A Fire Chief's Guide to PFAS Testing

Firefighter Toxin Tests

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About the company

Firefighter Toxin Tests is dedicated to improving the health and fitness of our nation's firefighters. We are a subsidiary of Relentless Health, which offers similar testing services to members of the general public.

To discuss how we can help your department with PFAS testing, email:

info@FirefighterToxinTests.com

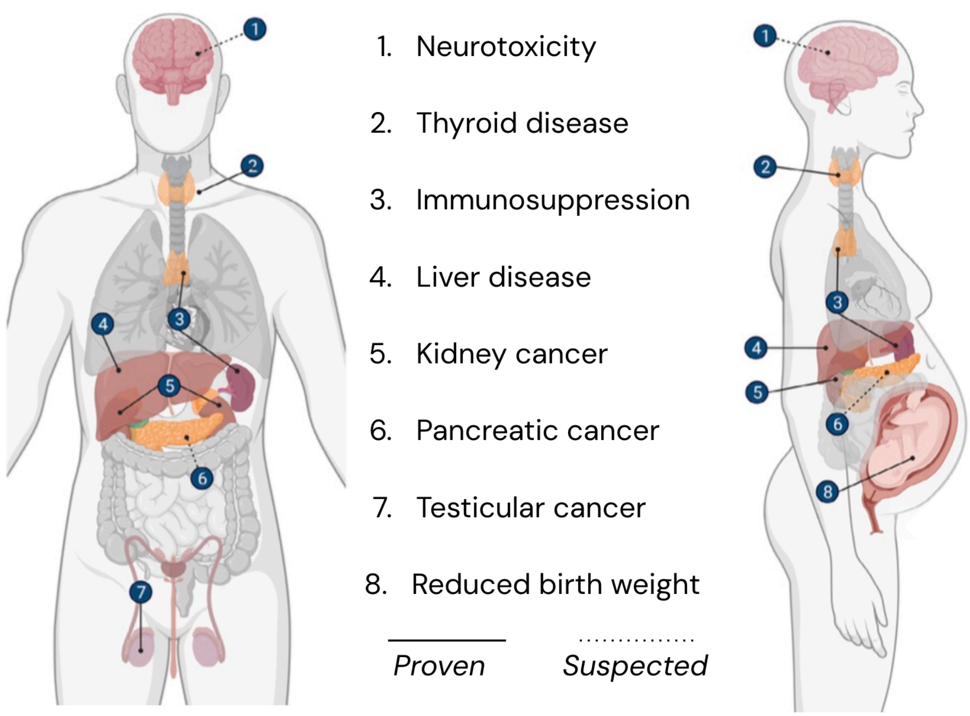
Introduction

This guide explains why PFAS testing is so important for firefighters. It lists some of the proven health risks posed by these chemicals. It clarifies why it is so important to monitor exposure over time. And it sets out some simple changes Fire Chiefs and leadership can make that should lead to changes in PFAS exposure for their firefighters.

PFAS, standing for per- and polyfluoroalkyl substances, are a large family of man made chemicals. They are known for their useful properties, including grease and stain resistance, waterproofing, and non-stick properties. Since the 1950s, their use has increased significantly, including in the fire service. While they provide unique properties, they have a major drawback—they are extremely hard to break down in the environment and in the human body.

More and more research is uncovering the dangers of PFAS compounds. There are an estimated 15,000 different PFAS chemicals with applications ranging from consumer products and textile coatings to industrial and commercial uses. It is estimated that up to 98% of Americans have detectable levels of PFAS, and public concern about the health effects of PFAS chemicals is increasing. PFAS is linked with an ever-increasing range of bad health outcomes as summarized in figure 1.

PFAS is linked to many serious health issues



Based on an illustration taken from an eBook titled "PFAS: The "New" Forever Chemicals" by Pamela Lein, UC Davis CA. Available at https://www.openaccessgovernment.org/

Figure 1: A summary of some of the health effects of PFAS

Brief background on PFAS chemicals

PFAS compounds are a large group of synthetic chemicals that provide desirable properties such as water or grease resistance. It is estimated that there are nearly 15,000 PFAS chemicals going back to the late 1930s and early 1940s. Over the past decades their use has propagated across all industries. Common uses of PFAS include:

- Firefighting foam known as aqueous film-forming foam and protective treatments on firefighters' personal protective equipment
- Water-repellent coatings on raincoats and other outdoor clothing
- Greaseproof coatings on fast food cartons and wrappers
- Stain-resistant treatments on fabrics, carpets, furniture, and shoes
- Non-stick coatings on cookware and bakeware
- Additives in pesticides and other chemicals to increase shelf-life and potency
- Additives in lubricants to reduce friction

As a result of their continued use over many decades, PFAS are now found in all natural environments (soil, water, air), in various animal species, and in humans.

Why PFAS is particularly relevant to firefighters

Since the 1970s, PFAS has been a key ingredient in aqueous film-forming foams (AFFFs). These foams are vital in combating liquid fuel fires, which couldn't be extinguished by water alone. AFFFs, laced with PFAS, were effective in quickly smothering fires, preventing re-ignition by creating a barrier between the fuel and oxygen. Given the success in emergency situations, particularly in military contexts, the use of PFAS-infused foams became a standard approach globally.

In fact, by 2004, the FAA mandated the use of firefighting foams that meet DoD military level specifications (a.k.a. "Mil-Spec"). Essentially, these foams had very high levels of PFAS chemicals that made them particularly effective for putting out large fuel fires. However, this began to change once people realized the risks posed by PFAS.

In 2018, Congress directed the FAA to loosen the requirement for commercial airports to use Mil-Spec foams (i.e. PFAS-containing foams). By 2022, Congress directed the FAA to develop a transition plan to replace all AFFF with fluorine free alternatives. Finally, in January 2023, the DoD issued Military Specification MIL-PRF-32725, which is a fluorine-free foam certification. These changes are beginning to increase the use of fluorine-free foams at commercial airports, but the transition has been slow. It is still important for any firefighters dealing with aircraft rescue and firefighting to be vigilant and reduce exposures to PFAS-containing AFFF as much as possible.

However, the application of PFAS in firefighting didn't stop at foams. By the late 20th century, the unique qualities of PFAS led to its incorporation into firefighters' turnout gear. Gear began being manufactured using fabrics treated with PFAS to allow it to meet the stringent requirements of NFPA 1971. This included the need to be waterproof, heat resistant, and to shed oil and grease. As a result, virtually all turnout gear tested by NIST has been shown to contain significant levels of PFAS (see reference 4)..

The result of all this is that firefighters have been exposed to far higher concentrations of PFAS than members of the general public. And this is borne out by the research, which shows that on average, they have 53% more PFAS in their bodies. But that number actually hides the true extent of the problem–some firefighters have levels that are tens of times higher than that.

Routes of exposure to PFAS

Human exposure to PFAS is primarily through ingestion and inhalation. Absorption through skin is also a concern, especially for high-risk occupations such as firefighting.

Inhalation of PFAS

Occupational inhalation of PFAS occurs when PFAS-containing materials and ingredients are used. This can occur, for example, by breathing in PFAS as aerosols or fumes, or breathing PFAS-contaminated dust or other particles. Organizations including the American Conference for Governmental Industrial Hygienists (ACGIH) are defining safety guidelines for PFAS exposure through inhalation.

For firefighters, inhalation may occur during fire incidents if proper PPE is not used. Fires that burn almost any synthetic material, including industrial fires and most household fires, can release PFAS.

PFAS absorption through skin

Like many chemicals, PFAS can enter the body through direct contact with the skin. Water-repellent or stain-proof clothing is a key source of PFAS exposure, including those that contain “Gore-Tex.” Raincoats, as an example, are commonly made with PFAS-containing liners that can absorb into the skin. The use of certain personal care products and cosmetics can also lead to PFAS exposure through skin (e.g., long-lasting makeup, eyeliner, bronzers, foundation, nail polish, shampoo, and dental floss). Other household products like paints, varnishes, sealants could also expose people to PFAs chemicals but are less common.

Firefighters are particularly vulnerable to exposure through skin contact. Their protective turnout gear typically contains numerous PFAS compounds to provide waterproofing, heat protection, and grease resistance. Recently published findings from the National Institute of Standards and Technology (NIST) showed that firefighter turnout gear releases high levels of PFAS as normal "wear and tear" occurs. This then can lead to skin exposure and absorption of PFAS chemicals.

Ingestion of PFAS-contaminated food and beverages

PFAS ingestion is the main route of exposure for most people due to the many potential sources. PFAS ingestion can occur from:

- Drinking PFAS-contaminated water, which is one of the most common sources with over 2,000 municipalities having high concentrations. This is especially problematic if fire houses are situated on or near superfund sites.
- Eating food grown or raised near PFAS-contaminated water or soil, including fruits, vegetables, meat, and dairy products
- Eating food that was packaged in PFAS-containing materials (processed food packaging, fast food wrappers and packaging, disposable cups or plates with water-resistant lining)
- Eating fish farmed in or caught from water contaminated by PFAS
- Eating foods prepared in cookware and bakeware coated with PFAS-containing non-stick materials such as Teflon, PTFE, and Xylan
- Accidental ingestion of PFAS-containing soil, dust, or other materials

The potential health impacts of PFAS exposure

Scientific research on PFAS has shown a range of health issues stemming from high exposure to PFAS. These include developmental disorders, high cholesterol, obesity, immune and hormone dysfunction, and greater risk of cancer in adults. The medical field's current understanding of the health effects of PFAS is informed by a combination of animal studies, human *in vitro* tissue studies, and human observational studies.

Proven health effects

Sufficient associations between chronic PFAS exposure and negative health outcomes have been established for the following:

- Kidney and testicular cancers – PFOA (perfluorooctanoic acid) is an IARC Group 1 carcinogen
- Metabolic disruption, including hypercholesterolemia
- Reduced effectiveness in vaccinations among children
- Decrease in birth weight among children exposed to PFAS *in utero*

Firefighters have a 12% higher rate of cancer than the general public, and chronic exposure to PFAS chemicals is thought to be a key contributor. Further research is ongoing to better understand this matter, including work by the Fire Fighter Cancer Cohort Study.

Probable health effects

Suggestive or limited association between PFAS exposure and negative health outcomes have been found for the following:

- Thyroid and sex hormone signaling disruption
- Altered liver enzyme function including changes in ALT, AST, ALP, and GGT
- Hypertension or preeclampsia during pregnancy

In 2021, the Agency for Toxic Substances and Disease Registry published a toxicological profile of perfluoroalkyl chemicals. This comprehensive review provides additional information about 12 specific PFAS chemicals and their health impacts.

As with other environmental exposures such as poor air quality, microplastics, glyphosate, and heavy metals, the health risks of PFAS to an individual could depend on a number of other factors. The frequency, duration, and quantity of PFAS exposure, comorbidities, general health status, occupation, and other factors may play a role in health outcomes.

CDC guidance for clinical evaluation and management of PFAS exposure

Occupational medicine specialists may be more likely to encounter patients with concerns about PFAS exposure. However, given the increasing awareness by the general public regarding PFAS, the following information could be helpful for all clinicians. The Agency for Toxic Substances and Disease Registry maintains a resource for clinicians with additional information on clinical evaluation and management.

Working with patients in the context of PFAS involves a number of steps. These include:

1. Listening to the patient's concerns about PFAS

2. Getting an exposure history to identify current and past exposures, including guiding the patient on potential exposure sources
3. Assessing the duration and level of PFAS exposure
4. Recommending PFAS reduction strategies
5. Educating patients about PFAS blood testing, including the benefits and limitations of such testing
6. If patients choose PFAS blood testing, reviewing and recommending additional screening for patients at higher risk of disease (see NASEM advice below)

There are no approved medical treatments to reduce or remove PFAS from the body. Clinicians can work with patients based on their health history, exposure to PFAS, and if available, PFAS testing results, to develop individualized care plans.

Advice from the National Academies of Science, Engineering, and Medicine

NASEM proposes the following guidelines for PFAS blood testing results. These values are based on the sum of **serum** levels of 10 different PFAS compounds measured by NHANES.

- <2ng/mL : Low risk. No additional care needed
- 2 to <20 ng/mL: Moderate risk. Work on PFAS exposure reduction and screening for dyslipidemia, hypertension in pregnancy, and breast cancer
- ≥20 ng/mL: Add the following additional screenings at well visits:
    - Thyroid function testing with serum TSH for patients >18 years
    - Assess signs and symptoms of kidney cancer, including urinalysis, for patients >45 years
    - Assess signs and symptoms of testicular cancer and ulcerative colitis in patients >15 years

NASEM estimated that for the U.S. population represented by NHANES in 2017–2018, 98% of people had PFAS levels ≥2 ng/mL; 9% had PFAS levels ≥20 ng/mL.

PFAS testing options

There are three main approaches to PFAS testing, which are blood serum testing, whole blood testing, and urinalysis.

Blood serum testing

Prescribing physicians and healthcare providers are able to order PFAS blood tests for their patients through Quest Diagnostics (Test Code 39307). This test is not available in all geographies, and ordering physicians should check availability. This test measures 6 different PFAS compounds and covers a subset of compounds as tested by the NHANES program. Alternatively, providers can guide patients to order their own blood serum PFAS test through Quest Health, which is a consumer service that measures 9 different PFAS compounds. This latter option still requires the patient to visit a Quest location for a venous blood draw.

Whole blood testing

Recently, labs have started using dried whole blood samples to test for PFAS. There are a few benefits to this. Firstly, the sample can be much smaller. Typically, just a few drops of blood are enough. Secondly, the sampling process can be done at home and needs no specialist medical knowledge. Patients can purchase these tests directly, get the results, and share these with their healthcare providers. Relentless Health provides a PFAS Core Panel test that is easy to use, affordable, and provides quick turnaround times.

Urinalysis

It is also possible to detect PFAS in urine samples. However, this is not such a widely used approach. The issue here is that each person's body eliminates PFAS differently and at different rates. So, it is harder to draw conclusions about the results of urinalysis.

Our testing technology

Recent advances in remote blood sampling has enabled Firefighter Toxin Tests to develop its PFAS test as an at-home test. Known technically as "Volumetrically Accurate Microsampling Collection Devices," these FDA-cleared blood sampling devices can be used to collect just a few drops of blood while still allowing for accurate testing. In our PFAS Core Panel, individuals use the supplied at-home collection kit to take a blood sample in minutes. Sample collection starts with thorough hand washing, followed by cleaning the finger tip with an alcohol wipe. Then, the supplied lancet is used to prick the finger tip with minimal discomfort. Two to three drops of blood are applied to the microsampling collection device tip, which collects and stores the blood. Finally, the collection device containing the blood drop sample is shipped in a prepaid envelope to Relentless Health's central lab for processing and analysis.

State-of-the-Art Scientific instruments and methods

The Firefighter Toxin Tests PFAS core panel uses State-of-the-Art scientific instruments and methods. These have been proven to deliver accurate and reliable results.

Liquid chromatography and mass spectrometry

The laboratory technique used to detect PFAS in blood is called liquid chromatography-mass spectrometry (LC-MS). LC-MS allows scientists to identify and quantify chemical compounds of interest, and is widely used in a range of analytical methods.

Preparing the sample

Our PFAS testing uses strict, quality-controlled processes for sample preparation and analysis. The main purpose of sample preparation is to dissolve the dried blood sample so we can analyze it for PFAS. We do this by using laboratory-grade solvents and materials to return the dried blood (and its contents) into a liquid that can then be injected into the LC-MS instrument for analysis. This requires multiple steps of preparation that are carried out by one of our qualified laboratory technicians. All our sample preparation methods are validated and have been verified in multiple laboratories.

Injecting and splitting the sample

Once the sample is prepared, it is injected into the LC-MS instrument. The solution flows through the instrument and enters a liquid chromatography analytical column–a part of the instrument that helps to separate the different PFAS compounds. Each PFAS compound interacts with the inside of the LC column differently, and exits the column at a different time as the solution continues to flow through the system. For example, a compound that interacts weakly with the analytical column will exit the column earlier than one that interacts strongly.

The role of the mass spectrometer

Once the PFAS compounds are separated by the LC column, they enter the mass spectrometer part of the instrument. In the mass spectrometer, the compounds are first converted from neutral molecules to ions (charged particles), and the ions then enter the detector within the MS instrument. The detector is engineered in a way that allows us to very accurately measure the mass of each ionized chemical that enters it. Therefore, in our test each compound is characterized by 1) the specific time it exits the analytical LC column, and 2) the mass of the compound as determined by the MS. As the mass of the PFAS compounds is known from their chemical structures, the detected mass in the LC-MS system can be matched with the PFAS compounds of interest.

Quantifying the PFAS compounds

The LC-MS signal recorded for each PFAS compound is also used to quantify the amount of that PFAS. This allows us to calculate the concentration of PFAS in the analyzed sample (typically in "ng/mL" or nanograms per milliliter), from which we can work out the PFAS concentration in the blood. This is the value that is recorded in the PFAS report.

Delivering quality, test after test

Relentless Health's lab has been CLIA Licensed by the State of Nevada. The Clinical Laboratory Improvement Amendments (CLIA) regulates laboratory tests on patient specimens. CLIA covers quality, accuracy, and reliability of tests used in a laboratory setting. It requires the laboratory to be certified, to employ qualified staff for specific regulated roles, and to maintain a laboratory information system. The PFAS Core Panel has been licensed as a lab developed test (LDT).

What is a lab-developed test?

Under the CLIA regulations, a lab-developed test, or LDT, is one that has been developed in-house for use in a specific laboratory. CLIA prohibits the release of any test results until the laboratory establishes performance characteristics relating to analytical validity of the test within that specific laboratory. This includes analyzing the accuracy, precision, analytical sensitivity, analytical specificity, reportable range, and other performance characteristics of the test.

Additional quality management

We perform ongoing quality control of all its systems and labs. We have an extensive quality control system with detailed documentation and protocols for every eventuality. The LC-MS instrument is calibrated and tested daily. We also have a schedule of routine maintenance and quality testing, validation, and verification to ensure ongoing optimal performance and accuracy. Furthermore, the laboratory actually holds itself to the rigorous standards set by the College of American Pathologists.

Ongoing research

Relentless Health is committed to improving their understanding around PFAS and PFAS testing. They actively pursue our own clinical studies to expand their knowledge of PFAS exposure and to prove the accuracy of our testing. The current research study is seeking to understand the levels of PFAS seen across the general population. This is important as it sets a benchmark against which we can compare firefighter results.

What is a safe level of PFAS?

There is still a lot of ongoing research into the risks and harms of PFAS. The National Academies of Science, Engineering and Medicine (NASEM) issued broad guidelines for safe levels of certain PFAS compounds in serum [see reference 1 for more details]. These guidelines are summarized below. This calculation is based on adding up the total level of PFAS compounds found in your blood.

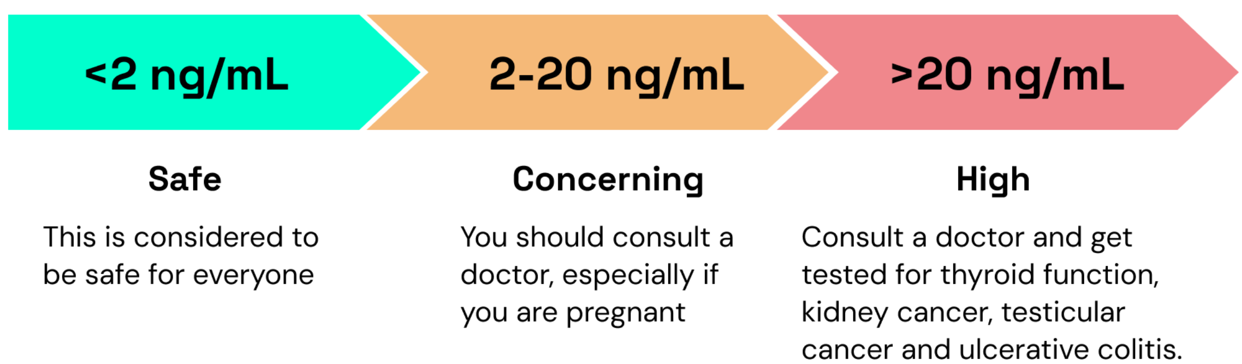


Figure 2 Overview of the NASEM guidelines for safe levels of PFAS in blood

The levels here are for serum testing. However, the Relentless Health PFAS Core Panel is a whole blood test. The following explains how to convert from whole blood to serum levels.

Converting whole blood to serum levels, and a simple example

At-home testing for PFAS in whole blood is a relatively new approach. Before this approach, most tests were performed on blood serum obtained from a blood-draw by a nurse or phlebotomist. This means that much of the published literature focuses on results from blood serum. Research has shown that there is a direct link between whole blood and serum PFAS levels. However, the precise ratio varies from compound to compound, with a conversion factor ranging from 0.2 to 2.7 and a median of 2.0 [see refs. 2, 3 for more details].

A good way to approximate the serum level is by doubling your blood level as reported by the PFAS Core Panel

> *As an example, if your PFAS Core Panel result for PFOA (perfluorooctanoic acid) is 0.75ng/mL, the equivalent serum level would be 1.5ng/mL.*

In this case, you would still be in the safe zone according to the NASEM guidelines.

Reducing PFAS Exposure

We are constantly exposed to PFAS chemicals, but making small, easy changes can add up to meaningful improvements and reduce exposure to PFAS.

Figure 3 How to reduce PFAS exposure in daily life

Some immediate ideas to try are:

- Eat less fast food and processed foods (many food wrappers and bags, as well as to-go containers and cups, contain PFAS).
- Use metal or glass containers to store leftovers at home and in the fire house.
- Use metal or glass mugs and cups for beverages instead of single-use cups.
- Test your water supply for PFAS using a service such as Tap Score. If it is too high, install a water filter that reduces PFAS.
- Reduce the use of non-stick pans and cookware, especially if the coatings are scratched or damaged. Stainless steel and cast iron are good alternatives.
- Avoid the use of fabrics and furniture that are treated to be "stain-resistant".

Reducing PFAS exposure as a firefighter

Firefighters are exposed to PFAS through their turnout gear, older forms of AFFF, and via PFAS released during structural, wildland, and training fires. One challenge in reducing PFAS comes from its widespread use in turnout gear. At the time of writing, it is hard to purchase PFAS-free turnout gear that meets the NFPA 1970 standard. And many so-called "PFAS-free" products actually contain substances that are nearly identical and may well prove to have similar long-term effects.

Staying safe, healthy, and fit for duty is a cornerstone of firefighting life. Keep these tips in mind to reduce the potential harm of PFAS.

During a Call, Incident, or Training

- Only wear turnout gear when necessary and only as long as needed
- Don't wear turnout gear for routine activities like grocery shopping
- When using AFFF, wear all protective gear and avoid direct contact with skin
- During a structural call, wear SCBA to reduce inhalation of PFAS-contaminated particles

After a call or training

- Clean all your turnout gear if you have used it for training or at an incident
- Clean fire truck cabs regularly, especially after incidents; handle soiled rags with care
- Shower after fires or hazardous incidents
- Wash hands thoroughly after handling turnout gear
- After training exercises, take off your gear promptly once the training is done

At all other times

- Do not bring turnout gear into living areas
- Thoroughly wash hands prior to cooking, handling food, or eating
- Replace torn or excessively worn turnout gear
- Maintain good ventilation & air purification in the bunker gear room
- If you transport your gear in your personal vehicle, store and transport it in a sealed container or bag, and place in the trunk

Figure 4 Guidance on reducing PFAS exposure from turnout gear

The importance of ongoing PFAS monitoring

PFAS are often inaccurately called “Forever Chemicals”. This is because many of them take a long time to break down in the environment. They also can take a long time to be eliminated from the human body. The key measure here is called the elimination half-life. Elimination half life is a measure of how much time it takes for a compound to be removed from the body. PFAS compounds sometimes have half lives measured in years if not decades.

If a compound has a half life of 2 years that means after 2 years, half of it is still in the body. And after 4 years a quarter is left. As a rule of thumb, scientists say that it takes five half-lives to effectively eliminate a chemical compound from the body. So, for many PFAS it takes decades for them to be eliminated. However, some modern PFAS compounds have far shorter half lives in the body. Therefore, by taking the steps above, you should see your blood levels dropping within a few months. The generally accepted advice is for most people to take a test once or twice per year. Those in high risk occupations or living in high contamination areas should consider taking tests 3 or 4 times a year.

Glossary

Comparing different tests and understanding scientific papers can be a bit challenging. Here's a brief explanation of some of the terminology you might come across in this guide and in other places.

- **CLIA (Clinical Laboratory Improvement Amendments).** CLIA regulates laboratory tests on patient specimens. CLIA covers quality, accuracy, and reliability of tests used in a laboratory setting. It requires the laboratory to be certified, to employ qualified staff for specific regulated roles, and to maintain a laboratory information system. The Relentless Health Lab has received CLIA certification for its PFAS test.
- **Limit of Detection (LOD).** This refers to the minimum level of a compound that a given test methodology is able to detect with 99% confidence that it is not a false positive. This is sometimes referred to as Method Detection Limit.
- **Limit of Quantification (LOQ).** This is the minimum level at which the lab is prepared to state with complete confidence that this result is not a false positive and where we have proven that we can measure (quantify) the substance precisely. It is sometimes referred to as the Reporting Limit.
- **Method Detection Limit (MDL).** See ***Limit of Detection***
- **Nanograms per milliliter (ng/mL).** This is the standard measure for levels of PFAS in whole blood or blood plasma. This is sometimes also called parts per billion (ppb) or micrograms per liter (ug/L)
- **Reference Range**. This indicates the typical range of results seen by a given lab for a given substance. Many factors affect this, including the specific populations being tested, the sensitivity of the equipment used, and the quality of the lab processes. Relentless Health is currently running a clinical study to set the reference ranges for our PFAS test.
- **Reporting Limit.** See ***Limit of Quantification***

References

1. National academies of science, engineering and medicine Guidance on PFAS Exposure, Testing, and Clinical Follow-Up: https://nap.nationalacademies.org/resource/26156/interactive/
2. Poothong, et Al. Distribution of Novel and Well-Known Poly- and Perfluoroalkyl Substances (PFASs) in Human Serum, Plasma, and Whole Blood. Environmental Science & Technology 2017
3. Carignan, et Al. Self-Collection Blood Test for PFASs: Comparing Volumetric Microsamplers with a Traditional Serum Approach. Environmental Science & Technology 2023
4. NIST, Per- and Polyfluoroalkyl Substances in Firefighter Turnout Gear Textiles Exposed to Abrasion, Elevated Temperature, Laundering, or Weathering, Technical note 2260 January 2024, https://nvlpubs.nist.gov/nistpubs/TechnicalNotes/NIST.TN.2260.pdf

Appendix A: Additional PFAS resources for clinicians

The following resources are available from government agencies and organizations to inform clinicians about PFAS exposure and patient care.

NASEM Guidance on PFAS Testing and Health Outcomes

CDC / ATSDR PFAS Information for Clinicians - 2024

ATSDR Toxicological Profile of PFAS

ATSDR PFAS Blood Level Estimation Tool

Appendix B: Details of each PFAS compound tested

Below we give details about each of the compounds we test for. This includes common routes of exposure, known risks, and where these compounds are used.

Found in AFFF? Has this compound been linked with AFFF?

Found in turnout gear? Did this compound appear in the NIST study of PFAS in firefighter turnout gear (reference 4)?

Seen in studies: How often is this detected in capillary blood (reference 3).

Tested in NHANES: Is it tracked by the CDC National Health and Nutrition Examination Survey (NHANES).

Fluorotelomer sulfonic acid 4:2 (4:2 FTS)

4:2 FTS, or Fluorotelomer sulfonic acid 4:2, is one of a family of PFAS compounds used in personal care and consumer products.

Routes of Exposure

Used in cosmetic products such as concealers. Found in some drinking water sources.

Risks

4:2 FTS is known to cause certain cancers. It can also cause harm to the immune system, hormone disruption, and harm to the liver. It is shown to harm fetal growth and child development.

Notes

Found in AFFF?	Yes	**Tested in NHANES?**	No
Found in turnout gear?	Unknown	**Seen in studies?**	N/A

Fluorotelomer sulfonic acid 6:2 (6:2 FTS)

6:2 FTS, or Fluorotelomer sulfonic acid 6:2, is one of a family of PFAS compounds used in personal care and consumer products as well as aqueous film-forming foams.

Routes of Exposure

6:2 FTS has been detected at chemical manufacturing sites and sites where PFAS-containing fire-fighting foams have been used. 6:2 FTS has also been detected at low levels in some consumer products, drinking water, air, and fish, and human exposure may occur through any of these sources. Available data indicate that the general population's exposure to 6:2 FTS is usually low.

Risks

6:2 FTS is less persistent than PFOS, but it still poses health risks. Short animal studies show that 6:2 FTS can cause kidney and liver damage, but does not cause DNA damage or damage to the reproductive system or to the developing fetus in available rodent models. No studies have been conducted to assess cancer, immune system toxicity, or endocrine disruption following 6:2 FTS exposure, and no long-term studies have been done.

Notes

Found in AFFF?	Yes	**Tested in NHANES?**	No
Found in turnout gear?	Unknown	**Seen in studies?**	N/A

Fluorotelomer sulfonic acid 8:2 (8:2 FTS)

8:2 FTS, or Fluorotelomer sulfonic acid 8:2, is one of a family of PFAS compounds used in personal care and consumer products as well as aqueous film-forming foams.

Routes of Exposure

8:2 FTS is closely related to 6:2 FTS, which has been found near chemical plants that manufacture aqueous film-forming foams. However, it is not so widely detected.

Risks

8:2 FTS is less persistent than PFOS, but it still poses health risks. Short animal studies show that the closely-related 6:2 FTS can cause kidney and liver damage, but does not cause DNA damage or damage to the reproductive system or to the developing fetus in available rodent models. A small number of studies have been done looking at 8:2 FTSA but none look specifically at its toxicity to humans.

Notes

Found in AFFF?	Yes	**Tested in NHANES?**	No

Found in turnout gear?	Unknown	**Seen in studies?**	N/A

2-(N-Methyllperfluorooctanesulfonamido) acetic acid (N-MeFOSAA)

N-MeFOSAA, or 2-(N-Methyllperfluorooctanesulfonamido) acetic acid, is a chemical used in the manufacture of other PFAS compounds.

Routes of Exposure

N-MeFOSAA is a PFAS chemical that breaks down (eventually) into other PFAS compounds. It is found in many consumer products and in the environment, including food packaging and wrappers, and drinking water.

Risks

There are a slew of negative health consequences of chronic exposure to N-MeFOSAA. These include cancer, organ damage (especially of the liver, kidney, and testes), infertility, birth defects, and developmental harm to children.

Notes

Found in AFFF?	Byproduct	**Tested in NHANES?**	Yes
Found in turnout gear?	No	**Seen in studies?**	47%

Perfluorobutanoic Acid (PFBA)

PFBA, or perfluorobutanoic acid, is a breakdown product of other PFAS compounds.

Routes of Exposure

PFBA is formed when other PFAS compounds decay in the environment. These other compounds have been used in stain-resistant fabrics, paper food packaging, carpets, and consumer products.PFBA has been frequently found in U.S. rivers. It is a 4 carbon version of PFOA.

Risks

In laboratory animal studies, exposure to high levels of PFBA results in thyroid and liver effects, such as increased thyroid and liver weight, changes in thyroid hormones, decreased cholesterol, and cellular changes in both organs.

Notes

Found in AFFF?	Byproduct	**Tested in NHANES?**	No
Found in turnout gear?	Yes	**Seen in studies?**	N/A

Perfluorobutane Sulfonate (PFBS)

PFBS, or perfluorobutane sulfonate, is a surfactant (a compound that reduces the surface tension between a liquid and another substance).

Routes of Exposure

Very high persistence, high mobility in water and soil, high potential for long-range transport, and difficulty of remediation and water purification as well as moderate bioaccumulation in humans. An active ingredient in stain-resistant coatings. Structurally similar to PFOS. PFBS was found in 6 of the 2,368 people tested in CDC biomonitoring studies.

Risks

Observed probable serious effects for human health and the environment are thyroid hormonal disturbances and reproductive toxicity seen in rodents, and effects on liver, kidney and hematological system in rats, hormonal disturbances and effects on reproduction in marine medaka fish and effects on expression of hormone receptors in tadpoles. Remediation is hard even with good water filtration.

Notes

Found in AFFF?	No	**Tested in NHANES?**	No
Found in turnout gear?	Yes	**Seen in studies?**	2%

Perfluorodecanoic Acid (PFDA)

PFDA, or perfluorodecanoic acid, is an industrial surfactant (a substance that changes the surface tension between a liquid and some other surface).

Routes of Exposure

PFDA is very widely used in a number of consumer products, including cosmetics, personal care products, cleaning products, clothing, textiles, and carpets. PFDA is also widely used in industry and manufacturing, and it is also commonly used as a ski wax and in fire-fighting foam. Ingestion of PFDA contaminated water and food are common, and absorption through the skin also occurs.

Risks

Available evidence indicates that high levels of PFDA exposure is likely to cause liver, immune, developmental, and male and female reproductive effects in humans. Research also shows that PFDA might cause liver damage and metabolic issues, as well as increase cholesterol.

Notes

Found in AFFF?	Yes	**Tested in NHANES?**	Yes
Found in turnout gear?	Some	**Seen in studies?**	36%

Perfluorododecanoic Acid (PFDoDA)

PFDoDA, or perfluorododecanoic acid, is an industrial surfactant (a substance that changes the surface tension between a liquid and some other surface). It is a 12-carbon version of PFOA.

Routes of Exposure

Breakdown product of stain- and grease-proof coatings on food packaging, couches, carpets. A 12-carbon version of PFOA; persistent; bioaccumulative. PFDoDA was only found in 1 of the 2,368 people tested in CDC biomonitoring studies.

Risks

While not much is known directly about the health effects of PFDoDA exposure, like other PFAS chemicals, it is expected to increase the risk of serious health issues.

Notes

Found in AFFF?	No	**Tested in NHANES?**	No
Found in turnout gear?	Some	**Seen in studies?**	0%

Perfluoroheptanoic Acid (PFHpA)

PFHpA, or perfluoroheptanoic acid, is a surfactant (a substance that changes the surface tension between a liquid and some other surface). It is a 7-carbon version of PFOA.

Routes of Exposure

PFHpA is a breakdown product of stain- and grease-proof coatings on food packaging, couches, carpets, and other textiles. It is a 7-carbon version of PFOA; It is known to be persistent in the environment. PFHpA has been found in 160 of the 2,368 people tested in CDC biomonitoring studies.

Risks

Over 80 studies have linked PDHpA to a range of different health conditions. The most significant are cancers as well as disorders of the endocrine system, metabolic system, reproductive system, and urinary system. A number of studies also link it with circulatory system issues.

Notes

Found in AFFF?	Yes	**Tested in NHANES?**	No
Found in turnout gear?	Yes	**Seen in studies?**	6%

Perfluoroheptanesulfonic acid (PFHpS)

PFHpS, or Perfluoroheptanesulfonic acid, is a surfactant (a substance that changes the surface tension between a liquid and some other surface). It is a 7-carbon version of PFOS.

Routes of Exposure

PFHpS is used in a variety of industrial and consumer products and can be found in fire-fighting foams, water-repellent apparel, stain-resistant upholstery, treated leather, and wood building materials. PFHpS accumulates in the environment and in people.

Risks

High levels of PFHpS exposure can cause serious acute (near-term) health effects, including dizziness, nausea, vomiting, muscle weakness, unconsciousness, and respiratory failure. Chronic or longer-term exposure to PFHpS can increase the risk of cancer, disrupt hormone levels, accelerate puberty, and damage the liver and immune system. During pregnancy, exposure to high levels of PFHpS is associated with decreased birth weight and other reproductive harm.

Notes

Found in AFFF?	Yes	**Tested in NHANES?**	Yes
Found in turnout gear?	Some	**Seen in studies?**	87%

Perfluorohexanoic Acid (PFHxA)

PFHxA, or perfluorohexanoic acid, is a surfactant (a substance that changes the surface tension between a liquid and some other surface). It is a 6-carbon version of PFOA.

Routes of Exposure

PFHxA is a breakdown product of other PFAS that are used in stain-resistant fabrics, paper food packaging, and carpets; it is also used for manufacturing photographic film, and it is used as a substitute for longer chain perfluoroalkyl carboxylic acids (PFCAs) in consumer products. PFHxA has been found to accumulate in agricultural crops and has been detected in household dust, soils, food products, and surface, ground, and drinking water. As such, exposure is possible via inhalation of indoor or outdoor air, ingestion of drinking water and food, and dermal contact with PFHxA-containing products.

Risks

PFHxA is linked with many diseases and health conditions. These include disorders of the endocrine system, digestion, metabolic system, reproductive system, and urinary system. It is also potentially linked with some forms of cancer and may cause issues related to body size, weight, and growth.

Notes

Found in AFFF?	Byproduct	**Tested in NHANES?**	No
Found in turnout gear?	Yes	**Seen in studies?**	N/A

Perfluorohexane Sulfonate (PFHxS)

PFHxS, or Perfluorohexane Sulfonate, is Perfluorohexanesulfonate (PFHxS) is one of the most widely distributed perfluoroalkyl compounds. It is a 6-carbon version of PFOS.

Routes of Exposure

PFHxS is used as a surfactant and protective coating in applications such as aqueous firefighting foams, textile coating, metal plating and in polishing agents. It is a long-chain PFAS with 6 carbon atoms. This means it is being slowly phased out. However, it has long persistence in the environment and in humans. It is listed in Annex A of the United Nations Stockholm Convention on Persistent Organic Pollutants. It has been found in 1,527 of the 1,591 people tested in CDC biomonitoring studies.

Risks

There are over 400 studies linking PFHxS with significant health issues in humans. This makes it one of the most widely researched PFAS compounds. PFHxS appears to have extremely wide-ranging effects across the body. These include genotoxicity and carcinogenicity. It also causes disorders of the circulatory system, endocrine system, metabolic system, reproductive system, and urinary system. A number of studies also link it with issues related to body size, weight, and growth and problems with the nervous system or behavior.

Notes

Found in AFFF?	Yes	**Tested in NHANES?**	Yes
Found in turnout gear?	Some	**Seen in studies?**	100%

Perfluorononanoic Acid (PFNA)

PFHxA, or perfluorohexanoic acid, is a surfactant (a substance that changes the surface tension between a liquid and some other surface). It is a 9-carbon version of PFOA.

Routes of Exposure

PFNA has been used in consumer products and various industries since the 1940s. It is found in carpets, clothing, furniture, and food packaging, to name a few sources. It is also used in fire-fighting foams. Because of its persistence in the environment, PFNA is also found in food sources such as eggs and in drinking water. It has been found in 2,058 of the 2,368 people tested in CDC biomonitoring studies.

Risks

Over 440 studies report adverse health effects in humans, including endocrine system disorders, reproductive issues, metabolic and digestive disorders, and cancer.

Notes

Found in AFFF?	Yes	**Tested in NHANES?**	Yes
Found in turnout gear?	Some	**Seen in studies?**	74%

Perfluorononanesulfonic acid (PFNS)

PFNS, or Perfluorononanesulfonic acid, is a surfactant (a substance that changes the surface tension between a liquid and some other surface). It is a 9-carbon version of PFOS.

Routes of Exposure

Perfluorononanesulfonic acid (PFNS) has been found in landfill leachate, which is water that's percolated through landfills and leaches out chemicals into the environment. Like many other PFAS chemicals, PFNS is also found in AFFF firefighting foam.

Risks

The Environmental Working Group (EWG) has set a health guideline of 1 part per trillion (ppt) for PFNS in drinking water. This guideline is based on studies that found adverse impacts on mammary gland development and reduced effectiveness of vaccines.

Notes

Found in AFFF?	Yes	**Tested in NHANES?**	No
Found in turnout gear?	No	**Seen in studies?**	N/A

Perfluorooctanoic Acid (PFOA)

PFOA, or perfluorooctanoic acid, is one of the oldest and most notorious PFAS substances. It is banned or its use has been voluntarily suspended in most jurisdictions. PFOA exists in 2 forms—branched and linear. Our test gives your total PFOA level.

Routes of Exposure

Used to make Teflon pan coatings; breakdown product of stain- and grease-proof coatings. Found in most people. Being phased out of some products. PFOA has been found in 2,085 of the 2,368 people tested in CDC biomonitoring studies.

Risks

In epidemiology studies, PFOA has been associated with decreased antibodies in infants and young children, lower birth weights, increased cholesterol in adults, and increased liver enzymes in adults. Additionally, an epidemiology study determined there is an association between long-term exposure to PFOA and the development of renal cell (kidney) cancer and others. This has led to PFOA being classified as a Class 1 carcinogen by the IARC. PFOA has a long half-life in humans with studies reporting ranges from 2.1 to over 10 years. This means that even though it is no longer manufactured, it is still routinely found in studies looking at PFAS exposure in humans.

Notes

Found in AFFF?	No	**Tested in NHANES?**	Yes
Found in turnout gear?	Some	**Seen in studies?**	98%

Perfluoropentanoic Acid (PFPeA)

PFPeA, or Perfluoropentanoic Acid, is a 5-carbon short-chain version of PFOA that has been used as a replacement following the phasing out of PFOA.

Routes of Exposure

Perfluoropentanoic acid is a short-chain perfluorocarboxylic acid commonly used as an industrial surfactant and surface protectant. It is breakdown product of stain- and grease-proof coatings on food packaging, couches, carpets and other textiles.It is persistent in the environment

Risks

Studies have linked PFPeA with numerous health problems including diseases of the metabolic system, digestive system, reproductive system, and urinary system. It has also been linked with issues related to body size, weight, and growth. There have also been a significant number of animal studies linking PFPeA with a wide range of health problems.

Notes

Found in AFFF?	No	**Tested in NHANES?**	No
Found in turnout gear?	Yes	**Seen in studies?**	N/A

Perfluoroundecanoic acid (PFUnDA)

PFUnDA, or perfluoroundecanoic acid, is a long-chain version of PFOA, with 11 carbon atoms instead of 8.

Routes of Exposure

Breakdown product of stain- and grease-proof coatings on food packaging, couches, carpets. An 11-carbon version of PFOA; persistent; bioaccumulative. PFUnDA has been found in 174 of the 2,368 people tested in CDC biomonitoring studies. Key routes of exposure include contaminated food and water.

Risks

There are a number of studies linking PFUnDA to health issues. PFUnDA accumulates in multiple organ systems, including the kidneys, liver, and testicles, which may lead to organ damage or cancer. Chronic exposure and accumulation of PFUnDA can also lead to DNA damage due to the body's reduced ability to deal with the toxic chemical.

Notes

Found in AFFF?	No	**Tested in NHANES?**	Yes
Found in turnout gear?	Some	**Seen in studies?**	21%