Understanding the Impact of PFAS in the Fire Service

BY JEFF PAULEY

FIRST RESPONDERS play a crucial role in protecting communities from the devastating effects of fire and other emergencies. However, our occupational duties expose us to a wide range of hazardous substances, including per- and polyfluoroalkyl substances (PFAS). PFAS compounds are synthetic chemicals known for their water- and grease-resistant properties, making them prevalent in firefighting foams, protective gear, and equipment. While PFAS compounds have contributed to the effectiveness of firefighting and related operations, concerns have arisen regarding their potential adverse health effects.

In February 2024, at the International Firefighter Cancer Symposium, two presentations discussed fire service PFAS exposure. Fire investigators are seekers of the truth, so I set out to read the scientific literature and talk to the experts to get a better understanding of this subject. This article is the result of that work and is designed to help fire service members understand the complexity of the PFAS exposure issue. You can read the documents listed below and others to educate yourself further. Note that the terms fire service and fire service member, as used here, include anyone who is occupationally exposed to the fire environment, such as firefighters, fire investigators, and fire instructors at all levels.

PFAS are a large class of manmade fluorinated compounds that have been around since the 1940s. They have many uses, and because of their extreme toxicity, they present a significant concern for environmental and human health. Many products used in industry and consumer products worldwide contain PFAS, including stain-resistant textiles, food-handling materials, firefighting foam, medical devices, paints, personal care products, construction materials, and industrial processing aids.[1] Some manufacturers of men's and women's athletic and workout apparel and footwear treat their products with PFAS. It is important to note that more than 98% of the world's population have PFAS in their blood serum because of the many exposure routes, including contaminated drinking water, contaminated food, food packaging, cookware, indoor dust, and ambient air.[2] PFAS are often described as forever chemicals because they do not break down in the environment. The PFAS compounds of particular concern include perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA) because they can accumulate in the body and stay there for a very long time. These are the two most-studied PFAS compounds.

For fire service members, there are additional PFAS exposure concerns. Fire service members can be occupationally exposed to carcinogens, including PFAS compounds and other hazardous substances, from exposure to combustion products, fire station dust, diesel exhaust, and contaminated fire equipment and gear. Firefighter studies have shown increased levels of PFAS compounds in their blood serum as compared to the general population. Because these remain in the body for a very long period and can bioaccumulate, the cumulative effects can be a health hazard.[3]

One recent study found that "[b]ased on median and typical exposures, food consumption accounted for 82% of the total PFAS intake of firefighters, followed by incidental ingestion and dermal exposure to PFAS in dust (15%). Accidental ingestion and skin absorbed PFAS from soil and utensil cleaning resulted in <1%."[2] This strongly suggests that exposure as a fire service member is only part of the overall issue.

While some household-type product manufacturers have stopped using some PFAS compounds in recent years, they still exist in older items such as furniture, carpeting, paper, and industrial products. PFAS are also used in many everyday items today, including clothing and pharmaceuticals, with the highest quantities in electronics, including wiring, cables, LCDs, and flat panel displays. These materials add to the toxicant[1] load of fire smoke during a fire. When the fire smoke cools, these partially consumed carbonaceous materials containing many aerosol toxicants fall to the ground, contaminating the area around the fire scene, the warm zone, and possibly farther away. This means that activities in this area are a probable sources of PFAS exposure. This includes training and demonstration fires.

Health Hazards

Because PFAS are so pervasive in the environment, they present ingestion, dermal absorption, and inhalation hazards. PFAS compounds can accumulate in the human body directly from contaminated water or through foods, including red meats, eggs, vegetables, snacks, seafood, animal fat, etc. The health concerns of PFAS compounds and their dietary exposures are by no means limited to the fire service and can affect everyone. As noted, water and food consumption has been broadly identified as the most important human exposure route.

A scholarly review in 2023 noted that "[t]here has been extensive research examining possible relationships between PFAS levels in blood and harmful health effects in human studies. These studies suggest that high levels of some PFAS exposure may lead to a variety of adverse health outcomes. These health effects include carcinogenicity, hormonal disruption, immunotoxicity, liver function alterations, low fetal weight, increased lipid level, tumor induction, and obesity."[2] In only a few other occupations (besides firefighters) are workers known to be exposed to PFAS more than the general U.S. population, and these are chemical manufacturing and processing workers and ski wax technicians.[1] Given our exposure numbers and durations, it is logical that all fire service members are at risk.

Adverse health effects reported in the fire service are like those of other occupational groups and the general population, including the risks for certain cancers. However, fire service members are also exposed to many chemical agents at fire scenes in addition to PFAS, some of which are known carcinogens such as benzene and benzo [a]pyrene.[2]

Considering their additive effects, these can cause additional health issues. Some of these compounds can remain at the scene for an extended time after the fire has been extinguished. How these may combine in the fire environment to create other harmful complex mixtures has not been studied,[4] but this should be an exposure concern to everyone in the fire service.

Determining the health risk of PFAS and precursors is difficult. And, due to limited scientific research in human and animal models, there is limited adverse public health toxicity information available. Fire service members are often exposed to unknown mixtures, so it isn't known how these affect the known exposures, and toxicity studies done on humans and animals frequently lack similarities, making relevance uncertain.[5]

According to the U.S. Environmental Protection Agency, "[c]urrent scientific research suggests that exposure to certain PFAS may lead to adverse health outcomes. However, research is still ongoing to determine how different levels of exposure to different PFAS can lead to a variety of health effects. Research is also underway to better understand the health effects associated with low levels of exposure to PFAS over long periods, especially in children."[6]

Many factors contribute to whether someone develops adverse health effects from PFAS exposure. In the fire service, such things as job duties, employment duration, and PPE use affect blood serum PFAS levels. Additionally, individual susceptibility is affected by many factors. However, PFAS compounds can pile up in our bodies, so cumulative exposure can become a health issue. Here are some of the possible health risks associated with long-term PFAS exposure.

Cancer

Epidemiological studies have suggested a potential link between PFAS exposure and an increased risk of certain types of cancers among firefighters. This would mean other fire service members as well. Elevated levels of PFAS compounds have been detected in the blood samples of firefighters, raising concerns about their carcinogenic effects, particularly in organs such as the liver, kidneys, and thyroid. Human occupational and community exposure to PFAS has been associated with several cancers, including those of the kidney, testis, prostate, and liver.[7] However, more research is needed to understand the impact of PFAS exposure to cancer.

In November 2023, a work group of 30 scientists from 11 countries met in Lyon, France, at the International Agency for Research on Cancer (IARC), part of the World Health Organization, to conduct a cancer hazard evaluation regarding the carcinogenicity of PFOA and PFOS, two of the most widely used chemicals in the group of PFAS

compounds. They determined that PFOA is carcinogenic to humans (Group 1) and that PFOS is possibly carcinogenic to humans (Group 2B).[8] There was sufficient evidence for cancer in experimental animals, strong mechanistic evidence (evidence about either the existence or the nature of a causal mechanism connecting two things) for epigenetic (the study of changes in organisms caused by modification of gene expression) alterations and immunosuppression in exposed humans, and limited evidence for renal cell carcinoma and testicular cancer. PFOA and, to a greater extent, PFOS have been widely used in some firefighting foams, including AFFF. The general population is exposed to them mainly through food and drinking water and could be exposed through some consumer products.

Additionally, in June 2022, the IARC classified the occupation of firefighter and, by extension, other fire service members who are exposed to the fire or post-fire environment, as a known carcinogenic occupation (Group 1). It found sufficient evidence for mesothelioma and bladder cancer and limited evidence for colon, prostate, and testicular cancers and for melanoma and non-Hodgkin lymphoma.[9] This clearly means that all fire service members should take steps to limit their exposure to PFAS and other hazardous substances at fire and post-fire scenes.

Reproductive Effects

PFAS compounds have been associated with reproductive abnormalities in both sexes. Unfortunately, the results are not always consistent because there is a wide range of factors impacting them.[10] Some study results show that these toxicants can adversely affect female reproductive organs, and limited research regarding males indicates potential health issues.[11] Reproductive health research for male and female firefighters exposed to PFAS is just getting underway; however, emerging evidence underscores the need for further investigation into these potential reproductive and developmental risks.

Immunotoxicity and Endocrine Disruption

There are indications that PFAS compounds possess immunotoxic and endocrine-disrupting properties,[7] which can compromise the immune system and disrupt hormonal balance in humans. These effects could impair the body's ability to respond to infections and regulate essential physiological processes, thereby increasing susceptibility to various health conditions.

PFAS Sources in the Fire Service

Fire Suppression Foam

Class B firefighting aqueous film-forming foams (AFFF), designed to extinguish flammable liquid fires, have been a primary source of PFAS exposure for firefighters.[6] These foams contain PFAS compounds, including PFOS, a known potential carcinogen, and PFOA. These can leach into the environment during training exercises, fire suppression activities, and firefighting PPE and equipment field decontamination.

While AFFF is a known source of historical groundwater contamination, increased exposure to AFFF through firefighting and fire training activities and post-fire activities, including overhaul and investigations at scenes where AFFF was used, presents a known health hazard to fire service members. Given its known persistence, it is assumed that PFAS remains at the scene and contributes to groundwater contamination from the runoff of the water used in suppression activities. Dermal absorption can occur when fire service members touch items that have been exposed to AFFF. While many fire departments have phased out the use of AFFF, others have not. And, because of its long half-life, exposure that happened years ago can still create current health issues.

Protective Gear

Fire service members rely on specialized protective gear, including turnout/bunker gear, gloves, and helmets, to safeguard themselves from fire-related hazards. However, almost all of this gear is treated with some form of PFAS substance. The coat and pants have three layers: an outer shell, a moisture barrier, and an inner thermal liner. PFAS are on the outer layer to provide a durable water- and oil-repellent (DWR) finish that helps limit exposure to water and hazardous liquids. The moisture-barrier layer is treated with a moisture-resistant and flame-retardant product that contains a type of PFAS. The inner thermal layer can contain higher amounts of PFAS than the other layers.[12] As a result, firefighters may experience dermal exposure to PFAS through direct contact with contaminated gear and inhalation exposure from shedding PFAS materials.

In addition to AFFF exposure, these PPE finishes can degrade over time from exposure to heat, sunlight, and water and from use. The material can then shed the PFAS coating, which adds to the environmental dust in fire stations and logically also (although not yet studied) in vehicles and homes. As much as 80% of the material can come off in 10 years of use.[13]

As part of the fiscal year 2021 National Defense Authorization Act, the National Institute of Standards and Technology (NIST) was directed to "complete a study of the contents and composition of new and unused personal protective equipment worn by firefighters" and to examine "the conditions and extent to which (PFAS) are released into the environment over time from the degradation of PPE from normal use ...."[12, 14] Two reports have subsequently been released and are referenced herein. Upcoming reports will look at PFAS in other gear, such as gloves and hoods, and at PPE service lifetime release of PFAS during repeated stressing.

The first NIST report examined 20 moisture barrier, outer shell, and thermal liner textiles used in the construction of new firefighter turnout gear and found that "PFAS concentrations varied widely among each textile type, which suggests that the amount of PFAS present in new turnout gear may depend on the specific textiles used in gear manufacturing." "PFAS concentrations varied within textile types, with largest differences observed among moisture barrier textiles."[12]

The follow-up report, published in early 2024, looked at the effects of stressing these 20 textiles through wear and tear.[14] NIST subjected PFAS-containing material to the effects of abrasion, elevated temperature, laundering, and weathering. Generally, it found that outer shells were stressed more than the other layers and that "as in unstressed textiles, summed PFAS concentrations tended to be highest in stressed DWR-treated outer shell textiles and lowest in stressed thermal liner textiles."

It is important to understand, however, that this apparel can also become

contaminated with PFAS and other toxins from the fire scene itself. Today's structure and other fire types expose fire service members to many toxic substances from the burning of manufactured materials that contain PFAS and other harmful chemicals. These can then accumulate on the clothing we are wearing at the fire and post-fire scene. In addition to PFAS, polycyclic aromatic hydrocarbons (PAHs), metals, and formaldehyde, among others, can result in a layer of contaminants on the PPE and off-gassing.[2] Field decontamination will not remove all these contaminants from the PPE. When these items are worn or placed in the apparatus cab or your personal vehicle or taken into the fire station or your home, they can then contaminate others.

"Although turnout gear has been identified as a source of PFAS, more research is required to evaluate the PFAS exposure level from turnout gear (because) turnout gear may get contaminated by PFAS from the smoke of a structural fire or PFAS-containing AFFF, which subsequently act as a source of exposure."[2]

It has been suggested that PPE manufacturers stop using PFAS in PPE. This presents a new set of issues. Transitioning away from PFAS-containing gear can be challenging due to the need for effective and safe alternatives, as well as the considerable cost and logistical considerations involved with switching. The disposal of PFAS-containing turnout gear can lead to additional environmental contamination. PPE apparel must be resistant to water and oil absorption and provide heat protection. It is also necessary to have flame-retardant properties on the outer layer.

In one study of gear treated with non-PFAS water repellents, the outer shell fabrics were found not to be diesel/oil-repellent, posing a potential flammability hazard if exposed to these fluids and subsequent flame on an emergency response. Both PFAS-based and non-PFAS sets of fabrics performed similarly in terms of thermal protective performance, tearing strength, and water repellency in this study.[15] Individual fire service members, decision makers, and organizations need to examine the performance trade-offs if they are going to use non-PFAS-treated outer shells.

Fire Station Dust

Multiple studies have shown that the dust in fire stations contains PFAS compounds. While all indoor air contains PFAS from a variety of sources, including furniture, carpeting, electronics, etc.,[16] this health exposure is increased in a fire station when PPE treated with PFAS is introduced. That PFAS burden can be compounded when the PPE is exposed to fire scene contaminants and brought into the station. Diesel exhaust particulates, which contain PAHs, sulfates, nitrates, and metals,[17] add to the station dust composition and are also a health hazard. Vehicle exhaust collectors can significantly reduce but likely not eliminate all these particulates. Effective field decontamination and PPE washing practices can also help reduce the PFAS burden in stations, but these practices need to be done properly and consistently.

For these reasons, new fire stations typically have clean and dirty areas, with methods to separate the two, including higher- and lower-pressure ventilation methods. Unfortunately, many existing stations do not have these barriers and systems, but separation can sometimes be made. There are other places where this can also be an issue. When we take gear into our homes, work areas, and training facilities, any preexisting PFAS burden is unnecessarily increased.

Equipment

Equipment used at fire and post-fire scenes can be contaminated with PFAS and other toxic substances from exposure to the fire and post-fire environment. Consider anything that has been exposed to fire smoke to be contaminated and thoroughly clean it. In addition to PPE, this includes radios and straps, cameras, eyeglasses, goggles, hand tools, etc. Cleaning also involves two parts: an initial field decontamination and a thorough washing. Unless both steps are done after every use, the toxicant burden is increased. This can happen when you place equipment in vehicle passenger areas; take it into clean areas of the station; or take it to your home, office, etc.

Discussion

PFAS compounds are a man-made group of substances that break down slowly and are very pervasive in the environment, which is why a significant portion of the world's population has them in their body. They are found in indoor and outdoor environments, wildlife, and human tissue and bodily fluids everywhere. They come from industrial processes and military and firefighting operations, and they migrate out of consumer products into the air, household dust, food, soil, ground, and surface water and then into drinking water.[18]

The pervasive presence of PFAS from multiple sources at firefighting operations poses significant potential health risks to firefighters and others, necessitating concerted efforts to minimize exposure and safeguard their well-being. By addressing the sources of PFAS contamination, implementing preventive measures, and advancing research on PFAS toxicity, stakeholders can work collaboratively to mitigate the impact of these persistent chemicals on fire service member health.

Recognizing the potential risks associated with PFAS exposure, regulatory agencies have implemented some measures to mitigate fire service exposure to these substances. Strategies include the development of PFAS-free firefighting foams, the development and use of alternative materials for protective gear, and enhanced training on proper handling and disposal practices. Additionally, ongoing research efforts aim to clarify the long-term health effects of PFAS exposure among firefighters and inform evidence-based prevention and intervention strategies.

The issue around PFAS is a complex problem that has no single solution. "The complex exposure patterns of PFAS coming from multiple sources make it challenging to predict associated risk."[2] Much additional research is needed, and changes are needed at the scientific, governmental, chemical, and product manufacturing levels and by purchasing organizations, retailers, and consumers.

Occupational exposure to the wide array of toxic substances at fire and post-fire scenes as a firefighter or anyone else in the fire service is a complex issue. There are so many variables in play, and these are affected by one's roles and responsibilities at the scene, work arrangement (full-time, part-time, volunteer), the fire type, and the fire's composition. This all means that everyone in the fire service should do a better job of reducing exposure to themselves and fellow workers from PFAS and the many other toxicants at almost every fire scene. Every fire scene exposes fire service members to many health hazards while in the hot (whatever is or has burned, its debris field, and its collapse zone) and warm (the area between the hot and cold zones where particulates from the cooling smoke likely have settled) zones; PFAS is just one of them.

Recommendations

Each of us needs to do our part to help protect ourselves, our families, and others from fire and post-fire scene toxicants, regardless of our employer's policies and procedures. Here are some things you can do to help reduce your exposure.

- Only wear PFAS-treated PPE when the protective qualities of that apparel are needed—at fire scenes and at training scenarios where it is necessary as part of the exercise.
- Wear PPE that protects you against dermal absorption in the hot and warm zones of every fire and post-fire scene. It is essential to cover as much exposed skin as possible.
- Wear adequate and appropriate respiratory protection during all hot and warm zone fire and post-fire scene activities. This means SCBA during all suppression and overhaul activities and an air purifying respirator with a P100 filter with an oily vapor, acid gas, and formaldehyde (OV/AG/FM) cartridge during other activities, at a minimum.
- Use effective field decontamination procedures for all personnel who were in the hot and warm zones at every fire and post-fire scene to reduce the fire scene contaminants on PPE and tools because everything is contaminated, even if you can't see it. This includes radios and holders, cell phones, eyeglasses, goggles, and anything else taken into the scene. This also includes all hoselines deployed into the hot and warm zones.
- Package all contaminated PPE and keep it out of the vehicle cabs until it is cleaned. This is also an important dust reduction step. Wear gloves to handle contaminated items.
- Take a shower as soon as you can after leaving every fire and post-fire scene, including training fires.
- Clean your PPE by appropriately washing all apparel after every use.
- Clean all tools, equipment, and hoselines after every use.
- Do not take any gear, apparel, tools, or anything else that could be contaminated into clean areas of your fire station or your office or home, where it could contaminate other people.
- At the fire station, have designated dirty and clean areas, and limit your time in the dirty areas, which include engine bays and PPE storage areas. ■

ENDNOTES

1. "Per- and polyfluoroalkyl substances (PFAS)." *National Institute for Occupational Safety and Health (NIOSH).* September 15, 2022 (reviewed). bit.ly/4a29AJB.
2. Mazumder, N.-U.-S., Hossain, M. T., Jahura, F. T., Girase, A., Hall, A. S., Lu, J., and Ormond, R. B. "Firefighters' exposure to per-and polyfluoroalkyl substances (PFAS) as an occupational hazard: A review," *Frontiers in Materials,* March 23, 2023, 1-22. bit.ly/3UH63Mv.
3. Rosenfeld, P. E., Spaeth, K. R., Remy, L. L., Byers, V.,

Muerth, S. A., Hallman, R. C., et al., "Perfluoroalkyl substances exposure in firefighters: Sources and implications," *Environmental Research*, March 1, 2023. bit.ly/4a1QEu0.

4. IAAI Health & Safety Committee, *Fire Investigator Health and Safety Best Practices, Third Edition.* Crofton, MD: International Association of Arson Investigators, Inc., 2022. bit.ly/4dqhYpw.
5. Mazumder et al., 2023a
6. "Our Current Understanding of the Human Health and Environmental Risks of PFAS," U.S. Environmental Protection Agency, June 7, 2023 (updated). bit.ly/3JJPV6A.
7. Boyd, R. I., Ahmand, S., Singh, R., Fazal, Z., Prins, G. S., Erdogan, Z. M., et al., "Toward a Mechanistic Understanding of Poly- and Perfluoroalkylated Substances and Cancer," *MDPI*, June 14, 2022. bit.ly/4bi7qqq.
8. Zahm, S., Bonde, J. P., Chiu, W. A., Hoppin, J., Kanno, J., and Abdallah, M., "Carcinogenicity of perfluorooctanoic acid (PFOA) and perfluorooctanesulfonic acid (PFOS)," *The Lancet Oncology*, January 2024. bit.ly/44qWJQb.
9. "Occupational Exposure as a Firefighter," *IARC Monographs on the Identification of Carcinogenic Hazards to Humans, Volume 132*, International Agency for Research on Cancer. Lyon, FR, 2023. bit.ly/3wppb8k.
10. Rickard, B. P., Rizvi, I., and Fenton, S. E., "Per- and poly-fluoroalkyl substances (PFAS) and female reproductive outcomes: PFAS elimination, endocrine-mediated effects, and disease," *Toxicology, Volume 465*, January 15, 2022. bit.ly/44lG80d.
11. Tarapore, P., and Ouyang, B., (2021). "Perfluoroalkyl Chemicals and Male Reproductive Health: Do PFOA and PFOS Increase Risk for Male Infertility?" *International Journal of Environmental Research and Public Health*, MDPI, April 5, 2021. bit.ly/3QvbaNj.
12. Maizel, A. C., Thompson, A., Tighe, M., Escobar, V. S., Rodowa, A. E., Falkenstein-Smith, R., et al., *Per- and Polyfluoroalkyl Substances in New Firefighter Turnout Gear Textiles* (Technical Note), National Institute of Standards and Technology (NIST), Gaithersburg, MD, May 2023. bit.ly/44p28ak/.
13. Peaslee, G. F., Wilkinson, J. T., McGuiness, S. R., Tighe, M., Caterisano, N., Lee, S., et al., "Another Pathway for Firefighter Exposure to Per-and Polyfluoroalkyl Substances: Firefighter Textiles," *Environmental Science and Technology Letters*, June 23, 2020. bit.ly/3WpTgQ2.
14. Maizel, A. C., Thompson, A., Tighe, M., Escobar, V.S., Rodowa, A.E., Falkenstein-Smith, R., et al., "Per- and Polyfluoroalkyl Substances in Firefighter Turnout Gear Exposed to Abrasion, Elevated Temperature, Laundering, or Weathering," (NIST Technical Note), National Institute of Standards and Technology, Gaithersburg, MD, January 2024. bit.ly/4a5Rk1Y.
15. Mazumder, N.-U.-S., Lu, J., Hall, A. S., Kasebi, A., Girase, A., Masoud, F., . . . Ormond, R. B., "Toward the future of firefighter gear: Assessing fluorinated and non-fluorinated outer shells following simulated on-the-job exposures," *Journal of Industrial Textiles*, November 30, 2023. bit.ly/4aYzKy9.
16. Young, A. S., Sparer-Fine, E. H., Pickard, H. M., Sunderland, E. M., Peaslee, G. F., and Allen, J. G. "Per- and polyfluoroalkyl substances (PFAS) and total fluorine in fire station dust," *Journal of Exposure Science & Environmental Epidemiology*, 31, 930-942, 2021. go.nature.com/3w8ZrND.
17. "Carcinogenicity of occupational exposure as a firefighter," *The Lancet Oncology*: News, pp. 985-986, August 23, 2022. bit.ly/3WpSTVn.
18. Blum, A., Balan, S. A., Scheringer, M., Trier, X., Goldenman, G., Cousins, I. T., . . . Weber, R. (2015, May 1). "The Madrid Statement on Poly- and Perfluoroalkyl Substances (PFASs)," *Environmental Health Perspectives*, May 1, 2015. bit.ly/3WrjCRG.

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