87.8%)	-	41 (13.0%)
>15 Years	17 (7.5%)	198 (87.6%)	11 (4.9%)	226 (71.5%)

The total participants, average NASEM PFAS value and NASEM category distribution for each Indiana Preparedness District is displayed in Figure 2. The highest NASEM PFAS results were observed in districts 1 (8.46 ng/mL; 6% high risk) and 2 (8.43 ng/mL; 9% high risk). On the other hand, the lowest NASEM PFAS results were observed among participants serving district 6 (4.6 ng/mL; 0% high risk).

Figure 2. NASEM PFAS average values and risk distribution by Indiana Preparedness District



Work activities and materials associated with PFAS biomarkers

What we know from the literature

- **Use scenarios:** Military and civilian firefighters historically used AFFF for fuel fires and ARFF training; these activities elevate occupational PFAS exposure.
- **Measured impacts during ARFF training:** In a Finnish ARFF training study, firefighters' serum PFHxS and PFNA increased following three training sessions using AFFF, despite PPE use and full-face masks—evidence of acute uptake from realistic training.
- **Environmental legacy:** Airports and military bases are documented sources of PFAS contamination in soil and groundwater, creating ongoing potential for secondary exposure during spill response, decon and site work.

Foam use exposure

In total, 235 (74.3%) and 233 (73.7%) participants reported some exposure to AFFF during the course of their work. Two self-reported measures, frequency of using PFAS-containing foams and frequency of exposure to foam during training/incidents, showed potential dose–response patterns between these known exposure sources and PFAS blood concentration. This pattern suggests that increased occupational exposure intensity or duration may increase the blood PFAS concentration.

The frequency of using PFAS-containing firefighting foams was statistically significantly associated with serum PFAS burden. Firefighters who reported daily foam use had a higher proportion of samples in the elevated biomarker categories compared with those who reported less frequent use. The percentage of participants with high-risk NASEM values increased as the frequency of foam use increased. Although daily users represented only a small subset of participants (n=2), one of two fell in the high-risk NASEM category.

Table 4. Self-reported PFAS-containing firefighting foams use frequency by NASEM category.

	Low Risk	Medium Risk	High Risk	Overall
Never	6 (8.0%)	67 (89.3%)	2 (2.7%)	75 (23.7%)
A few times a year	20 (9.3%)	191 (88.4%)	5 (2.3%)	216 (68.4%)
Monthly	-	17 (85.0%)	3 (15.0%)	20 (6.3%)
Weekly	-	3 (100.0%)	-	3 (0.9%)
Daily	1 (50.0%)	-	1 (50.0%)	2 (0.6%)

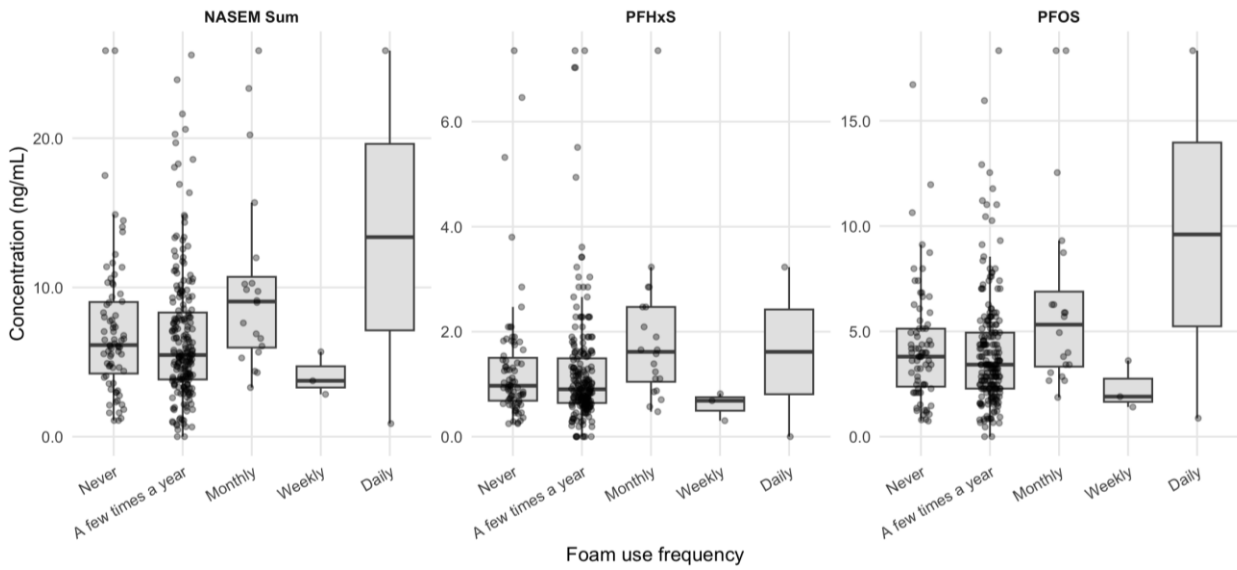
A similar but more moderate trend was observed for self-reported foam exposure during training or firefighting (Table 5). Participants who reported being exposed most shifts or every shift showed a greater proportion of elevated PFAS values than those exposed rarely or only on some shifts, while those who reported never being exposed generally had lower PFAS levels. Although this association did not reach statistical significance, the gradient across exposure categories mirrors the pattern seen for foam use frequency, suggesting that repeated occupational contact with AFFF may contribute to higher systemic PFAS burdens. Taken together, these data suggest a dose-response pattern - more frequent foam use corresponded to higher PFAS concentrations.

A boxplot is a visual summary of how a set of numbers are spread out, it shows where most of the data fall and whether there are any unusually high or low values: a taller box or longer whiskers means the data are more spread out (more variation between people); a shorter box means the values are more similar (less variation); a box higher on the graph means more people have higher values; and the line shows the middle 50^{th} percentile value. The boxplots in Figure 3 display serum concentrations of PFHxS, PFOS and the NASEM composite across categories of firefighting foam use frequency. Although the small number of participants in the most frequent-use categories introduces wider variability, participants who reported more frequent foam use tended to exhibit higher median and interquartile PFAS levels, particularly for PFOS and PFHxS, compounds strongly associated with aqueous film-forming foam (AFFF) exposure profiles. In contrast, firefighters who never or rarely used foam generally had lower PFAS concentrations.

Table 5. Self-reported frequency of exposure to firefighting foam during training or firefighting by NASEM category.

	Low Risk	Medium Risk	High Risk	Overall
Never	1 (12%)	7 (88%)		75 (23.7%)
Rarely	15 (8%)	157 (89%)	5 (3%)	216 (68.4%)
Some Shifts	10 (8%)	110 (89%)	4 (3%)	20 (6.3%)
Most Shifts	1 (17%)	4 (66%)	1 (17%)	3 (0.9%)
Every Shift			1 (100%)	2 (0.6%)

Figure 3. Boxplots for PFHxS, PFOS, and total PFAS concentrations displayed by self-reported foam use frequency.



Gear contact and decontamination practices

What we know from the literature

- **PFAS in gear**: Laboratory and field studies have identified multiple PFAS classes in turnout textiles (outer shells, moisture barriers). Gear can shed PFAS and contribute to contact and dust pathways.
- **Migration/off-gassing**: Coatings used for durable water repellency can release volatile and non-volatile PFAS into indoor air; these compounds have been measured in indoor environments.
- **Handling risk**: Repeated donning/doffing, wear and repairs likely increase transfer of PFAS to hands and station environments, consistent with measured PFAS on station wipes and gear surfaces.
- **Station dust as a reservoir**: Studies in U.S. fire stations measured both total fluorine and specific PFAS in dust. PFAS were also detected on gear stored in stations. This suggests stations can accumulate PFAS from gear and past foam activities, leading to incidental ingestion or inhalation.
- **Dust to serum linkage**: In occupational and office settings, PFAS in indoor dust correlate with serum levels, indicating a plausible contribution pathway, particularly relevant to stations with heavy gear and frequent gear handling.
- **Laundry and wastewater**: Functional textiles with side-chain fluorinated polymers can shed PFAS-bearing microfibers during washing, contributing to wastewater PFAS loads (a facility-level concern for turnout-gear maintenance areas).

In addition to fire response, full gear is commonly worn in medical and vehicle responses. Table 6 displays the summary of self-reported percentage of time fire gear was used by participants during emergency calls.

Table 6. Summary statistics for percentage of time participants wear full gear by emergency call type.

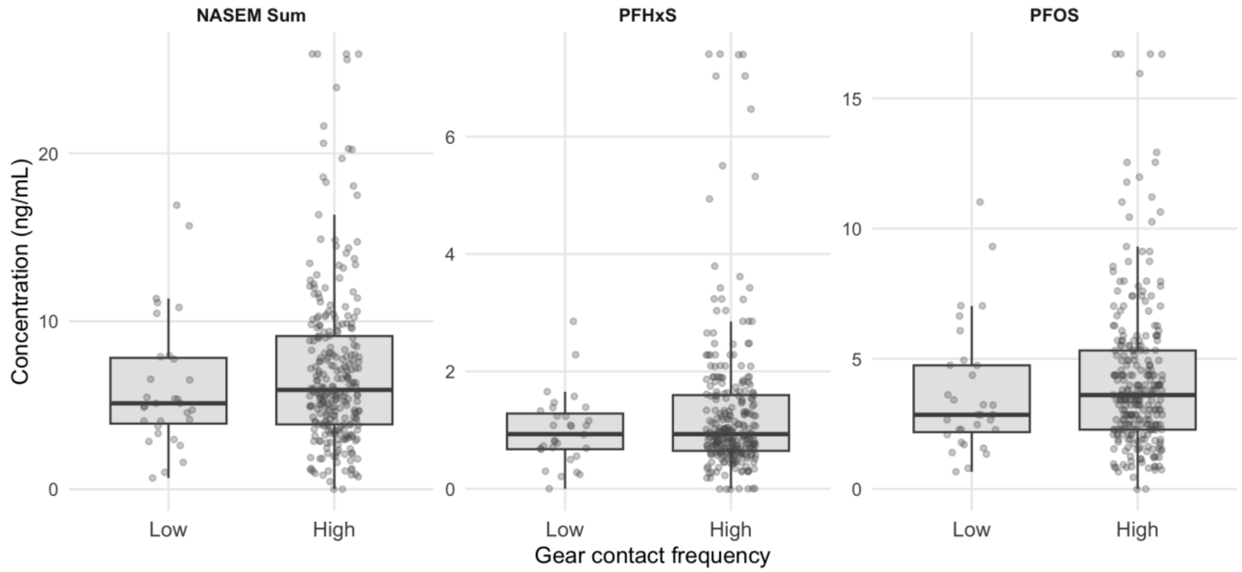
Specialty Task	Minimum	25th %	Median (50th %)	75th %	Maximum	Mean
Fire Response	3%	39%	99%	100%	100%	73.9%
Medical Response	0%	20%	50%	70%	100%	45.1%
Vehicle Response	1%	25%	80%	100%	100%	64.9%

It was observed that participants with more frequent contact with PFAS-containing equipment or gear were more likely to present in the high-risk NASEM category (Table 7). Further exploring this relationship, Figure 4 demonstrates that firefighters who reported high PFAS containing gear contact frequency – those handling or wearing turnout gear during *most or every shift* – tended to have higher median PFAS biomarker levels compared with those with lower gear contact (rarely or only on some shifts). This pattern is most apparent for the NASEM sum and PFOS, both of which include compounds associated with contamination from firefighting gear and foam residues. Although variability is substantial, the distribution shift toward higher concentrations among the high-contact group suggests that repeated or prolonged contact with gear may contribute to elevated systemic PFAS levels.

Table 7. Self-reported frequency of contact with PFAS containing equipment or gear by NASEM category.

	Low Risk	Medium Risk	High Risk	Overall
Rarely	1 (50.0%)	1 (50.0%)	-	2 (0.7%)
Some Shifts	2 (6.9%)	27 (93.1%)	-	29 (9.5%)
Most Shifts	5 (10.6%)	41 (87.2%)	1 (2.1%)	47 (15.4%)
Every Shift	18 (7.9%)	200 (87.7%)	10 (4.4%)	228 (74.5%)

Figure 3. Blood concentrations of NASEM sum, PFHxS and PFOS PFAS biomarkers across gear contact frequency (high vs. low).



Aside from foam use, residues on gear and station dust can be ongoing exposure sources. Routine gear and personal decontamination appear to be protective among participants. A statistically significant association was observed between how often firefighters decontaminated their turnout gear and their PFAS biomarker category (Table 8). Firefighters who reported cleaning their gear after every exposure showed a modestly higher proportion of lower-level PFAS results (16% in low risk, 80% in medium risk) than those who decontaminated less frequently. In contrast, participants who rarely or never decontaminated PPE tended to cluster in the medium or high risk PFAS categories. Although absolute differences are small, the overall pattern suggests that regular gear decontamination is associated with reduced systemic PFAS burden, consistent with the hypothesis that accumulated PFAS residues on gear may serve as a secondary exposure source.

Similarly, self-cleaning behaviors followed a similar, though statistically nonsignificant, trend (Table 9). Participants who reported decontaminating themselves after every exposure (e.g., showering or handwashing) generally showed lower PFAS category distributions compared with those who did so only occasionally or rarely. Those who seldom or inconsistently practiced personal decontamination exhibited slightly higher proportions of elevated PFAS results.

Table 8. Self-reported frequency of decontaminating gear after exposure by NASEM category.

	Low Risk	Medium Risk	High Risk	Overall
Never	-	-	1 (100%)	1 (0.3%)
Rarely	1 (5.6%)	16 (88.9%)	1 (5.6%)	18 (5.7%)
After some exposures	4 (5.3%)	69 (90.8%)	3 (3.9%)	76 (24.1%)
After most exposures	14 (8.2%)	153 (89.5%)	4 (2.3%)	171 (54.1%)
After every exposure	8 (16.0%)	40 (80.0%)	2 (4.0%)	50 (15.8%)

Table 9. Self-reported frequency of self-decontamination after exposure by NASEM category.

	Low Risk	Medium Risk	High Risk	Overall
Rarely	1 (16.7%)	4 (66.7%)	1 (16.7%)	6 (1.9%)
After some exposures	-	29 (96.7%)	1 (3.3%)	30 (9.5%)
After most exposures	7 (6.6%)	94 (88.7%)	5 (4.7%)	106 (33.5%)
After every exposure	19 (10.9%)	151 (86.8%)	4 (2.3%)	174 (55.1%)

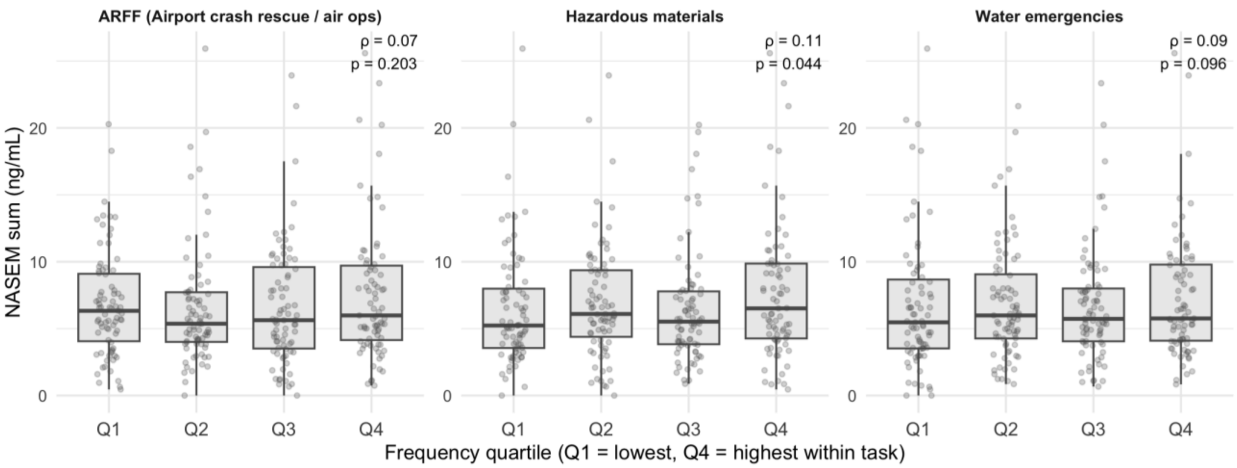
Participants demonstrated wide participation in specialized response activities (Table 10). The most reported specialty was hazardous materials response (23.1% reporting often/very often), followed by water emergencies (13.3%) and construction-related rescues (12.3%). Engagement in other technical disciplines, including airport crash rescue (ARFF), farm-machinery incidents, structural collapse and urban search and rescue, was more infrequent (< 6%).

As shown in Figure 4, the NASEM sum of PFAS concentrations tended to rise modestly across increasing quartiles of task frequency for the three common specialties ARFF, hazardous materials and water emergencies. Although variability was substantial, trends indicated small positive associations between more frequent task participation and higher serum PFAS levels, rising to statistical significance for hazardous materials. These patterns are consistent with incremental PFAS accumulation through repeated contact with contaminated foams, runoff or gear in high-exposure specialties.

Table 10. Self-reported frequency of specialized response activities.

Specialty task	Often or very often
Airport crash rescue/air operations	11 (3.5%)
Hazardous materials	73 (23.1%)
Construction accidents	39 (12.3%)
Water emergencies	42 (13.3%)
Farm machinery	10 (3.2%)
Structural collapse	15 (4.7%)
Urban search & rescue	18 (5.7%)

Figure 4. NASEM PFAS blood concentration quartiles for airport crash and rescue, hazardous materials and water emergencies.



Safety awareness, training, concern and preventive practices

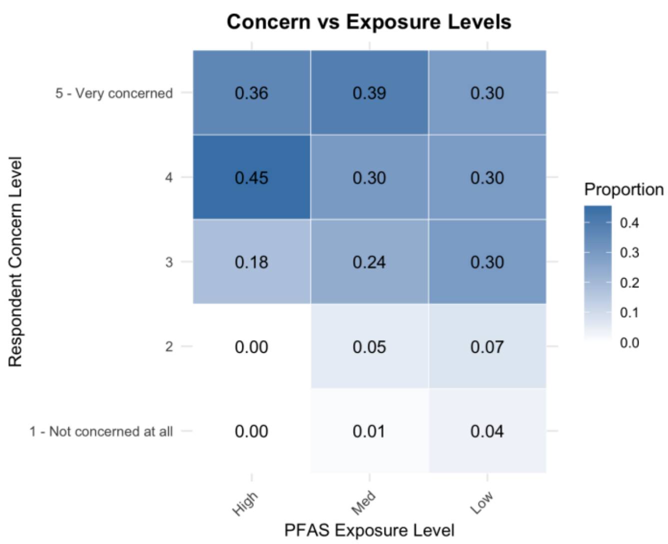
PFAS safety awareness was widespread but uneven (Table 11). Roughly three-quarters of participants reported at least some PFAS safety awareness (Some 44.3%; Fully 32.6%), while nearly one in four (23.1%) reported no awareness at all. Formal training lagged behind awareness, with a majority having not completed PFAS-specific training (72.1%), more than half of which unaware of any training offered (none, unaware; 40.8%; none, aware 31.3%), with only about one quarter (25.6%) reported having completed training. In other words, most firefighters recognize PFAS as a safety issue, but many have not yet received structured exposure mitigation training.

Perceived PFAS risk tracked closely with that awareness profile. Concern levels were skewed high, with 93% selecting moderate to very high concern on a Likert scale (3 = 24.3%; 4 = 30.4%; “Very” = 38.3%); only 1.6% reported “no” concern. Furthermore, those with higher risk NASEM categories were more likely to report greater concern. This combination, broad concern and limited formal training, suggests strong receptivity to practical guidance, standardized procedures and targeted education at the department and state levels.

Table 11. Participant safety awareness, training awareness and level of concern about exposure to PFAS.

Safety awareness	Training awareness	Level of concern (scale)
None - 73 (23.1%)	**None, unaware** - 129 (40.8%)	**1 (none)** - 5 (1.6%)
Some - 140 (44.3%)	**None, aware** - 99 (31.3%)	**2** - 17 (5.4%)
Fully - 103 (32.6%)	**Yes, completed** - 81 (25.6%)	**3** - 77 (24.3%)
	No answer - 7 (2.2%)	**4** - 96 (30.4%)
		5 (very) - 121 (38.3%)

Figure 5. Comparison of participant level of concern with NASEM category.



When we examined whether self-reported preventive behaviors (e.g., storing wipes on apparatus, using alternative foams, regular health screenings, routine PPE or self-decontamination) corresponded to lower PFAS biomarker categories (Table 12), we observed PPE and self-decontamination practices were common (72.8% and 81.6%, respectively) and few reported not taking any preventive measures to reduce PFAS exposure (4.4%). These findings should be interpreted cautiously. First, the prevention measure is broad and self-reported; it may not capture fidelity to specific high-leverage practices (such as on-scene gross decon, bagging contaminated gear or "shower within the hour"), nor their timing relative to long PFAS half-lives. Second, much of a firefighter's cumulative PFAS burden can reflect exposures accrued over years; newer practices may not yet be detectable in current serum profiles.

Table 12. Self-reported preventive measures to limit the exposure to PFAS.

	n (%)
Following safety guidelines and protocols	180 (57%)
Frequent decontamination of PPE	230 (72.8%)
Frequent decontamination of self	258 (81.6%)
Regular health screenings	207 (65.5%)
Storing sanitary wipes on firetruck	174 (55.1%)
Using alternative firefighting foams	125 (39.6%)
None of the above/do not currently take preventative measures to reduce exposure	14 (4.4%)

DISCUSSION AND RECOMMENDATIONS GUIDED BY FEDERAL PFAS INITIATIVES

PRELIMINARY FINDINGS AND PLAUSIBLE EXPOSURE ASSOCIATIONS SUMMARY

This pilot program established a baseline understanding of PFAS blood concentration, demonstrating elevated PFAS blood levels among a small cross section of Hoosier firefighters compared with the general U.S. population (by NASEM's summed metric). These results do not attribute specific exposures as the definitive source of PFAS but describe PFAS blood concentration and potential risk as observed.

The findings, however, provide strong evidence to inform protective action and justify expanded future research, particularly when viewed in the context of the national EPA's PFAS Strategic Roadmap centered on the three main goals to research, restrict and remediate PFAS contamination; along with the recognition by the Department of Defense (DoD) that PFAS-containing firefighting foams (AFFF) must be phased out for training and procurement due to health risks.

The federal government, recognizing the elevated occupational exposure risks faced by firefighters, has executed specific, high-impact actions centered on eliminating known sources, studying long-term exposure and providing clinical guidance.

These steps highlight the national consensus that immediate action is required to protect the fire service and that states like Indiana, through programs like this, are contributing essential data to a rapidly evolving health and policy landscape. Key actions that have been taken at the federal level are summarized in Table 13 below.

Table 13. Summary of major federal initiatives related to PFAS mitigation and prevention.

Focus area	Agency(ies)	Key action
Source elimination (AFFF)	*DoD, Federal Aviation Administration (FAA)*	**Mandated phase-out of AFFF:** The National Defense Authorization Act (NDAA) for Fiscal Year 2020 required the DoD to discontinue the use of PFAS-containing AFFF at all installations by October 1, 2024 (with possible waivers until 2026). The DoD has transitioned to new fluorine-free foams.
Clinical guidance & testing	*NASEM, CDC ATSDR, NIEHS*	**NASEM clinical guidance:** NASEM developed the first authoritative, tiered guidance for clinicians on PFAS exposure, testing and follow-up.
Occupational monitoring	*DoD, NIOSH*	**Firefighter blood testing programs:** The DoD offers annual blood testing to its military and civilian firefighters and is consolidating results for trend analysis. The National Institute for Occupational Safety and Health (NIOSH) is actively studying PFAS exposure and health effects in the fire service.
Equipment research	*NIST*	**Turnout gear analysis:** The National Institute of Standards and Technology (NIST) is analyzing firefighting gear and textiles for PFAS to evaluate the potential for chemical release, supporting the transition to safer PPE.
Incident management	*FAA*	**Testing restrictions:** The FAA issued policy guidance to airports to reduce or eliminate the discharge of AFFF during annual ARFF timed response tests.

With this in mind, these pilot data provide the first occupational exposure baseline for Indiana firefighters, with findings pointing towards plausible exposure pathways that warrant further investigation:

- **Foam matters**. Frequency of AFFF use and foam exposure during training/operations show a dose–response with PFAS biomarkers.
- **Decontamination helps**. Gear decontamination frequency is protectively associated with lower PFAS risk categories; self-decontamination trends the same way.
- **Tasks contribute**. HazMat and water-related specialties – where contact with contaminated runoff/soils and legacy foam sites is plausible – show small but consistent elevations with increasing participation.
- **Gear & station pathways remain plausible**. Frequent gear contact analyses suggest a higher risk for high-contact groups.
- **Most firefighters fall in NASEM's medium-risk band** (88%), with 3% in the high-risk band, which serves as a potential path for exposure-reduction counseling and targeted clinical screening in line with NASEM's interpretation framework.

This pilot establishes an initial, preliminary baseline understanding of PFAS levels in a targeted population of Indiana firefighters. While these data are not conclusive, they serve as a foundation for future, larger-scale efforts, enabling longitudinal studies that track changes in PFAS levels over time and correlate them with health outcomes. This longitudinal approach is essential for understanding the long-term health effects of occupational exposure to these compounds. Indiana is at the forefront of addressing this critical issue. Findings from this pilot can inform targeted public health interventions and policy changes. By identifying the observed types and levels of PFAS in this specific cross section of firefighters, state and local agencies can develop educational campaigns, health screenings and preventative strategies to reduce exposure risks for firefighters. This proactive approach can lead to a healthier workforce and contribute to the broader effort to mitigate PFAS-related health risks within the community.

For policy makers and departmental leadership, these findings suggest three parallel responses are warranted

1. **Advance** future testing and research to understand and combat PFAS.
2. **Protect** firefighters today by driving exposure reduction.
3. **Inform** care by offering sensible, standardized biomonitoring that does not overpromise what testing can do clinically.

Advance – increase testing efforts and research

Federal partners, like the EPA and Council on Environmental Quality (CEQ) have issued reports highlighting the need for expansive data collected to further understand and combat PFAS.

To meaningfully contribute to this ongoing federal work and better protect local communities, there is a great need and high interest in expanded exposure testing and research at the state level.

- **Need for expanded testing:** Given that PFAS are environmentally persistent and found across soil, water and air, we suggest that future work should integrate a more comprehensive methodology, including residential information (e.g., proximity to industrial sites), primary drinking water sources (e.g., well water) and dietary habits. Additionally observational studies could further control for non-occupational exposures through paired testing with spouses or those living in the same house or neighborhood. This expanded scope is necessary to help to better distinguish between potential occupational and non-occupational exposure sources.
- **Firehouse environmental sampling (exposure pathways):** Further testing supports the need to identify environmental PFAS contamination within the fire service ecosystem. This includes sampling for PFAS in fire station dust, turnout gear, apparatus cabs and training grounds. This environmental sampling is a direct way to pinpoint specific departmental exposure pathways for targeted mitigation, supporting efforts by agencies like the National Institute of Standards and Technology (NIST) to analyze firefighter gear.
- **Funding and collaboration**: It is recommended that the Indiana Department of Environmental Management (IDEM) should identify and pursue future funding opportunities (such as those made available through the Bipartisan Infrastructure Law and federal research grants) for environmental PFAS testing and general population biomonitoring, supporting the continued measurement of PFAS exposure in humans and the environment.

Protect – drive exposure reduction

Indiana’s pilot data supports the potential impact of physical and procedural controls. Participants who reported more frequent gear and self-decontamination tended to have lower PFAS categories, while infrequent or no decontamination clustered in intermediate or higher categories. These patterns, coupled with observed dose–response gradients for foam use and foam exposure frequency, support a statewide emphasis on post-incident hygiene, turnout-gear management and station housekeeping as feasible and credible exposure-reduction steps.

Thus, a strategic area of opportunity could be to reduce the potential for contact with PFAS from known sources: legacy foam, contaminated runoff and dust and PFAS-treated textiles. Practical controls include:

- Phasing out AFFF in favor of fluorine-free agents where mission-appropriate;
- Eliminating foam from training;
- Pre-planning containment for any emergency foam use and managing legacy stocks under EPA-consistent disposal practices;
- Reducing the skin, inhalation and hand-to-mouth exposure pathways by implementing station and apparatus controls such as gross decontamination on scene, bagging and prompt laundering of turnout gear, dedicated extractors, clean cab/clean quarters procedures, HEPA vacuuming and wet mopping and keeping gear out of living spaces; and
- Implementing training and practices for gear and self-decontamination following exposure. While roughly three-quarters of participants reported at least some PFAS safety awareness (44.3% Some; 32.6% Fully), the finding that a majority (72.1%) have not received formal, structured exposure mitigation training highlights the critical need to standardize and deliver these protective protocols.

Because exposure is not evenly distributed, approaches could prioritize groups with higher probable contact: ARFF personnel and foam trainers, members in departments with legacy AFFF or historical foam training, firefighters working near PFAS-impacted water sources, pregnant or planning-pregnancy members, early-career firefighters who can benefit most from early habits and roles with frequent gear handling/laundering.

Inform – offer sensible biomonitoring

Voluntary serum testing should be available to all active and retired Indiana firefighters, with outreach prioritized to higher-risk groups (e.g., ARFF, foam trainers, hazardous-materials specialists, departments with legacy foam). To ensure that clinical recommendations are grounded in the best available science supported by federal efforts, ongoing research should use the NASEM summed metric (MeFOSAA, PFHxS, total PFOA, PFDA, PFUnDA, total PFOS, PFNA) to categorize results and anchor follow-up in three action bands that reflect current evidence:

- **< 2 ng/mL**: routine standard of care; reinforce exposure-reduction practices.
- **2–< 20 ng/mL**: encourage exposure reduction and prioritize routine screenings already recommended in primary care (e.g., dyslipidemia per age-appropriate guidance; close blood-pressure monitoring in pregnancy).
- **≥ 20 ng/mL**: in addition to the above, clinicians should add thyroid-stimulating hormone testing (>18 y), assess for signs/symptoms of kidney cancer (>45 y, including urinalysis) and assess for signs/symptoms of testicular cancer and ulcerative colitis (>15 y).

These clinical screening recommendations directly align with the guidance provided by the NASEM, which was requested by the CDC ATSDR and NIEHS to support clinicians in patient care.

All communications should set expectations clearly – **PFAS blood tests measure exposure, not disease**; they do not identify the specific source, do not predict future illness and there is no approved medical treatment to remove PFAS from the body. The utility and optimum interval for repeat testing remain uncertain, so departments should repeat testing only when it will inform prevention program performance (e.g., every 2–3 years to evaluate whether exposure-control policies are working).

To integrate biomonitoring into practice, consider addition of a brief PFAS exposure history module to pre-placement and annual firefighter evaluations (foam use, training frequency, gear handling, decontamination, station hygiene, work/home water sources). Upon testing, provide each participant with a one-page results summary (their NASEM band plus practical steps) and a parallel clinician letter using CDC/ATSDR and National Academies language. Where possible, embed results (de-identified) in a state exposure registry to track trends, support equity in access and avoid widening disparities (concerns the National Academies highlight when testing is available only to those with stable access to care).

STUDY LIMITATIONS

As this was IDHS' first time conducting a pilot program requesting biological sample, it faced some limitations primarily related to the emerging nature of PFAS research and the logistical constraints of the project.

PFAS level baseline

Establishing a baseline for PFAS levels is inherently challenging because there is no single national average since exposure varies significantly by individual, location and even down to the specific PFAS compound. While current scientific research suggests that exposure to certain PFAS may lead to adverse health outcomes, ongoing research is still needed to determine how different levels of exposure to various PFAS compounds can lead to a range of specific health effects. This made it difficult to compare our firefighter population to a general baseline along with making specific correlations to exposure attributes. However, Indiana's proactive stance in studying its firefighting workforce is essential mainly because these individuals are at high risk of exposure from PFAS being found in firefighting foam, equipment and materials.

Logistical limitations

Participant reconsent process for handling PHI

A rather significant logistical limitation was the required reconsent process for handling PHI. While an initial informed consent form was provided at the beginning of the program, the additional reconsent form was required to acknowledge new protocols for handling participant data. This step resulted in an unexpected and substantial delay in our timeline. During this phase, we lost nearly half (47.68%) of our sample with 485 out of the initial 927 respondents reconsenting (52.32%). This reduction in the participant pool meant we could no longer select individuals using our pre-planned study design quota groups designed to ensure a representative sample across various factors such as by Indiana ten districts, rural vs. urban location and years of experience. Instead, we had to prioritize reaching our target of 380 blood samples, which led to a less structured, more generalized sampling approach. Also, the postponement of the second phase may have led to the assumption among some participants that the PFAS Pilot Program had been canceled.

Study design and analysis

This was a cross-sectional, single-point-in-time pilot program. Since we did not set this program up to follow participants over time, we were unable to track changes in their PFAS levels or account for fluctuations due to exposure. Further, this design is incapable of establishing a time relationship between potential exposure sources and PFAS blood concentration, limiting ability to draw causal conclusions about the sources of exposure. This pilot program only included living participants, which excluded individuals who may have been lost, potentially omitting data from a group with unique health outcomes or exposure histories. Additionally, the study design did not allow us to fully explore other potential sources of exposure, such as living environmental factors, water sources or non-occupational contact with PFAS-containing products.

This is a descriptive pilot study that makes no attempt to isolate and attribute specific sources of exposure. For any single result, the underlying mechanism may be confounded by a number of interrelated factors, such as foam use, tenure, department type (e.g., ARFF), gear contact and decontamination behaviors. Future analysis should supplement the descriptive results above with multivariable models (e.g., ordinal logistic regression for NASEM category; quantile regression for PFHxS/PFOS) to estimate adjusted associations.

CONCLUSION

With this pilot, Indiana has positioned itself as a leader in informing and protecting firefighters. The high level of interest and participation in this pilot program not only shows the deep interest among Indiana firefighters but also highlights a collective readiness to contribute to impactful change. The data collected from this project will serve as a pivotal tool, providing the evidence needed to inform proactive health policies, improve safety protocols and protect the well-being of those who dedicate their lives to public service. The pilot study marks a first step, and the continued expansion and analysis of this data will be key to driving meaningful advancements in firefighters' health and safety.

This report was prepared by Delineate, LLC, in collaboration with the Indiana Department of Homeland Security (IDHS).

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APPENDICES

APPENDIX A: SURVEY INSTRUMENT

PFAS exposure among firefighters survey instrument

- **KEY:**
  - * Indicates required field / forced question
  - [BLUE TEXT] – survey question type & format

Consent Page

PFAS Testing Pilot Program

In 2023, the Indiana General Assembly appropriated $200,000 to the Indiana Department of Homeland Security (IDHS) to establish a pilot program to determine if firefighters in Indiana have per- and polyfluoroalkyl substances (PFAS) in their blood.

According to the National Institute of Standards and Technology, PFAS, which are ubiquitous in manufactured products due to their oil- and water-resistant properties, do not break down easily and persist in our bodies and the environment, earning them the moniker of 'forever chemicals.' These suspected carcinogens have found their way into the bodies of most Americans. However, researchers have shown that firefighters are burdened by comparatively high levels of at least one type of PFAS. The U.S. Fire Administration states firefighters are at a higher risk due to exposure from protective gear, products of combustion, and some firefighter foams.

IDHS created a voluntary program where firefighters in Indiana can apply to have their blood tested for PFAS free of charge. The results will be shared with the individual firefighter. The de-identified data collected from the pilot program will be analyzed by IDHS and other state agencies to determine how to better protect Indiana's firefighters from PFAS exposure.

Participation in this study is strictly voluntary, and you may revoke your participation at any time before your data is anonymized, for any reason. **If you wish to withdraw, please click here to access the withdrawal form.**

Study Procedure

1. **To be eligible, you must be an active or retired Indiana firefighter.** If you are an active or retired firefighter in Indiana, and choose to continue, you will be asked a series of questions about your service experience and potential occupational exposure to PFAS using the self-administered survey that follows this page. It will take approximately 10-15 minutes to complete. Completing the survey is required but does not guarantee you will receive a PFAS blood test.

2. If you are selected, you will be notified at the provided email address and a PFAS blood test collection kit will be supplied by Eurofins Scientific. To complete the test, you will follow the directions included in the test kit to collect a small blood sample using a finger prick lancet. To guarantee your PFAS test, your sample must be postmarked for return no later than 14 days after delivery.

3. Eurofins Scientific will analyze your blood sample and results will be provided.

Risks and Benefits

The risks associated with this study are minimal:

1. The potential for disclosure of personally identifiable information. IDHS will mitigate this risk by keeping your survey responses confidential and use them solely for the purposes of this study to understand the relationship between firefighter service and exposure to PFAS. Your reported survey data and PFAS blood test results will not be merged in a manner that can personally identify you. These two sources will be linked using an arbitrary study identifier number and will remain anonymized thereafter.

2. You may spend time completing the survey but are not selected to receive a PFAS blood test.

3. You may experience slight discomfort or bruising at the sight of the finger prick following your self-administrated blood sample collection.

4. There is a possibility that the test results indicate elevated PFAS levels, which may have implications for your health. Elevated PFAS levels have been associated with various health conditions, and learning about high levels could cause you anxiety or distress.

The primary personal benefit of participating in this study is the opportunity to receive a PFAS blood test and obtain the results at no financial cost.

By checking the "I understand and choose to participate in this study" box below and providing your signature, you are indicating that you understand the risks and benefits of participation and are voluntarily consenting to participate in this study.

I understand and choose to participate in this study. [SINGLE SELECT]
I don't wish to participate in this study. [TERMINATE]
First Name [OPEN END TEXT] Last Name [OPEN END TEXT] Date [DATE FIELD]

Signature [ELECTRONIC SIGNATURE PANEL]

Section 1: Demographics

1. First Name:* [OPEN END TEXT]
2. Last Name:* [OPEN END TEXT]
3. Email Address:* [OPEN END TEXT]
4. Phone Number:* [OPEN END TEXT]
5. Public Safety Identification (PSID) Number:* [NUMERIC OPEN END TEXT]
6. Date of Birth:* [NUMERIC OPEN END TEXT]

Section 2: Fire Department / House Affiliation + Experience

We understand many of you have experience with multiple fire departments. To ensure the most accurate data, please consider the following when answering these questions:

- **For current firefighters:** Please answer based on your **current department.**
- **For retired firefighters:** Please answer based on your **most recent department.**

7. What is the **name** of the fire department where you are currently or were most recently previously employed? [OPEN END TEXT, OPTIONAL]
8. What **county** is your current or previous fire department located?* [DROP DOWN OF ALL 92 INDIANA COUNTIES]
9. Which of the following best describes your **department type**? [DROP DOWN, SINGLE SELECT]
    1. Municipal
    2. Volunteer / Combination
    3. Airport
    4. Industrial
10. [SHOW IF Q10.R1 OR R2 ("Municipal" or "Volunteer")] Which of the following best describes the type of community your fire department serves?* [DROP DOWN, SINGLE SELECT]
    1. Rural (less than 2,500 residents)
    2. Suburban (2,600 – 49,999 residents)
    3. Urban (greater than 50,000 residents)

11. How many total years have you served in the fire service overall?* [DROP DOWN, SINGLE SELECT]
    1. 0 – 5 years
    2. 6 – 10 years
    3. 11 – 15 years
    4. More than 15 years
12. What is / was your role(s) in the fire department? [MULTIPLE SELECT]
    1. Firefighter
    2. Fire Officer
    3. EMT / Paramedic
    4. Other (please specify)________
13. [SHOW IF Q12.R1 OR R2] Select the option the best describes your firefighter status.*
    1. Currently employed as a firefighter/ fire officer
    2. Previously employed as a firefighter / fire officer
    3. Retired firefighter / fire officer
14. [SHOW IF Q12.R3] Select the option the best describes your EMT / Paramedic status.*
    1. Currently employed as an EMT / Paramedic
    2. Previously employed as an EMT / Paramedic
    3. Retired EMT / Paramedic
15. For each of the following specialties, please indicate how often you have participated in calls that require that specific skill set during your time as a firefighter either on runs or training. [GRID, SINGLE SELECT PER ROW]

	Never	**Rarely** (Less than 5 times)	**Occasionally** (5-49 times)	**Frequently** (50-100 times)	**Very frequently** (More than 100 times)
Airport crash rescue / air operations					
Hazardous materials					
Construction accidents					
Water emergencies					
Farm machinery					
Structural collapse					
Urban search & rescue					
Other (please specify)					

16. Approximately, how many fires, whether real work incidents or training, have you responded to during your time as a firefighter? Please select a rough estimate.* [SINGLE SELECT]
    1. None – I haven't responded to any fires
    2. Less than 5
    3. 5-49
    4. 50-100
    5. More than 100

Section 3: Exposure Assessment

17. What specific environmental factors or substances are you exposed to during firefighting? [MULTIPLE SELECT, RANDOMIZE]
    1. Smoke inhalation / inhalation of toxic combustion
    2. Benzene
    3. Formaldehyde
    4. Exposure to chemicals (i.e. cleaning agents, solvents)
    5. Contact with hazardous materials (i.e. asbestos, lead)
    6. Contact with contaminated water
    7. Contact with bloodborne pathogens
    8. Exposure to gas (i.e. radon, butane, propane)
    9. Exposure to burning plastics (i.e. hydrogen cyanide, phthalates)
    10. Exposure to high temperatures
    11. Exposure to firefighting foam
    12. Exposure to aqueous film forming foam (AFFF)
    13. Exposure to pesticides
    14. Other (please specify)

18. Do you wear any of your firefighting gear when you are **not on a run or training**? [SINGLE SELECT]
    1. Yes
    2. No
    3. Prefer not to answer

19. During your tenure, on average, what percentage of each type of emergency call do you estimate you have responded to wearing your PPE / fire gear? [NUMERIC, **DOES NOT NEED TO** SUM TO 100%]
    1. Fire calls ____ Medical emergencies ___ Car accidents ____Other ____

Section 4: PFAS Exposure Assessment
In this survey, "PFAS exposure" refers to coming into close contact with PFAS-containing materials, such as firefighting gear and foam, and can include touching these materials or breathing in their dust, aerosols, or fumes.

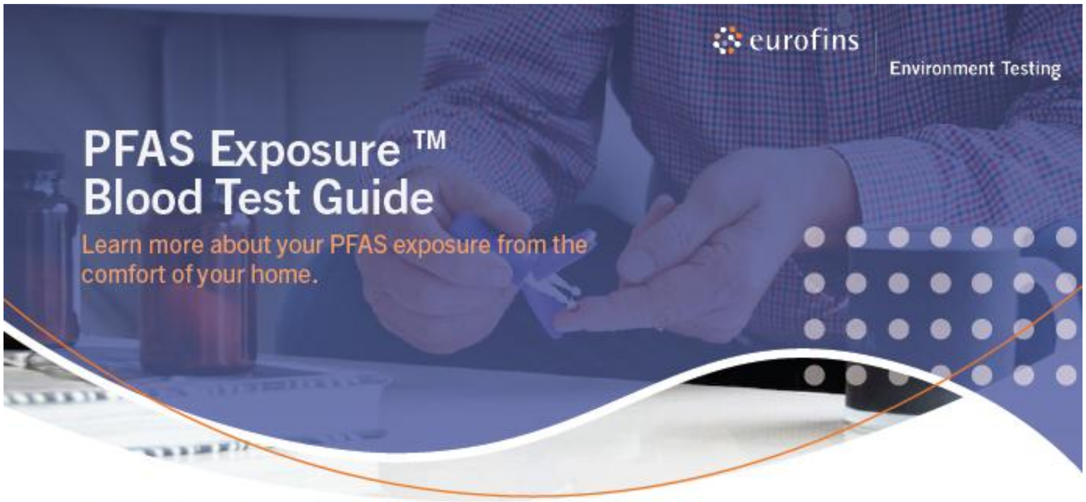
20. On average, how often have you been in contact with **equipment containing PFAS** (e.g. firefighting gear, apparatus and hardware)? [SINGLE SELECT]
    1. Every shift
    2. Most shifts
    3. Some shifts
    4. Rarely
    5. Never
    6. Don’t know
21. How frequently do you use **PFAS-containing firefighting foams**? [SINGLE SELECT]
    1. Daily
    2. Weekly
    3. Monthly
    4. A few times a year
    5. Never
22. How often were you exposed to **firefighting foam** during training or actual firefighting? [SINGLE SELECT]
    1. Every shift
    2. Most shifts
    3. Some shifts
    4. Rarely
    5. Never
23. How often do you **decontaminate** *your PPE* after exposure? [SINGLE SELECT]
    1. After every exposure
    2. After most exposures
    3. After some exposures
    4. Rarely
    5. Never
24. How often do you **decontaminate** *yourself* after exposure? [SINGLE SELECT]
    1. After every exposure
    2. After most exposures
    3. After some exposures
    4. Rarely
    5. Never

Section 5: Health and Safety PFAS Practices

25. Are you aware of any health guidelines or safety practices related to PFAS exposure in your fire department? [SINGLE SELECT]
    1. Yes, fully aware
    2. Yes, but little knowledge / awareness
    3. No
26. Have you received information, educational material, or been part of any trainings on the risks of PFAS exposure offered by your fire department? [MULTIPLE SELECT]
    1. Yes, I have participated in formal trainings from my fire department on PFAS exposure risks.
    2. Yes, I have received educational materials (i.e. pamphlet, brochure, online resources) from my fire department about PFAS exposure risks.
    3. Yes, I have heard some information about PFAS exposure risks from my fire department, but I haven't received formal training or materials.
    4. No, I haven't received any information or training on PFAS exposure risks from my fire department.
    5. Prefer not to answer
27. How concerned are you about the potential health impacts of PFAS exposure in your role as a firefighter? [Likert Scale, 1-5]
    1. 1 – Not concerned at all
    2. 2
    3. 3
    4. 4
    5. 5 – Very concerned
28. How frequently do you donate blood?
    1. Regularly (more than 5 times per year)
    2. Sometimes (2-4 times per year)
    3. Rarely (once a year)
    4. I have in the past, but do not donate regularly
    5. Never
29. What steps do you take to reduce your exposure to PFAS on the job? [MULTIPLE SELECT]
    1. Using alternative firefighting foams
    2. Frequent decontamination of PPE
    3. Frequent decontamination of self
    4. Regular health screenings
    5. Following safety guidelines and protocols
    6. Storing sanitary wipes on firetruck
    7. Other (please specify)
    8. None of the above / not interested

APPENDIX B: BLOOD SAMPLE TEST KIT INSTRUCTIONS

Eurofins PFAS Exposure Blood Test Guide literature



What are PFAS?

Per- and Polyfluorinated Alkyl Substances (PFAS), such as PFOA and PFOS, are "forever chemicals" that resist natural breakdown in both our environment and our bodies.

These chemicals were created intentionally to resist heat, stains, oil, and water. They can be found in Aqueous Film Forming Foam (AFFF) firefighting products and a variety of consumer products. These include food packaging, carpet, clothes, cosmetics, cookware, and cleaning products.

PFAS can also be found in your surrounding environment: soil, air, drinking water, and ground water. Exposure to certain PFAS is associated with a number of negative health outcomes including certain types of cancer, impaired immune response, elevated cholesterol, changes in liver enzymes, decreased birth weight, and pre-eclampsia[1].

What do my lab values mean?

Nearly all Americans have PFAS in their blood due to their persistence in the body and the environment. Your results, combined with the information provided in our test guide, will tell you if your exposures are at, below, or above the average American's exposure levels. This is an environmental exposure test used for research and informational purposes only.

Biomonitoring for PFAS in humans has been conducted by the Centers for Disease Control and Prevention (CDC) on serum for many years. The CDC publishes and updates national averages for this serum data based on the National Health and Nutrition Examination Survey (NHANES). This is where the national averages are generated from. To date, the CDC only monitors for 16 PFAS compounds in the general population. In 2020, the National Academies of Sciences, Engineering and Medicine (NASEM) established guidance for practitioners on when to recommend testing and how to interpret the results, which include risk thresholds to compare test results to.

Serum Equivalent Your results are based on the newest technology for whole blood. The serum equivalent is the conversion from whole blood to serum to allow you to compare your results to the national averages generated by the CDC and the risk thresholds established by the NASEM. Of the PFAS analytes tested and shown in your lab report, 7 of these analytes have a serum equivalent. These are the same 7 PFAS that NASEM has provided risk thresholds for. Values from NHANES and NASEM have been provided in this test guide for easy comparison.

17006 0324

1 Potential Health Effects of PFAS Chemicals." Centers for Disease Control and Prevention, 24 June 2020, www.atsdr.cdc.gov/pfas/health-effects/index.html.

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KEY TERMS

Below are some key terms to help you better understand your lab results:

ANALYTE
The name of the specific PFAS tested

RESULT
A number reported means that the lab was able to detect the specific PFAS tested in your blood

ND (NOT DETECTED)
The specific PFAS tested might not be there at all, or it could be present at such a low level that the lab could not reliably measure it.

REPORTING LIMIT
Represents the lowest amount of that specific PFAS that the lab can reliably measure in blood samples

SERUM EQUIVALENT
Your results are based on the newest technology for whole blood. The serum equivalent is the conversion from whole blood to serum to allow you to compare your results to the national averages generated by the CDC. Of the PFAS analytes tested and shown in your lab report, 7 of these analytes have a serum equivalent. These comparisons have been provided in this test guide as individual pages.

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Is there a safe level of exposure for these chemicals?

Safe exposure levels are being developed for certain PFAS chemicals. With the establishment of these levels, the Environmental Protection Agency (EPA) and several states have begun the process of regulating PFAS in drinking water. The establishment of toxicity levels is still in progress and there are no current clinical diagnoses specific to elevated PFAS levels. With the establishment of the NASEM guidance document there are recommendations for practitioners to inform clinical care.

What can I do if PFAS are present in my body?

The following recommendations from the Agency for Toxic Substances and Disease Registry (ATSDR) may help limit and reduce your exposure to PFAS chemicals[1]:

Reduce your use of consumer products associated with PFAS chemicals:

- Water repellent clothing, furniture, flooring
- Stain resistant clothing, furniture, carpeting
- Cleaning products with similar water repellent or stain resistant properties
- Fast food and take-out food wrappers or containers
- Non-stick cookware
- Paints, varnishes, and sealants
- Personal care products

- Avoid contaminated drinking water and water used for food preparation. Check with your local health department about your water quality.
- Avoid eating contaminated fish. Check with your local health and environmental quality departments for fish advisories.

1 Agency for Toxic Substances and Disease Registry. Per- and Polyfluoroalkyl Substances (PFAS) and Your Health. https://www.atsdr.cdc.gov/pfas/resources/pfas-faqs.html

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NASEM Thresholds

The Centers for Disease Control and Prevention (CDC) and the National Institute of Environmental Health Sciences (NIEHS) asked the National Academies of Sciences, Engineering, and Medicine (NASEM) to form a committee to advise on PFAS testing and clinical care for patients exposed to PFAS. In 2022, the committee published the following: **Guidance on PFAS Exposure, Testing, and Clinical Follow-Up.**

A key recommendation directs clinicians to use the sum of seven PFAS (MeFOSAA, PFHxS, Total PFOA, PFDA, PFUnDA, Total PFOS, and PFNA) detected in serum to inform clinical care of exposed patients. The sum of these PFAS can be compared to the table provided for an understanding of risk thresholds established by the committee.

<2 (ng/mL) PFAS
Adverse health effects not expected

2 - <20 (ng/mL) PFAS
Potential for adverse health effects, especially for sensitive populations

≥20 (ng/mL) PFAS
Increased risk of adverse health effects

To compare your results to the NASEM established risk thresholds, locate your "NASEM Total Value To Inform Clinical Care" serum equivalent found here:

CDC NHANES Analytes:

Analyte	Result	Reporting Limit	Serum Equivalent	Unit
L-Perfluorooctanoic acid	21	0.30	See "Total PFOA"	ng/mL
Br-Perfluorooctanoic acid	0.33	0.30	See "Total PFOA"	ng/mL
Total PFOA	21	0.30	42	ng/mL
L-Perfluorooctanesulfonic acid	0.55	0.20	See "Total PFOS"	ng/mL
Br-Perfluorooctanesulfonic acid	0.50	0.20	See "Total PFOS"	ng/mL
Total PFOS	1.1	0.20	2.09	ng/mL
N-methylperfluorooctanesulfonamidoacetic acid (NMeFOSAA)	ND	0.10	ND	ng/mL
Perfluorodecanoic acid (PFDA)	ND	0.20	ND	ng/mL
Perfluorohexanesulfonic acid (PFHxS)	1.2	0.10	2.28	ng/mL
Perfluorononanoic acid (PFNA)	ND	0.20	ND	ng/mL
Perfluoroundecanoic acid (PFUnA)	ND	0.10	ND	ng/mL
*NASEM Total Value To Inform Clinical Care:			46.37	ng/mL

These biomonitoring lab results are intended for informational and educational purposes only. Information from Eurofins Environment Testing is not meant to serve as treatment advice or treatment recommendation for any health condition. We strongly recommend you review lab results with your physician.

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What if PFAS are Detected in my Blood?

It's estimated that 98% of the US population has detectable levels of PFAS in their blood. This information comes from the CDC NHANES study of the general population[1]. You can understand how your values compare to national averages by comparing your test results to the CDC's most recent NHANES 2017-2018 data provided in subsequent pages of this test guide.

It is important to note PFAS are foreign substances and there is no 'normal range' for detectable levels in human blood. Higher levels of certain PFAS are associated with various health conditions[2].

If an analyte is highlighted in blue on your lab report, then the lab detected it in your blood sample.
Find the "Serum Equivalent" column and identify your serum equivalent value.
This is the value you will use to compare to the national averages determined by the CDC.

Sample Report	Analyte	Result	Reporting Limit	Serum Equivalent	Unit
	Total PFOA	XX.XX	XX.XX	XX.XX	

1 National Report on Human Exposure to Environmental Chemicals. Biomonitoring Data Tables for Environmental Chemicals https://www.cdc.gov/exposurereport/data_tables.html

2 "Potential Health Effects of PFAS Chemicals." Centers for Disease Control and Prevention, Centers for Disease Control and Prevention, 24 June 2020, www.atsdr.cdc.gov/pfas/health-effects/index.html.

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Total PFOA
CDC Name: Serum Perfluorooctanoic acid

Percentage of the total US population with Total PFOA in their bloodstream

1.47
Middle Range
EXPOSURE
Half of the population is above this level and half is below.
(50th Percentile)

2.07
Upper Range
EXPOSURE
Only 25% of the study population is above this level.
(75th Percentile)

3.77
Highest Range
EXPOSURE
Only 5% of the study population is above this level.
(95th Percentile)

Total PFOS
CDC Name: Serum Perfluorooctane sulfonic acid

Percentage of the total US population with Total PFOS in their bloodstream

4.30
Middle Range
EXPOSURE
Half of the population is above this level and half is below.
(50th Percentile)

7.50
Upper Range
EXPOSURE
Only 25% of the study population is above this level.
(75th Percentile)

14.6
Highest Range
EXPOSURE
Only 5% of the study population is above this level.
(95th Percentile)

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PFDA | Perfluorodecanoic acid

CDC Name: Serum Perfluorodecanoic acid

Percentage of the total US population with Total PFDA in their bloodstream

0.200
Middle Range
EXPOSURE
Half of the population is above this level and half is below.
(50th Percentile)

0.300
Upper Range
EXPOSURE
Only 25% of the study population is above this level.
(75th Percentile)

0.600
Highest Range
EXPOSURE
Only 5% of the study population is above this level.
(95th Percentile)

PFHpS | Perfluoroheptanesulfonic acid

CDC Name: Serum Perfluoroheptane sulfonic acid

Percentage of the total US population with Total PFHpS in their bloodstream

0.200
Middle Range
EXPOSURE
Half of the population is above this level and half is below.
(50th Percentile)

0.400
Upper Range
EXPOSURE
Only 25% of the study population is above this level.
(75th Percentile)

1.00
Highest Range
EXPOSURE
Only 5% of the study population is above this level.
(95th Percentile)

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PFAS Exposure Blood Test Guide

PFHxS | Perfluorohexanesulfonic acid
CDC Name: Serum Perfluorohexane sulfonic acid

Percentage of the total US population with Total PFHxS in their bloodstream

1.10
Middle Range
EXPOSURE
Half of the population is above this level and half is below.
(50th Percentile)

1.90
Upper Range
EXPOSURE
Only 25% of the study population is above this level.
(75th Percentile)

3.70
Highest Range
EXPOSURE
Only 5% of the study population is above this level.
(95th Percentile)

PFNA | Perfluorononanoic acid
CDC Name: Serum Perfluorononanoic acid

Percentage of the total US population with Total PFNA in their bloodstream

0.400
Middle Range
EXPOSURE
Half of the population is above this level and half is below.
(50th Percentile)

0.700
Upper Range
EXPOSURE
Only 25% of the study population is above this level.
(75th Percentile)

1.40
Highest Range
EXPOSURE
Only 5% of the study population is above this level.
(95th Percentile)

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PFAS Exposure Blood Test Guide

PFUnA Perfluoroundecanoic acid

CDC Name: Serum Perfluoroundecanoic acid (PUFA or PFUnDA)

Percentage of the total US population with Total PFUnA in their bloodstream

0.100
Middle Range
EXPOSURE
Half of the population is above this level and half is below.
(50th Percentile)

0.200
Upper Range
EXPOSURE
Only 25% of the study population is above this level.
(75th Percentile)

0.400
Highest Range
EXPOSURE
Only 5% of the study population is above this level.
(95th Percentile)

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APPENDIX C: PFAS EXPOSURE ANALYTICAL LAB REPORT EXAMPLE

Client Sample Results

Job ID: 320-99999-1

Client Sample ID: Jane Doe	**Lab Sample ID: 320-99999-1**
Specimen Source Name:	**Date Collected: 04/05/2023**
Date Of Birth:	**Date Received: 04/06/2023**
Method: PFAS Exposure - Whole Blood Test	

CDC NHANES Analytes:

Analyte	Result	Reporting Limit	Serum Equivalent	Unit
L-Perfluorooctanoic acid	**21**	0.30	See "Total PFOA"	ng/mL
Br-Perfluorooctanoic acid	**0.33**	0.30	See "Total PFOA"	ng/mL
Total PFOA	**21**	0.30	42	ng/mL
L-Perfluorooctanesulfonic acid	**0.55**	0.20	See "Total PFOS"	ng/mL
Br-Perfluorooctanesulfonic acid	**0.50**	0.20	See "Total PFOS"	ng/mL
Total PFOS	**1.1**	0.20	2.09	ng/mL
N-methylperfluorooctanesulfonamidoacetic acid (NMeFOSAA)	ND	0.10	ND	ng/mL
Perfluorodecanoic acid (PFDA)	ND	0.20	ND	ng/mL
Perfluorohexanesulfonic acid (PFHxS)	**1.2**	0.10	2.28	ng/mL
Perfluorononanoic acid (PFNA)	ND	0.20	ND	ng/mL
Perfluoroundecanoic acid (PFUnA)	ND	0.10	ND	ng/mL
***NASEM Total Value To Inform Clinical Care:**			**46.37**	ng/mL
9Cl-PF3ONS	ND	0.10	ND	ng/mL
4,8-Dioxa-3H-perfluorononanoic acid (ADONA)	ND	0.10	ND	ng/mL
Hexafluoropropylene Oxide Dimer Acid (HFPO-DA)	ND	0.10	ND	ng/mL
Perfluoroheptanesulfonic acid (PFHpS)	**0.30**	0.20	0.75	ng/mL
Perfluorohexanoic acid (PFHxA)	ND	0.50	ND	ng/mL

Eurofins Expanded Analyte List:

Analyte	Result	Reporting Limit	Serum Equivalent	Unit
Perfluoroheptanoic acid (PFHpA)	ND	0.10	ND	ng/mL
Perfluorododecanoic acid (PFDoA)	ND	0.10	ND	ng/mL
Perfluorotridecanoic acid (PFTriA)	ND	0.10	ND	ng/mL
Perfluorotetradecanoic acid (PFTeDA)	**0.10**	0.10	Not Available	ng/mL
Perfluoro-n-hexadecanoic acid (PFHxDA)	**0.17**	0.10	Not Available	ng/mL
Perfluorobutanesulfonic acid (PFBS)	ND	0.10	ND	ng/mL
Perfluoropentanesulfonic acid (PFPeS)	ND	0.10	ND	ng/mL
Perfluorononanesulfonic acid (PFNS)	ND	0.20	ND	ng/mL
Perfluorodecanesulfonic acid (PFDS)	ND	0.10	ND	ng/mL
Perfluorododecanesulfonic acid (PFDoS)	ND	0.10	ND	ng/mL
Perfluorooctanesulfonamide (PFOSA)	ND	0.10	ND	ng/mL
N-ethylperfluorooctanesulfonamidoacetic acid (NEtFOSAA)	ND	0.20	ND	ng/mL
1H,1H,2H,2H-Perfluorohexane sulfonic acid (4:2 FTS)	ND	0.50	ND	ng/mL
1H,1H,2H,2H-Perfluorodecane sulfonic acid (8:2 FTS)	ND	0.50	ND	ng/mL
1H,1H,2H,2H-Perfluorododecane sulfonic acid (10:2 FTS)	ND	0.50	ND	ng/mL
11Cl-PF3OUdS	ND	0.10	ND	ng/mL
5:3 FTCA	ND	0.20	ND	ng/mL
7:3 FTCA	ND	0.20	ND	ng/mL
6:2 FTCA	ND	0.20	ND	ng/mL
6:2 FTUCA	ND	0.20	ND	ng/mL
Nonafluoro-3,6-dioxaheptanoic acid (NFDHA)	ND	0.50	ND	ng/mL
Perfluoro-4-methoxybutanoic acid (PFMBA)	ND	0.10	ND	ng/mL
Perfluoro (2-ethoxyethane) sulfonic acid (PFEESA)	ND	0.10	ND	ng/mL
8:2 FTCA	ND	0.20	ND	ng/mL
8:2 FTUCA	ND	0.10	ND	ng/mL
PFECHS	ND	0.10	ND	ng/mL
PFPE-1	ND	0.50	ND	ng/mL
PFO5DA	ND	0.20	ND	ng/mL
Hydro-PS Acid	ND	0.10	ND	ng/mL

PFAS Exposure™ results require conversion from PFAS in whole-blood to PFAS in serum in order to compare to the CDC (Centers for Disease Control and Prevention) national averages for PFAS or the National Academies of Science, Engineering and Medicine (NASEM) thresholds. Your results can easily be compared using the values in the "Serum Equivalents" column.

This is an environmental exposure analysis, commonly referred to as biomonitoring. This is not a clinical test. There is no diagnosis specific to the presence of PFAS in human blood and there is no treatment for elevated PFAS levels. This information serves as an indicator of environmental exposure to PFAS.

Eurofins Sacramento - Page 1 of 1

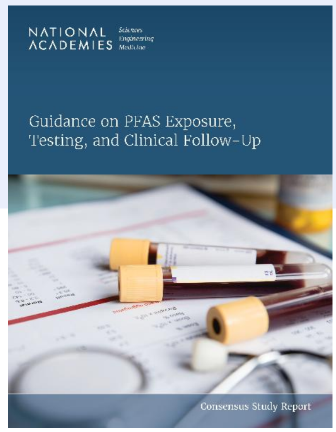
APPENDIX D: SUPPLEMENTAL PFAS INFORMATION FOR CLINICAL GUIDANCE

NASEM PFAS Guidance highlights

NATIONAL ACADEMIES Sciences Engineering Medicine

Consensus Study Report
Highlights

Guidance on PFAS Exposure, Testing, and Clinical Follow-Up



Perfluoroalkyl and polyfluoroalkyl substances (PFAS) are a class of chemicals that includes over 12,000 different compounds, some of which are linked to health effects including certain cancers, thyroid dysfunction, small reductions in birth weight, and high cholesterol. PFAS are used in thousands of products, such as water and stain proof fabrics, non-stick cookware, and fire-fighting foams, because they have desirable chemical properties that repel oil and water, reduce friction, and resist temperature changes. PFAS compounds are often referred to as "forever chemicals" because they are resistant to degradation and when they do break down, the chemical products will include another PFAS.

An estimated 2,854 U.S. locations (in all 50 states and two territories) have some level of PFAS contamination (Figure 1). Although not all of the contamination exceeds health advisories, the pervasiveness of the contamination is alarming. The people who live, work, and play in environments where PFAS contamination exceeds standards most often do not know how to protect themselves from the health risks of exposure. Some members of communities who have discovered their exposure exceeds health advisory levels are calling for a medical program that prevents, leads to early disease detection, or treats diseases related to the health risks they may face.

To help clinicians respond to patient concerns about PFAS exposure, the Agency for Toxic Substances Disease Registry (ATSDR) published guidance for clinicians that summarizes general information about PFAS and PFAS health studies and suggests answers to example patient questions. However, the ATSDR's guidance does not provide specific recommendations on when to test for PFAS, how to interpret the results, or what clinical follow-up based on PFAS exposure might look like. Conducted at the request of ATSDR and the National Institute of Environmental Health Sciences (NIEHS), this report develops principles and recommendations for biological testing for PFAS exposure and

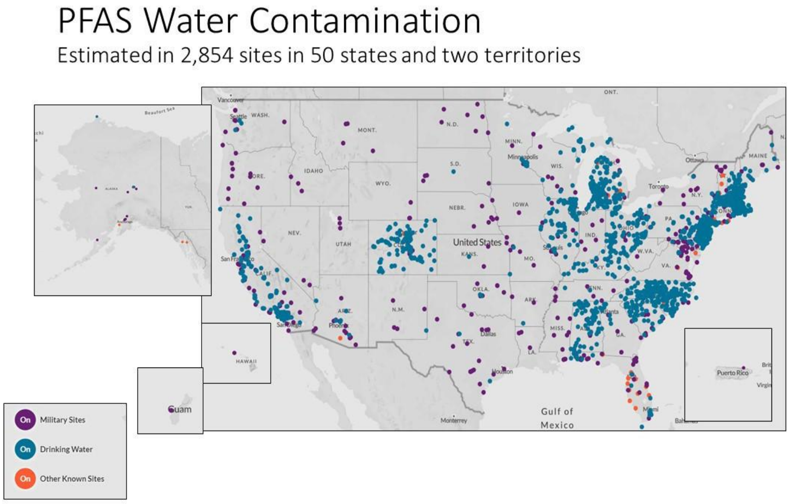


FIGURE 1 PFAS Contamination Across the U.S. SOURCE: Environmental Working Group (EWG).

clinical evaluation for those exposed to help ATSDR update its guidance.

POTENTIAL HEALTH EFFECTS OF PFAS

In order to determine the health effects of PFAS, the Committee conducted a literature review of studies that evaluated the effects of PFAS in humans. The committee's review focused on the PFAS compounds that are currently being measured in the National Health and Nutrition Examination Survey.[1] The Committee synthesized available evidence, including previous decisions from other authoritative bodies and more recent human studies, into four categories of "strength of evidence" used by other National Academies' committees: (1) Sufficient evidence of an association; (2) Limited suggestive evidence of an association; (3) Inadequate or insufficient evidence of an association; and (4) Limited suggestive evidence of no association. The Committee's conclusions are summarized in Table 1. Because most people are exposed to mixtures of PFAS, making it difficult to disentangle the specific effects of each PFAS, the Committee provided one strength of evidence determination for all PFAS for each health effect.

PFAS EXPOSURE REDUCTION

The primary exposure route to PFAS in non-occupational settings is likely ingestion. This may include drinking contaminated water and eating contaminated foods such as vegetables, fish, wildlife, meat, or dairy products from contaminated soil or water. PFAS are often used in food contact materials such as microwave popcorn bags or packaging of fast foods or processed foods. Exposure may also occur when dust containing PFAS is ingested. PFAS can transfer to the fetus during pregnancy, and in early life through feeding with formula made with contaminated water or through breastfeeding. Inhalation is the most common pathway in occupational settings, and is a route of exposure for people living near fluorochemical plants, or incinerators. Dermal exposure has not been well-studied but could be possible.

To advise patients who would like to reduce their exposure to PFAS, clinicians should: (1) talk with their patients to determine if and how they might be exposed to PFAS; (2) advise that those with occupational exposure

[1] PFAS compounds currently being measured in the National Health and Nutrition Examination Survey are perfluorooctanoic acid (PFOA), perfluorooctanesulfonic acid (PFOS), perfluorohexanesulfonic acid (PFHxS), perfluorononanoic acid (PFNA), Perfluorodecanoic acid (PFDA), Perfluoroundecanoic acid (PFuDA), and Methyl-perfluorooctane sulfonamide (MeFOSAA)

TABLE 1

CATEGORY OF ASSOCIATION	HEALTH OUTCOMES WITH INCREASED RISK ASSOCIATE WITH PFAS EXPOSURE
++ **Sufficient evidence of an association** Based on strong evidence, there is high confidence that there is an association between exposure to PFAS and the health outcome. It is unlikely that the association is due to chance or bias.	• Decreased antibody response (in adults and children) • Dyslipidemia (in adults and children) • Decreased infant and fetal growth • Increased risk of kidney cancer (in adults)
+ **Limited suggestive evidence of an association** Based on limited evidence, there is moderate confidence that there is an association between exposure to PFAS and the health outcome. It is possible that the association is due to chance or bias.	• Increased risk of breast cancer (in adults) • Liver enzyme alterations (in adults and children) • Increased risk of pregnancy-induced hypertension (gestational hypertension and preeclampsia) • Increased risk of testicular cancer (in adults) • Thyroid disease and dysfunction (in adults) • Increased risk of ulcerative colitis (in adults)
? **Inadequate or Insufficient Evidence to Determine an Association** Based on inconsistent evidence, a lack of evidence, or evidence of insufficient quality, there is moderate confidence that there is an association between exposure to PFAS and the health outcome. No conclusion can be made about a potential association.	• Immune effects other than reduced antibody response, and ulcerative colitis; Cardiovascular outcomes other than dyslipidemia; • Developmental outcomes other than small reductions in birthweight • Cancers other than kidney, breast, and testicular; Reproductive effects other than hypertensive disorders of pregnancy; Endocrine disorders other than thyroid hormone levels; Hepatic effects other than liver enzyme levels; Respiratory effects; Hematological effects • Musculoskeletal effects, such as effects on bone mineral density; Renal effects, such as renal disease; Neurological effects
– **Limited Suggestive Evidence of No Association** Based on at least limited evidence, there is at least moderate confidence that there is NO association between PFAS and the health outcome.	• No outcomes were identified.

to PFAS consult with occupational health and safety professionals about reducing exposure; (3) advise individuals with elevated PFAS in their drinking water to filter their water; (4) advise patients living in areas of known PFAS contamination that PFAS can be present in fish, wildlife, meat, and dairy. Clinicians counseling parents of infants on PFAS exposure should discuss infant feeding and steps that can be taken to lower sources of exposure to PFAS.

PFAS TESTING AND LEVELS THAT CAN INFORM CLINICAL CARE

Report advises ATSDR to update its guidance to say, clinicians should offer PFAS blood testing to patients who are likely to have a history of elevated exposure to PFAS. PFAS testing has many potential benefits, such as empowering people to manage their own health, but it also carries some harms, such as stress or concern about the health effects of PFAS exposure. Decisions about PFAS testing require shared, informed decision making between patient and clinician. Clinicians should explain that exposure biomonitoring may provide important information about an individual's exposure levels which might guide clinical follow-up. But PFAS testing measures exposure at the time of sample collection, and a person with low levels today may have had higher levels in the past. At the same time, this information cannot indicate or predict how likely it is that an individual will end up with a particular condition. Discussions about PFAS testing should always include information about how PFAS exposure occurs, potential health effects of PFAS, limitations of PFAS testing, and the benefits and harms of PFAS testing.

To determine PFAS levels in serum or plasma that could inform clinical care, the Committee considered publications from the Human Biomonitoring Commission in Germany and the European Food Safety Authority. These organizations determined guidance values that can be interpreted as levels below which health effects are unlikely to be observed, and levels above which effects have been observed in both the general population and more sensitive groups such

≥20 (ng/mL) PFAS*

Encourage PFAS exposure reduction if a source of exposure is identified, especially for pregnant persons.

In addition to the usual standard of care, clinicians should:

- Prioritize screening for dyslipidemia with a lipid panel (for patients over age 2) following American Academy of Pediatrics (AAP) recommendations for high-risk children and American Heart Association (AHA) guidance for high-risk adults.
- At all well visits:
  - Conduct thyroid function testing (for patients over age 18) with serum thyroid stimulating hormone (TSH),
  - Assess for signs and symptoms of kidney cancer (for patients over age 45), including with urinalysis, and
  - For patients over age 15, assess for signs and symptoms of testicular cancer and ulcerative colitis.

2–<20 (ng/mL) PFAS*

Encourage PFAS exposure reduction if a source has been identified, especially for pregnant persons.

Within the usual standard of care clinicians should:

- Prioritize screening for dyslipidemia with a lipid panel (once between 9 and 11 years of age, and once every 4 to 6 years over age 20) as recommended by the AAP and AHA.
- Screen for hypertensive disorders of pregnancy at all prenatal visits per the American College of Obstetricians and Gynecologists (ACOG).
- Screen for breast cancer based on clinical practice guidelines based on age and other risk factors such as those recommended by US Preventive Services Task Force (USPSTF).

<2 (ng/mL) PFAS*

Provide usual standard of care

* Simple additive sum of MeFOSAA, PFHxS, PFOA (linear and branched isomers), PFDA, PFUnDA, PFOS (linear and branched isomers), and PFNA in serum or plasma

FIGURE 2 Clinical guidance for follow-up with patients after PFAS testing.

as pregnant persons. Using the risk based values the committee found and assumptions of dose additivity, the committee determined that:

- Adverse health effects related to PFAS exposure are not expected at less than 2 nanograms per milliliter (ng/mL).
- There is a potential for adverse effects, especially in sensitive populations, between 2 and 20 ng/mL.
- There is an increased risk of adverse effects above 20 ng/mL.

Testing for PFAS, though expensive, offers an opportunity to identify people who may need to reduce PFAS exposure and who are at increased risk of certain health outcomes. Race, age, and other social and demographic characteristics already have disadvantaged many patients from accessing clinical preventive services, meaning that these groups may not be offered PFAS testing and the accompanying exposure reduction counseling. If testing primarily occurs among those with stable access to health care, there could be the unintended consequence of aggravating disparities in exposure to PFAS, a severe disadvantage of encouraging testing without a funded PFAS testing program with a national scope.

PATIENT FOLLOW-UP FOR PFAS-ASSOCIATED HEALTH EFFECTS

Most health effects or conditions found to be associated with PFAS exposure are already common in the general population and all have multiple known risk factors. The Committee's guidance for patient follow-up is summarized in Figure 2, which suggests that clinicians engage in shared, informed decision making with their patients regarding follow-up care for PFAS-associated health endpoints. For patients with a PFAS level of 2 ng/mL to less than 20 ng/mL, clinicians should encourage the standard of care for conditions associated with PFAS. For a PFAS level of 20 ng/mL or greater, clinicians should screen for dyslipidemia following guidance for high risk individuals, thyroid dysfunction (for patients over 18), signs and symptoms of testicular cancer (for patients over 15) and ulcerative colitis, and signs and symptoms of kidney cancer with urinalysis (for patients over 45).

NEXT STEPS TO GUIDE CLINICIANS AND PROTECT PUBLIC HEALTH

ATSDR should revise its guidance to ensure consistency with the findings, conclusions, and recommendations in this report, and improve the writing, design, dissemination, and implementation of the guidance. Evidence of the health effects of PFAS should be updated every two years, and the clinical guidance should be updated at least every five years.

Public health requires the use of multifaceted approaches to emerging health issues. In environmental health—the subset of public health focused on environmental factors—mitigation of potential harms associated with chemical exposures is often complicated because there is no exposure surveillance system exists for most chemicals. The people and communities with high exposures to PFAS need to be identified. The recommendations in this report will be most protective of the public's health if they are part of a national effort toward increased biomonitoring, exposure surveillance, and clinicians' and public health professionals' education on environmental health issues.

COMMUNITY LIAISONS

Laurene Allen
Merrimack Citizens for Clean Water

Andrea Amico
Testing for Pease

Stel Bailey
Fight for Zero

Kyla Bennett
Public Employees for Environmental Responsibility

Karen Blondel
Public Housing Civic Association, Inc.

Phil Brown
Northeastern University

Alberto J. Caban-Martinez
University of Miami

Cheryl Cail
South Carolina Indian Affairs Commission/SC Idle No More

Courtney Carignan
Michigan State University

Tracy Carluccio
Delaware Riverkeeper Network

Jamie Dewitt
East Carolina University

Emily Donovan
Clean Cape Fear

Alan Ducatman
West Virginia University

Patrick Elder
Military Poisons

Teresa Gerade
Don't Undermine Memphremagog's Purity

Hope Grosse
Buxmont Coalition for Safe Water

Loreen Hackett
PFOA Project New York

Ayesha Khan
Nantucket PFAS Action Group

Rainer Lohmann
University of Rhode Island Superfund Research Center

Samraa Luqman
Concerned Residents for South Dearborn

Beth Markesino
North Carolina Stop Gen-X In Our Water

Aaron Maruzzo
University of California, Berkeley

Tobyn Mcnaughton
Resident of Belmont, Michigan

Kristen Mello
Westfield Residents Advocating for Themselves

Elizabeth Neary
Wisconsin Environmental Health Network

Laura Olah
Citizens for Safe Water Around Badger

COMMITTEE ON THE GUIDANCE ON PFAS TESTING AND HEALTH OUTCOMES

Bruce N. Calonge (*Chair*)
University of Colorado School of Medicine and School of Public Health

Laura Anderko
Villanova University

Dana Boyd Barr
Emory University Rollins School of Public Health

Erin Bell
School of Public Health, University at Albany

Kevin Elliott
Michigan State University

Melissa Gonzales
Tulane University School of Public Health and Tropical Medicine

Erin Haynes
University of Kentucky College of Public Health

Jane Hoppin
North Carolina State University

Tamarra James-Todd
Harvard T.H. Chan School of Public Health

Alex Kemper
The Ohio State University College of Medicine, Nationwide Children's Hospital

Marc-André Verner
Université de Montréal

Veronica Vieira
University of California, Irvine

Xiaobin Wang
Johns Hopkins Bloomberg School of Public Health and School of Medicine

Chris Wiant
Caring for Colorado Foundation

STUDY STAFF

HEALTH AND MEDICINE DIVISION STAFF

Elizabeth Barksdale Boyle
Study Director

Alexis Wojtowicz
Associate Program Officer

Alexandra McKay
Senior Program Assistant

Rose Marie Martinez
Senior Board Director, Board on Population Health and Public Health Practice

DIVISION ON EARTH AND LIFE STUDIES STAFF

Marilee Shelton-Davenport (until March 2012)
Senior Program Officer

Kate Guyton
Senior Program Officer

Clifford Duke
Board Director, Board on Environmental Studies and Toxicology

CONSULTANTS

Allie Boman
Briere Associates, Inc.

Rona Briere
Briere Associates, Inc.

Cary Haver
ICF Resources, LLC

Jordan Kuiper
Johns Hopkins University

Judy LaKind
LaKind Associates

Kate Marquess
Johns Hopkins University

Melissa Miller
ICF Resources, LLC

Josh Naiman
LaKind Associates

Anna Ruth Robuck
Icahn School of Medicine at Mount Sinai

Margaret Shandling
Briere Associates, Inc.

Lauren Tobias
Maven Messaging

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Health and Medicine Division
Division on Earth and Life Studies

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