Evaluation of Health Symptoms and Conditions Among Employees at a Fire Station

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Program Description

The National Institute for Occupational Safety and Health (NIOSH) Health Hazard Evaluation Program investigates possible health hazards in the workplace under the authority of the Occupational Safety and Health Act of 1970 [29 USC 669a(6)]. The Health Hazard Evaluation Program also provides, upon request, technical assistance to federal, state, and local agencies to investigate occupational health hazards and to prevent occupational disease or injury. Regulations guiding the Program can be found in Title 42, Code of Federal Regulations, Part 85; Requests for Health Hazard Evaluations [42 CFR Part 85].

Disclaimer

This document is a NIOSH health hazard evaluation report prepared in response to a specific workplace or technical assistance request. The recommendations in this report are made on the basis of the findings at the workplace evaluated and may not be applicable to other workplaces. As such, this health hazard evaluation report is not intended as industrywide Centers for Disease Control and Prevention (CDC) or NIOSH guidelines or policy, and it does not establish new health standards, guidance, or regulatory requirements.

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Availability of Report

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Abbreviations of Per- and Poly-fluoroalkyl Substances (PFAS)

6:2 FTMAC	6:2 Fluorotelomer methacrylate
6:2 FTOH	6:2 Fluorotelomer alcohol
8:2 FTOH	8:2 Fluorotelomer alcohol
10:2 FTOH	10:2 Fluorotelomer alcohol
APFO	Ammonium perfluorooctanoate
HFPO-DA	Hexafluoropropylene oxide dimer acid; GenX
MeFBSE	*N*-methyl perfluorobutane sulfonamido ethanol
MeFOSAA	Methylperfluorooctanesulfonamidoacetic acid
PCBTF	Parachlorobenzotrifluoride
PFBA	Perfluorobutanoic acid
PFBE	Perfluorobutyl ethylene
PFBS	Perfluorobutanesulfonic acid
PFDA	Perfluorodecanoic acid
PFHpA	Perfluoroheptanoic acid
PFHpS	Perfluoroheptanesulfonic acid
PFHxA	Perfluorohexanoic acid
PFHxS	Perfluorohexanesulfonic acid
PFIB	Perfluoroisobutylene
PFMOAA	Perfluoro-2-methoxyacetic acid
PFNA	Perfluorononanoic acid
PFO2HxA	Perfluoro(3,5-dioxahexanoic) acid
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctanesulfonic acid
PFPeA	Perfluoropentanoic acid
PFPeS	Perfluoropentanesulfonic acid
PFPrA	Perfluoropropanoic acid
PFUnDA	Perfluoroundecanoic acid
TFA	Trifluoroacetic acid

Introduction

Request

The union representing firefighters at a county fire department requested a health hazard evaluation concerning health symptoms and conditions reported by firefighters at one fire station, particularly gastrointestinal symptoms and gallbladder removals (cholecystectomy). The requestors were not sure whether these symptoms and conditions were related to exposures at the fire station, including per- and poly-fluoroalkyl substances (PFAS) from well water and environmental contamination near the fire station.

About PFAS

PFAS are a group of human-made chemicals that have been used in industry and consumer products since the 1940s. PFAS do not readily break down and can stay in the environment for a long time. They can also stay in the body for a long time. Some PFAS have been associated with adverse health effects, including higher cholesterol levels, changes in liver enzymes, and kidney and testicular cancer.

Workplace

The fire department had eight stations throughout the county. The station of concern used well water that may have been contaminated with PFAS from past upstream manufacturing operations. The fire station was located in the geographic area covered by a consent order. The order required the manufacturer to address PFAS sources and contamination at the upstream facility and prevent further impacts to air, soil, groundwater, and surface waters, including water testing.

Sampling in 2017 revealed that PFAS were present in the well groundwater. A filter (specifically, a two-stage granular activated carbon filter) was installed to treat the water. The specific date of installation is unknown, but it was after 2017, likely between 2023 and 2024. Beginning in 2023, firefighters at this station were provided with bottled water. Other potential exposures, including environmental exposures from nearby properties, were discussed as potential concerns.

At the time of the request, the county fire department employed about 140 full-time employees, with 9 firefighters assigned to the fire station of concern. In January 2026, the firefighters assigned to this station were moved permanently to a newly built fire station at a different location.

To learn more about the workplace, go to Section A in the Supporting Technical Information

Our Approach

Over the period of February to November 2025, we spoke with union and employer representatives and with firefighters who had worked at the station. We also reviewed documents to learn more about their health and exposure concerns. We completed the following activities during our evaluation:

- Reviewed past water and air sampling documents.
- Reviewed documents with health information.
- Interviewed current and former firefighters who had been assigned to work at the station at any time during January 2010–November 2025 about health symptoms and conditions as well as demographic and work characteristics.

To learn more about our methods, go to **Section B in the Supporting Technical Information**

Our Key Findings

There was evidence of recurring moisture issues and mold growth at the fire station

- Reports from an indoor environmental quality consultant, dated 2022 through 2025, found evidence of mold growth, water damage, and water intrusion in the exercise room, restrooms, locker rooms, kitchen, day room, and in transitional areas.
- Inadequate heating, ventilation, and air conditioning (HVAC) systems may have contributed to ongoing damp conditions that could support mold growth in the fire station.
- These spaces were cleaned following a consultant's remediation protocols. Dehumidifiers and high-efficiency particulate air (HEPA) units were installed near the locker room and restroom.
- In January 2026, the firefighters working in that station were relocated permanently to a newly constructed station that uses well water in the same municipality.

Prior sampling found some PFAS in drinking water and air

- Water samples were collected both before passing through the installed water filter (pre-treatment) and after passing through the filter (post-treatment).
- Some PFAS were detected in pre-treatment water samples at levels exceeding state groundwater quality standards and available federal recommended levels.
- Fewer PFAS were detectable in post-treatment water samples, and none exceeded available recommended levels.
    - PFMOAA and PFPrA, which are ultra short-chain PFAS compounds, were detected.
- Air samples from the apparatus bay and day room of the fire station found detectable levels of PFAS in air, including 6:2 FTOH, 8:2 FTOH, 10:2 FTOH, 6:2 FTMAC, MeFBSE, and PCBTF.

Prior sampling found other compounds in drinking water and air

- Pre-treatment water samples found methyl tert-butyl ether and barium; neither were found post-treatment.
- Lead was found in post-treatment water samples. The U.S. Environmental Protection Agency (EPA) has set the health-based goal for lead at zero, because there is no safe level of lead in the human body.
- Air samples from the apparatus bay and day room of the fire station found detectable levels of some polyaromatic hydrocarbons (PAHs). Naphthalene levels did not exceed health-based indoor air limits established by the EPA and the World Health Organization, and no limits are established for the other PAHs detected.

Station firefighters reported various symptoms and conditions, but it was unclear if these were due to exposures at the station, working as a firefighter, or factors outside of work

- Among the 17 station firefighters we interviewed, the most common symptom that improved when not on duty was headaches. Headaches, along with nasal and sinus symptoms that were also reported, are common and can have many causes, including building-related indoor environmental quality issues.
- The next most common symptoms were loose stool or diarrhea and nausea. Gastrointestinal symptoms can have many causes, including shift work and exposure to PAHs through firefighting, along with factors such as diet and physical activity levels.
- Dyslipidemia (abnormal levels of cholesterol or triglycerides in the blood), high liver enzymes, and fatty liver were the most common conditions reported. Three (18%) interviewed firefighters said they had gallbladder disease for which cholecystectomy (gallbladder removal surgery) was recommended. No medical records were reviewed. Some of these conditions are common in both the general population and among firefighters.
- Fatty liver was a common ultrasound finding, identified in more than half of current firefighters who participated in a department-wide health screening in February 2025. Fatty liver has many causes, including diet or lifestyle factors or having other medical conditions.
- While prior environmental assessments showed the presence of mold, dampness, PFAS, and PAHs at the station, it is unclear whether these exposures are the cause of the reported symptoms and conditions. The symptoms and conditions are nonspecific, relatively common, and can also be linked with firefighting, nonwork exposures, or both.

To learn more about our results, go to **Section B in the Supporting Technical Information**

Our Recommendations

The potential benefits of improving workplace health and safety are:

- Improved worker health and well-being
- Better workplace morale
- Easier employee recruiting and retention
- Enhanced image and reputation
- Superior products, processes, and services
- Increased overall cost savings

The recommendations below are based on the findings of our evaluation of the fire station before the January 2026 relocation. These recommendations are workplace-specific, based on the information available for the workplace evaluated, and are intended to improve this workplace's conditions. For each recommendation, we list a series of actions you can take to address the issue at your workplace. The actions at the beginning of each list are preferable to the ones listed later. The list order is based on a well-accepted approach called the "hierarchy of controls." The hierarchy of controls is a way of determining which actions will best control exposures. In most cases, the preferred approach is to eliminate hazards or to replace the hazard with something less hazardous (i.e., substitution). Installing engineering controls to isolate people from the hazard is the next step in the hierarchy. Until such controls are in place, or if they are not effective or practical, administrative controls and personal protective equipment might be needed. Read more about the [hierarchy of controls] on the NIOSH website.

We encourage management to use a health and safety committee to discuss our recommendations and develop an action plan. Both employee representatives and management representatives should be included on the committee. Helpful guidance can be found in the Occupational Safety and Health Administration's (OSHA) Recommended Practices for Safety and Health Programs.

Recommendation 1: Continue to monitor and address environmental conditions at the new station

Why? Athough the fire station has permanently moved to a new location, maintaining a healthy fire station environment is essential for firefighter well-being because they spend a lot of time at the station. The following principles still apply. Keeping the building dry prevents mold- and dampness-related respiratory issues. Properly maintaining the HVAC systems improves ventilation and reduces contaminants moving from apparatus bays into living areas. Regular water testing according to federal and local standards ensures a safe, reliable water supply and helps detect contaminants before they create health or operational concerns.

How? At your workplace, we recommend these specific actions:

Identify and eliminate moisture and water sources if you suspect mold growth.

- To reduce or eliminate mold growth, find and stop moisture sources and keep indoor relative humidity below 60%.
- Refer to the U.S. Environmental Protection Agency (EPA) Mold Cleanup and Centers for Disease Control and Prevention (CDC) Mold, Testing, and Remediation to properly remediate suspected mold growth.
- Routine air sampling for mold is not recommended because there are no health-based standards for mold in indoor air.
- NIOSH has developed tools to assess for dampness and mold in schools and general buildings.

Continue to monitor drinking water quality.

- Continue following local guidance on monitoring drinking water quality at the new fire station.
- Follow CDC Guidelines for Testing Well Water.
- Maintain water treatment, including granular activated carbon systems or reverse osmosis systems, as directed by the manufacturer.
- Continue using bottled water if concerns of contaminants persist.
- Stay informed about emerging guidance and research on PFAS in the region. Follow updated recommendations for reducing exposure through drinking water.

Encourage employees to report building-related concerns.

- Consider allowing anonymous reporting, if not already doing so.
- Regularly review these reports to help identify common themes and take action if needed.
- Provide all employees with information on response actions taken.

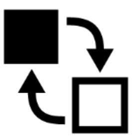
Recommendation 2: Reduce firefighters' exposure to PFAS and PAHs

Why? PFAS were detected in the previous station's drinking water and air, and PAHs were detected in station air. PFAS accumulate in the body and research has linked them to cancer, thyroid issues, immune suppression, liver damage, and reproductive harm. PAHs, present in fire smoke and gear, are known carcinogens (can cause cancer) that can be absorbed by breathing them in or through skin contact. These have been linked to increased cancer incidence in firefighters. It is important to reduce exposure wherever possible because both PFAS and PAHs contribute to long-term health risks, even at low levels. Firefighters have increased exposure compared with the general public.

How? At your workplace, we recommend these specific actions:

Follow recommendations to reduce overall PFAS exposure from community sources.

- The Agency for Toxic Substances and Disease Registry and EPA has information on preventing exposure to PFAS.



When purchasing new turnout gear, consult updated standards.

- The National Fire Protection Association (NFPA) Standard 1970 has updated requirements for turnout gear, including limits on specific substances and the total fluorine concentration.

Prevent PFAS and PAH exposure during firefighting work tasks.

- The International Association of Fire Fighters and the Firefighter Cancer Support Network developed a fact sheet with information on reducing exposure to PFAS in the fire service.
- Follow recommendations presented in a previous Health Hazard Evaluation report that evaluated PAH exposure to firefighters.

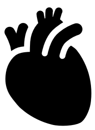
Recommendation 3: Support department firefighters in improving their health

Why? When employees are concerned that workplace exposures may be related to a health symptom or diagnosis, it can be useful to have a qualified health professional trained in workplace exposures evaluate their concerns. High liver enzymes, dyslipidemia, and fatty liver were common among interviewed firefighters, and ultrasound findings of fatty liver were common according to a department-wide health screening. These findings suggest that department firefighters might benefit from programs to reduce risk factors for fatty liver, which overlap with risk factors for heart disease, diabetes, and stroke.

How? At your workplace, we recommend these specific actions:

Encourage firefighters to report work-related health symptoms and seek care from a provider who is knowledgeable in occupational and environmental medicine.

- The American College of Occupational and Environmental Medicine and the Association of Occupational and Environmental Clinics maintain databases of providers to help locate an occupational medicine clinician in your geographic area.



Help firefighters modify their cardiometabolic risk factors.

- Train firefighters so they understand what health conditions might be common in this department, or among firefighters in general, and ways to modify their risk factors. Information on cardiometabolic risk factors may be found on the NIH Metabolic Syndrome website.
- Consider starting or improving a wellness and fitness program consistent with NFPA 1583, Standard on Health-Related Fitness Programs for Fire Department Members, (consolidated into NFPA 1580) and the International Association of Fire Fighters/International Association of Fire Chiefs (IAFF/IAFC) Wellness-Fitness Initiative.

Supporting Technical Information

Evaluation of Health Symptoms and Conditions Among Employees at a Fire Station

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Section A: Workplace Information

Fire Department

This fire department serves a county with a year-round population of 230,000 and responds to approximately 6,000 emergency calls per year involving emergency medical services, fire suppression, technical rescue, and hazardous materials. The department has full-time, part-time, and volunteer staff, with approximately 140 full-time employees. The department has eight fire stations.

Fire Station

The county leased the fire station of interest. The facility had been in service since 1983 and had always served as a fire station. It consisted of an 8,840 square foot main building with four truck bays, a communications room, a day room with sleeping quarters for three firefighters, and a small kitchen. In May 2025, the building also contained an unused commercial kitchen where the appliances had been removed. Sleeping quarters on the second floor were also no longer in use. An outside shelter/building was used for storage and a small work area. A three-bay storage building was also located on site, but it was only used to store a trailer.

The fire station had a groundwater well for its water supply. Before this health hazard evaluation (HHE), a two-stage granular activated carbon filter was installed at the fire station to treat the groundwater supplying the station. Based on sampling records, the installation likely occurred between 2023 and 2024.

After this station's firefighters permanently moved to a newly built station in early 2026, it was no longer used as a fire station.

Employee Information

The fire station of interest was staffed 24 hours a day, 7 days a week. Three crews of three full-time career firefighters worked in 9-day shift cycles. Firefighters worked 24-hour shifts on Days 1, 3, and 5 of the cycle and were off on Days 2, 4, and 6–9. Most firefighters had one assigned primary station but could work at other stations to cover shifts.

History of Issues at Workplace

Union representatives requested an HHE because multiple firefighters who worked at the station reported health symptoms and conditions, especially gastrointestinal symptoms and gallbladder removals (cholecystectomy). The requestors were unsure whether these symptoms and conditions were related to exposures at the fire station. Concerns about the fire station included PFAS from well water and exposures in air and soil from environmental contamination near the fire station.

In 2017, state agencies began investigating the presence of PFAS in a nearby river. Elevated levels of PFAS were found in well water in the area. In 2019, the company responsible for the PFAS release and the state signed a consent order. Among other things, the order required the company to provide well water testing, and depending on the PFAS levels found, replacement drinking water supplies (e.g., bottled water, granular activated carbon filters). In 2022, the company was directed to expand drinking water well sampling in downstream communities, including the county where the fire station was located.

Section B: Methods, Results, and Discussion

The objectives of this evaluation included the following:

- Assess environmental exposures at the fire station before the January 2026 relocation based on records from prior water and air sampling conducted 2023–2025
- Characterize the health symptoms and conditions of current and former station firefighters as it related to the concerns raised in the HHE request.

Methods: Environmental Sampling Document Review

We reviewed results of water sampling for various PFAS, metals, and volatile organic compounds (VOCs) conducted at the fire station by various contractors and laboratories, dated May 2023 through April 2025. Most sampling was conducted in partnership with the North Carolina Department of Environmental Quality (NCDEQ).

The fire station's water treatment was a two-stage granulated activated carbon filter. Generally, contractors took water samples at different points between the well and the point of use at the fire station: pre-treatment (generally at the well), mid-treatment, or post-treatment. We reviewed the records and documents (Table C1) pertaining to sampling of well water pre-treatment, mid-treatment, and post-treatment for PFAS and other compounds. Consultants generally reported results in nanograms per liter (ng/L). However, we discuss results in parts per trillion (ppt) to compare them with available Environmental Protection Agency (EPA) water standards, which are reported in ppt. In water concentration measurements, 1 ng/L equals 1 ppt.

The EPA National Primary Drinking Water Regulations and many state-level drinking water regulations are not legally applicable to private well systems. However, benchmarking well water quality against these guidelines provides well owners with valuable insight into the safety and potability of their water.

When possible, water sampling results for PFAS are compared with the EPA National Primary Drinking Water Regulations, which are legally enforceable primary standards intended to protect public health by limiting the levels of contaminants in municipal drinking water [EPA 2025a]. Maximum Contaminant Levels (MCLs), which are enforceable, are defined as the highest level of a contaminant allowed in drinking water, taking feasibility and cost into consideration. Maximum Contaminant Level Goals (MCLGs) are nonenforceable public health goals defined as the level of contaminant in drinking water below which there is no known or expected risk to health.

When possible, the PFAS Hazard Index, a tool used by the EPA to understand health risk from chemical mixtures, was calculated for water sampling results. The Hazard Index considers the different toxicities of HFPO-DA (GenX chemicals), PFBS, PFNA, and PFHxS (in ppt) to determine if the combined levels of these PFAS in the drinking water pose a potential risk to health [EPA 2024].

$$Hazard\ Index = \frac{GenX_{ppt}}{10\ ppt} + \frac{PFBS_{ppt}}{2000\ ppt} + \frac{PFNA_{ppt}}{10\ ppt} + \frac{PFHxS_{ppt}}{10\ ppt}$$

The EPA's proposed Hazard Index MCL for PFAS is 1.0 for the annual average Hazard Index. When possible, we calculated the Hazard Index.

We reviewed the results of air sampling conducted at the station by the North Carolina Firefighter Cancer Cohort Study. The report, dated August 2025, included evaluations of PFAS and combustion byproducts like PAHs. Samples were collected over 3 days in June 2025.

We reviewed 20 reports with mold testing results conducted by a contractor (March 2022 through June 2025). Some of the reports and results occurred after remediation was completed by fire station staff or by the contractor.

Results: Environmental Sampling Document Review

PFAS Water Sampling

In May 2023, well water samples analyzed by two different contractors (Contractor 1 and Contractor 2) identified several PFAS using a modified EPA 537 or 537.1 method [EPA 2026b]. These included PFAS compounds regulated by the EPA [2025c].

Contractor 1 reported a detection limit (DL) that was lower than the reporting limit (RL). Contractor 2 only reported an RL. Results above detection with corresponding RLs are shown in Table C2. Both contractors identified PFOA, PFOS, and PFHxS in well water samples. For both reports, PFOS and PFHxS were analyzed at concentrations above the EPA MCL of 4 ppt and 10 ppt, respectively.

Three PFAS compounds covered in the consent order (PFO2HxA, PFMOAA, and PFHpA) were also identified by Contractor 1 using a lower RL. However, values that are above the DL and lower than the RL are more uncertain. The Hazard Index averaged 1.6 between the two contractors, however, this value was calculated using data from sampling done in a single month. Therefore it may not be representative of the full year or directly comparable with the EPA Hazard Index MCL.

In June 2023, Contractor 1 analyzed water samples collected pre-treatment (from the faucet at the well head) and post-treatment (from faucets at the fire station) using a modified EPA 537.1 method. Table C3 shows pre-treatment and post-treatment sampling results from June 2023 where at least the pre-treatment sample result was above the DL. In post-treatment water samples, PFOS, PFMOAA, and PFBA were identified. PFOS concentrations decreased by more than two orders of magnitude following treatment, declining from 144 ppt to 1.16 ppt. PFMOAA and PFBA concentrations also declined post-treatment, though to a lesser extent, decreasing from 2.39 ppt to 1.52 ppt and from 1.85 ppt to 1.13 ppt, respectively.

In October 2023, Contractor 1 analyzed water samples collected pre-treatment (from the faucet at the well head), mid-treatment (from faucets at the fire station between treatment stages), and post-treatment (from faucets at the fire station after treatment) using a modified EPA 537.1 method. Several PFAS compounds were identified in pre-treatment water samples. Levels of PFOS and PFHxS collected pre-treatment exceeded their respective EPA MCL values. However, no PFAS compounds were identified in mid- and post-treatment water samples above DLs.

In April and May 2024, Contractor 3 analyzed water samples using a modified EPA 1633 method. In April, water samples were taken from the kitchen and bathroom sink faucets. These samples did not have PFAS compounds identified above their respective limits of detection. The DLs for PFOS, PFMOAA, and PFBA were 1–2 ppt. In May, the collection point was unclear but samples had lower DLs for most PFAS (< 1 ppt).

In September 2024, Contractor 4 analyzed water samples of treated water using a modified EPA 1633 method. The report does not include a description of where these samples were collected. This contractor analyzed water samples for 55 PFAS, which included some of the PFAS in the consent order and some of the PFAS the other contactors analyzed for. No PFAS compounds were identified above the DL of 1.0 ppt.

In late October 2024, Contractor 1 analyzed water samples collected pre-treatment (from the faucet at the well head), mid-treatment (from faucets at the fire station), post-treatment (from faucets at the fire station), and post-sink (from sink faucets at the fire station) using a modified EPA 537.1 method. PFAS compounds were found in pre- and mid-treatment samples. In pre-treatment samples, PFOS (71.9 ppt) and PFHxS (11.8 ppt) were quantified at levels above EPA MCLs. PFOS was quantified above the state groundwater standard and PFHxS was above the practical quantitation limit of 4 ppt. In post-sink samples, PFMOAA was identified at 0.230 ppt and PFPrA was identified at 5.15 ppt. For PFMOAA, levels dropped between mid-treatment and post-treatment samples with post-treatment levels similar to the post-sink sample results. For PFPrA, levels remain constant from pre-treatment to post-sink.

In March 2025, Contractor 4 analyzed samples of treated water using a modified EPA 1633 method [EPA 2026a]. The sampling location was not described. This contractor analyzed water samples for 55 PFAS, which included some of the PFAS in the consent order and some of the PFAS the other contactors analyzed for. Similar to the mid-October 2024 results, no PFAS compounds were identified above the DL of 1.0 ppt.

From May 2023 through April 2024, the calculated Hazard Index was 1.4 for pre-treatment water samples. This is above the EPA MCL of 1.0 and is the highest calculated annual Hazard Index. After April 2024, the Hazard Index decreases and remains below 1.0. Mid-treatment and post-treatment water samples were tested for these compounds, but were below DLs or RLs.

Other Water Sampling

In October 2024, Contractor 2 analyzed water samples collected pre-treatment, mid-treatment, post-treatment, and post-sink from the fire station. The samples were tested for VOCs, semi-volatile organic compounds, organochlorine pesticides, dioxins and furans, metals, and nitrates using EPA Methods 8260D, 8270E, 8081B, 1613B, 6020B, 7470A [EPA 2025b] and general chemistry techniques.

In pre-treatment samples, methyl tert-butyl ether was identified at levels of 2.69 micrograms per liter (μg/L) with an RL of 5.00 μg/L, and barium was identified at levels of 38.0 μg/L with an RL of 5.00 μg/L. Pre-treatment samples were compared with NCDEQ groundwater quality standards, with both contaminants at least one magnitude below these standards [NCDEQ 2025]. No compounds were detected above DLs in mid-treatment water samples. In post-treatment samples, lead was found at 0.625 μg/L with an RL of 2.50 μg/L. No compounds were detected above DLs in the post-sink water samples.

In February 2025, Contractor 5 analyzed water samples collected at the well, post-treatment, and upstairs bathroom in the fire station for arsenic using EPA Method 200.8 and hexavalent chromium using colorimetric Standard Method 3500-Cr B. No detectable levels of arsenic (RL 0.005 milligrams per liter [mg/L]) or hexavalent chromium (RL 0.01 mg/L) were found in the collected samples.

PFAS and PAHs in Air Sampling

The North Carolina Firefighter Cancer Cohort Study conducted air sampling for PFAS and PAHs in the fire station, with samples collected over 3 days in June 2025. Samples were taken in the apparatus bay and day room of the fire station. PFAS evaluated were mainly volatile and semi-volatile PFAS and PFAS precursors, including fluorotelomer alcohols (FTOHs), fluorotelomer acrylates and methacrylates (FTACs, FTMACs), and sulfonamidoethanols and sulfonamides.

For PFAS, air sampling results identified 6:2 FTOH, 8:2 FTOH, 10:2 FTOH, 6:2 FTMAC, MeFBSE, and PCBTF above their minimum DLs (not specified). In comparison with other fire stations in the study, each of the detectable PFAS compound concentrations were within or below the range found in other fire stations for that PFAS compound.

For PAHs, air sampling results identified acenaphthylene, acenaphthene, anthracene, fluoranthene, fluorene, naphthalene, phenanthrene, and pyrene above their minimum DLs (not specified). In comparison with other fire stations in the study, most of the PAH compound concentrations were within or below the range found in other fire stations for that PAH compound. Compared with other fire stations in the study, concentrations of fluoranthene in the apparatus bay (5.72 nanograms per cubic meter of air [ng/m^3] exceeded the maximum level found in other fire stations in the study (3.62 ng/m^3), naphthalene in the apparatus bay (825 ng/m^3) exceeded the maximum level found in other fire stations in the study (627 ng/m^3), and pyrene in the apparatus bay (7.32 ng/m^3) and day room (4.01 ng/m^3) exceeded the maximum level found in other fire stations in the study (3.46 ng/m^3).

Mold Sampling

From 2022 through 2025, an indoor environmental quality (IEQ) consultant conducted investigations and produced reports of the findings. Of the 20 reports provided, 6 were periodic sampling reports, 2 investigations, 2 remediation protocols, and 10 post-remediation verification reports. In these reports, the consultant conducted a visual inspection, mold testing on surfaces using a tape lift method, mold testing in air using spore traps, and measured relative humidity.

Visual inspections described throughout the reports identified suspected mold growth, water damage, or water intrusion in the exercise room, both restrooms, locker rooms, kitchen, day room, and transitional areas. The mold testing in surface and air identified multiple types of fungal organisms, with the same species identified repeatedly throughout the reports. Four of the reports stated that relative humidity exceeded 60%, with two occurrences during summer months, one during autumn, and the most recent in winter.

The reports indicated years of ongoing moisture-related issues, particularly involving heating, ventilation, and air conditioning (HVAC) systems at the fire station, that may have resulted in persistent damp conditions conducive to mold growth. Following remediation reports, dated March 2023 and August 2024, fire station management representatives shared that they had cleaned spaces according to the recommended protocols. However, no records were provided that detailed the methods and extent of cleanings. As a result of these reports, dehumidifiers and high-efficiency particulate air (HEPA) air filtration units were installed near the locker room and restroom area.

Methods: Consultative Report Review

In May 2025, the state's Department of Labor conducted a consultative visit and provided observations, results, and recommendations to the fire station. This included a health survey and a safety survey of the fire station on the same date. We reviewed the reports for the health survey (dated May 2025) and the safety survey (dated June 2025).

Results: Consultative Report Review

Health Survey Report

An industrial hygiene consultant conducted a Health Survey Report listing 17 serious hazards that were either immediately corrected or would be within one month of the report date. Of these hazards, four were related to the bloodborne pathogen exposure control plan, four were related to hazard communication, two were related to fire extinguisher maintenance, one was related to the written respiratory protection program, one was related to half facepiece respirator storage, one was related to machine guarding, and one was related to compressed gas cylinder storage.

The report described that at the time of the consultative visit "no evidence of mold growth was visible in any area that was surveyed," including the exercise room, kitchen (no longer in use), and second floor locker room (no longer in use). The report also discussed concerns regarding water quality and confirmed that a granular activated carbon filtration system had been installed on the well after the initial PFAS water testing.

In addition to conducting a walkthrough to recognize and document these hazards, the industrial hygiene consultant provided recommendations to address current hazards and prevent hazards from recurring. The industrial hygiene consultant provided informal training on hazard communication, hearing conservation, and bloodborne pathogens.

Safety Survey Report

A safety consultant conducted a Safety Survey Report listing 17 serious hazards that were either immediately corrected or would be within one month of the report date. Of these hazards, six were related to machine/power tool/live parts guarding, three were related to tool or equipment maintenance, three were related to power cords, one was related to ladder safety, one was related to compressed gas cylinder storage, one was related to workplace hazard assessments, one was related to legibility of safety communication, and one was related to a missing outlet box cover.

In addition to conducting a walkthrough to recognize and document these hazards, the safety consultant provided recommendations to address current hazards and prevent hazards from recurring. The safety consultant provided informal training on relevant topics including hazard communication and labeling, personal protective equipment (PPE) hazard assessment, lockout/tagout program and inspection, fall protection, machine guarding, ladder inspection, heat stress, fire prevention, and electrical safety.

Methods: Health Information Document Review

We reviewed the following documents:

- A de-identified list provided by the union of current and former station firefighters with symptoms and conditions in February 2025. The union provided an updated list in June 2025.
- Station assignment reports for December 2010–July 2025 provided by the fire department.
- A description of the health screenings offered by the fire department via a contractor in February 2025 and slides with a deidentified summary of results.

A NIOSH physician reviewed the list of symptoms and conditions and grouped similar terms together so they can be summarized. One term can be in more than one group. We used R versions 4.4.0 and 4.5.3 and Microsoft Excel version 2512 to organize and summarize the list and station assignment reports.

Results: Health Information Document Review

Health Symptoms and Conditions

According to the union, the de-identified firefighter list was initially generated in August 2024. Information on the list was originally based on answers to 5–6 questions for current and former firefighters of the station. However, when some firefighters mentioned that they had other conditions, additional questions were added to later versions. Some firefighters were contacted again. It was not clear which questions each person was asked. Over time, firefighters also updated their conditions.

Both versions of the list included individuals identified by a unique number, the number of years they worked at the station, and a list of various symptoms and conditions for those individuals. Neither version included any information on when the symptoms or conditions began, although we were informed that the questions were phrased for the period after starting to work at the station or after no longer working at the station.

The February 2025 version included 30 individuals, of whom 8 (27%) had "nothing to report." The top five symptoms or conditions were "gastrointestinal distress" (57%, n = 17), gallbladder removal (27%, n = 8), any mention of "kidney" (20%, n = 6), headaches (17%, n = 5), and gastrointestinal symptoms (13%, n = 4).

The June 2025 version included 41 individuals, of whom 3 (8%) had "nothing to report." The top five symptoms or conditions reported were any mention of "liver" (41%, n = 17), "gastrointestinal distress" (n = 17), any mention of "kidney" (n = 11), gallbladder removal (24%, n = 10), and gastrointestinal symptoms (20%, n = 8). Of the 17 mentions of "liver," 12 (71%, or 29% overall) specifically mentioned fatty liver or steatohepatitis.

Station Assignments

According to the station assignment reports, 57 unique firefighters were assigned to the station for any time from December 2010 through July 2025, when the report was generated.

February 2025 Health Screening Results

The fire department contracted with a company to provide on-site ultrasound-based screening for currently employed firefighters. The screening included an echocardiogram (ultrasound imaging of the heart) and ultrasound examinations of the carotid arteries, thyroid, abdominal aorta, liver, spleen, kidneys, bladder, and testicles in men and the pelvic area in women. The examinations were reviewed by a cardiologist or radiologist.

According to the summary, 112 firefighters across the department participated in screening. No information was available about each individual participant or whether they have ever worked at the station. Regarding findings related to the concerns in the list of symptoms and conditions provided by the union, there were 57 findings of "fatty liver" and 3 findings of "fatty enlarged liver size," which corresponds to 54% of participants having any ultrasound findings of fatty liver.

Methods: Interviews

We sought to interview all current and former firefighters who have been assigned to work at the station at any time during January 2010 through the time of the interview (late 2025). We asked the fire department and union to inform current and former station firefighters of the opportunity to participate in an interview. We provided an information sheet about the HHE and the interview process that the fire department and union could share with firefighters. Interested firefighters were asked to contact the NIOSH team to schedule a telephone interview over three one-week periods in September and October 2025. Since the NIOSH team was unavailable to perform interviews in October 2025 due to a lapse in appropriations for the federal government, the interview period was extended for approximately 1 week after the lapse in appropriations ended in November 2025.

At the beginning of the telephone call, we described the interview to the firefighter and asked if they would like to voluntarily participate in the interview. Participating firefighters verbally consented. Most interviews took approximately 20–30 minutes to complete.

During the interview, we asked questions about work and demographic characteristics, sources of drinking water at the station, diet, and health symptoms and conditions. If a participant reported having had a blood test for PFAS or participating in the February 2025 health screening, we asked if they were willing to share their results with us.

We asked firefighters whether they experienced symptoms while working at the station that occurred at least once during a 9-day shift cycle. We defined a symptom as station-related if the symptom was reported to improve while not on duty, such as during days off or on vacation.

We asked participants who reported being diagnosed with fatty liver additional questions to help classify the type of steatotic (fatty) liver disease they might have had. A participant was considered to have a given type of steatotic liver disease if they reported a specific diagnosis or met the diagnostic criteria for metabolic dysfunction-associated steatotic liver disease (MASLD), with some modifications due to the lack of imaging or laboratory data (Table C4) [Rinella et al. 2023; Sheth and Chopra 2025].

When a participant provided PFAS test results, we computed the sum of seven PFAS and compared it with the National Academies of Sciences, Engineering, and Medicine (NASEM) [2022] proposed health screenings for people exposed to PFAS with 20 ng/mL as a clinical threshold above which health screenings beyond the usual standard of care are recommended. The seven PFAS included in the sum are PFOA, PFOS, PFHxS, PFDA, PFNA, PFUnDA, and MeFOSAA.

We used R versions 4.4.0 and 4.5.3 and Microsoft Excel version 2512 for statistical analysis. We calculated medians and ranges for continuous variables and counts and percentages for categorical variables.

Results: Interviews

Work and Demographic Characteristics

Seventeen firefighters voluntarily participated in the interviews, which corresponded to 30% of the 57 eligible firefighters based on the station assignment reports. All participants were white males. At the time of the interview, their median age was 42 years (range: late 20s–early 60s).

Participants had started working in the fire service a median of 17 years before the interview (range: >10 to >40 years). Median job tenure at the fire department was 16 years (range: <5 to >30 years); 11 participants (65%) were working for this fire department at time of the interview. Median tenure at the station was 3 years (range: <1 to >20 years), three participants (18%) were working at the station at the time of the interview.

Drinking Water

Since PFAS contamination of drinking water in the area became known in 2017, we asked about sources of drinking water at the station over two periods: "2017 or before" and "after 2017."

Figure B1 shows the number of participants who reported using each drinking water source during the two periods. Seven (41%) participants only worked at the station in 2017 or before and six (35%) worked at the station during both periods. Of these 13 participants, 10 (77%) reported using tap water, 10 (77%) reported using bottled water, and 3 (23%) reported using water brought from home at the station in 2017 or before. Two (15%) reported only using tap water and bottled water, respectively. Bottled water was the most widely used (i.e., exclusive or most common) source of drinking water in 2017 or before, which was reported by nine (70%) participants.

Four (24%) participants reported working at the station after 2017, in addition to the six (35%) who worked at the station during both periods. Of these 10 participants, 3 (30%) reported using tap water, 10 (100%) reported using bottled water, and 2 (20%) reported using water brought from home at the station. Bottled water was the most widely used source of drinking water after 2017, with six (60%) reporting it as the only source.

All six participants who worked at the station over the two periods reported using tap water in 2017 or before. However, five of six (83%) participants reported switching to only bottled water after 2017.

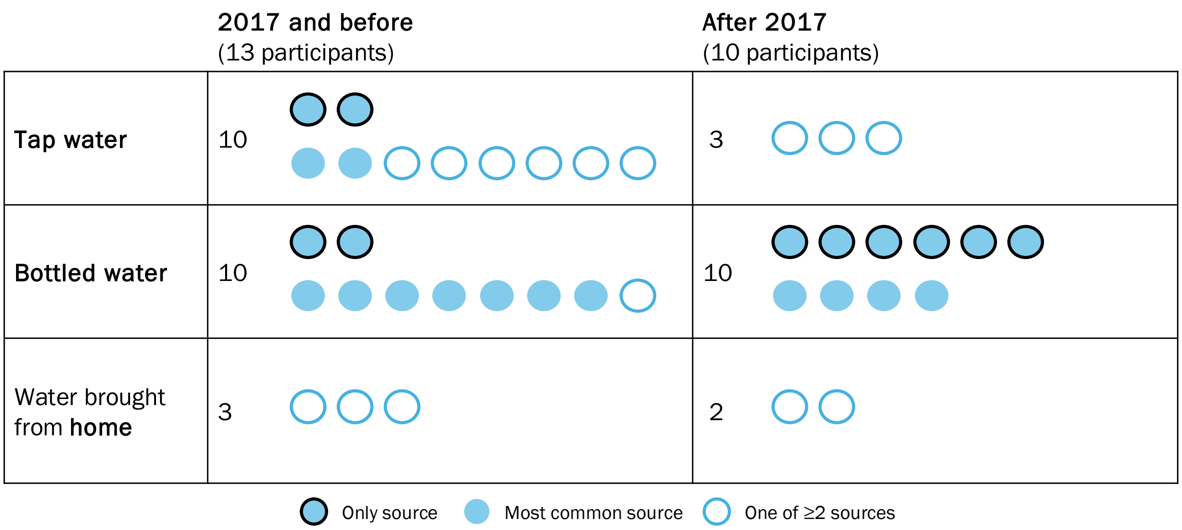

Figure B1. Sources of drinking water reported by interviewed firefighters (n = 17) during 2017 and before and after 2017.

Diet

Table C5 shows the usual meal practices while working at the station. Shared meals with coworkers cooked at the station were reported by all participants, comprising 10%–99% of meals at the station. In general, most participants reported no differences in their diet at the station compared with their diet on days off and their diet prior to working at the station.

Health Symptoms and Conditions

Symptoms

Figure B2 shows the number of participants with each station-related symptom. The most common was headaches (35%, n = 6), followed by loose stool or diarrhea (24%, n = 4) and nausea (18%, n = 3). Eight (47%) participants did not report any station-related symptoms.

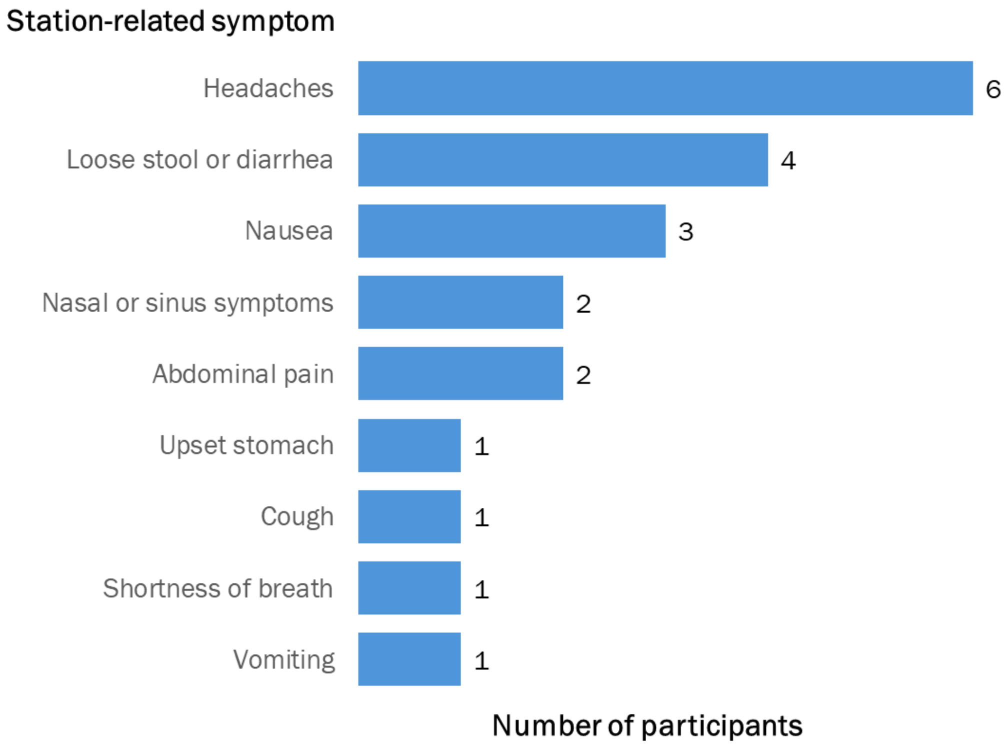

Figure B2. Station-related symptoms reported by interviewed firefighters (n = 17). A symptom was defined as station-related if it was reported to improve while not on duty, such as during days off or on vacation. Participants can report more than one symptom.

Conditions

Figure B3 shows the distribution of conditions diagnosed in or after the year when a participant began working at the station (n = 13). Four participants reported not having any of the conditions we asked about during this time period. The most common conditions were high liver enzymes (41%, n = 7), dyslipidemia (abnormal levels of cholesterol or triglycerides in the blood) (41%, n = 7), and fatty liver (35%, n = 6). Based on responses regarding cardiometabolic risk factors, alcohol consumption, and other potential causes of liver disease, all six participants with fatty liver were classified as having MASLD; one of these respondents reported being diagnosed with MASLD. Age of diagnosis for the reported conditions ranged from late 30s to early 40s. While some conditions were diagnosed while working at the station, others were diagnosed 4–12 years after no longer working at the station.

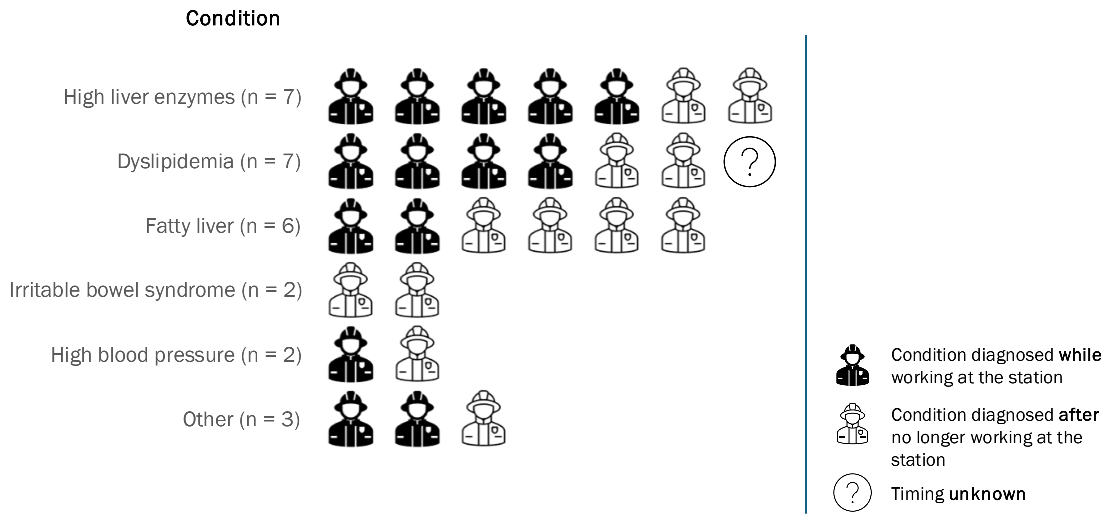

Figure B3. Number of participants who reported select conditions by timing of diagnosis (n = 13). The "other" category included kidney disease, thyroid disease, and cancer. Four of the 17 participants did not report any conditions diagnosed in or after the year when they started working at the station.

Of the 17 participants, 3 (18%) reported that they had gallbladder disease where a health professional recommended cholecystectomy (surgery to remove the gallbladder). Two (12%) had undergone cholecystectomy. Reasons that the surgery was recommended included gallstones that caused pain or other symptoms (n = 2) and persistent right upper quadrant pain (n = 1).

PFAS Testing

Of the 17 participants, 9 (53%) reported they had received a blood test for PFAS. We received two (12%) PFAS results. These two participants had started in the fire service more than 20 years before the blood test. The tests consisted of different panels of PFAS. Neither participant had a NASEM sum greater than 20 ng/mL. Of the PFAS detected in post-treatment water samples, only two PFAS were included in the blood tests: PFOA and PFBA (in one participant). Serum PFOA levels were below the 2017–2018 NHANES 50th percentile for one participant and between the 50th and 95th percentile for the other. Serum PFBA levels were below the limit of detection in the one participant who was evaluated.

February 2025 Health Screening

Of the 11 participants who were working at the fire department at the time of the interview, 10 (91%) participated in the February 2025 health screening. However, we did not receive any results.

Discussion

Exposures in the Fire Station and Firefighting Environment

PFAS and Other Contaminants in Drinking Water

PFAS are a group of synthetic chemicals widely used in industrial and consumer products for their resistance to heat, water, and oil. The three primary routes of exposure to PFAS are ingestion (swallowing), inhalation (breathing), and dermal absorption (through the skin). Because PFAS are persistent and bioaccumulative, even low-level exposure over time can pose health risks.

Concerns about PFAS in drinking water have grown due to their persistence in the environment and potential health risks. To protect public health, regulatory agencies worldwide have begun developing standards and guidelines to limit PFAS contamination in drinking water. In the United States, the EPA is the primary federal body responsible for regulating contaminants in drinking water, including PFAS. The EPA does not regulate well water [EPA 2026d], but comparing results from the station with standards established by EPA may be useful in understanding potential contaminants and their levels. In North Carolina, where the fire station is located, groundwater quality standards apply to well water.

The EPA established MCLs for the following PFAS compounds: PFOA at 4.0 ppt (also expressed as ng/L), PFOS at 4.0 ppt, PFHxS at 10 ppt, PFNA at 10 ppt, and HFPO-DA (commonly known as GenX chemicals) at 10 ppt. Additionally, PFAS mixtures containing at least two or more of PFHxS, PFNA, HFPO-DA, and PFBS have a Hazard Index MCL of 1.0. Pre-treated well water at the fire station had levels of PFOS and PFHxS that exceeded EPA MCLs. The Hazard Index exceeded 1.0 in April 2024 for pre-treatment groundwater samples; after April 2024 for pre-treatment results, the Hazard Index decreased to below 1.0. The Hazard Index is meant to evaluate levels of PFAS for treated drinking water.

In October 2024, NCDEQ established interim maximum allowable concentrations in groundwater for PFOS, PFOA, HFPO-DA (GenX), PFBS, PFNA, PFHxS, PFBA, and PFHxA. In September 2025, NCDEQ adopted the proposed groundwater standards for PFOS, PFOA, and HFPO-DA at the same levels as the EPA standards [NCDEQ 2025]. NCDEQ did not adopt groundwater standards for the other five PFAS. However, according to state regulation, PFBS, PFNA, PFHxS, PFBA, and PFHxA shall not be permitted in concentrations at or above the practical quantitation limit [NCDEQ 2025].

North Carolina has defined the practical quantitation limit for PFOA and PFOS as 4 ng/L according to EPA Method 1633 [NCDEQ 2024]. The quantitation limit for PFAS compounds may vary depending on the laboratory and analysis method. Some of the contractors involved in water sampling at this station may have used lower limits of quantitation than those described by NCDEQ [2024]. However, 4 ng/L may be assumed as the practical quantitation limit for most PFAS compounds according to EPA Methods 1633 and 537.

The last water sampling collected in October 2024 had pre-treatment well water samples exceeding state groundwater standards for PFOS and PFHxS levels exceeding the assumed practical quantitation limit of 4 ng/L. Contractor 1 achieved a lower DL and RL than this assumed practical quantitation limit, for example, in pre-treatment water samples collected in October 2024 for PFBS (DL: 0.580 ng/L, RL: 1.56 ng/L); PFHxS (DL: 0.580 ng/L, RL: 1.76 ng/L); PFBA (DL: 0.703 ng/L, RL: 1.76 ng/L); and

PFHxA (DL: 0.703, RL: 1.76 ng/L). PFBS, PFBA, and PFHxA were detected but below the concentration of 4 ng/L. The levels exceeding state groundwater standards confirm that the fire station is eligible for filtration systems at the cost of the polluting party.

Most PFAS levels were under their DL for post-treatment water samples. These results, when considered in the context of pre-treatment water sample results, indicate that the fire station's well water required a treatment system such as a granular activated charcoal treatment system to remove PFAS compounds. The treatment system effectively removed the federally regulated PFAS, and post-treatment water samples met all EPA National Primary Drinking Water Regulations standards.

Two PFAS compounds, PFMOAA and PFPrA, persisted after treatment. These ultrashort-chain PFAS had been detected post-treatment in municipal water [CFPUA, no date]. This suggests that granular activated charcoal filtration systems may not fully remove these and other ultrashort-chain PFAS compounds. No federal MCLs or state drinking water limits exist for these two compounds.

The fire station is in a watershed downstream from a chemical manufacturer that discharged PFAS into the river from the 1980s until 2017. In a study with blood serum samples collected 2010–2016 [Cheng et al. 2025] from adults residing in the municipality where the fire station is located, 10 PFAS (PFPrA, PFOA, PFNA, PFDA, PFUnDA, PFBS, PFHxS, PFHpS, PFOS, and PMOAA) were found in nearly all (≥ 98%) serum samples.

PFMOAA had the highest median concentration at 42 ng/mL, followed by trifluoroacetic acid (TFA) at 17 ng/mL. When water samples from the municipality's drinking water treatment plant were collected in May 2017 and analyzed for PFAS concentration, the finished drinking water leaving the drinking water treatment plant had TFA at 108,000 ng/L and PFMOAA at 38,400 ng/L, among others. These compounds are short-chain PFAS (containing four or fewer carbons) and have not been studied as widely for health impacts as longer-chain PFAS. They are also believed to have a significantly shorter biological half-life (days to weeks) compared with their longer-chain counterparts. Therefore, testing in serum after the discontinuation of exposure would not capture serum levels reflective of when exposure was occurring. Although they do not persist in the body or the environment as long as long-chain PFAS that they have replaced, short-chain PFAS may still be associated with negative health effects. There is still limited toxicity data available for short-chain PFAS. A study in rats suggests maternal and neonatal effects associated with PFMOAA exposure [Conley et al. 2024]. Prior to the publication of this study, TFA had not been part of routine drinking water testing [CFPUA, no date].

Fire station water sampling occurred from May 2023 through March 2025, years after the discharge of PFAS into the river ended. However, PFAS are mobile and can be transported through rainwater and surface water, seeping through the soil and migrating into large groundwater aquifers [EPA 2025c]. Groundwater contamination can persist for many years following contamination, even when surface water may no longer be contaminated.

Other contaminants in water were also a concern at the fire station, including VOCs, semi-volatile organic compounds, and metals. The only detectable levels found in the water sample collected October 2024, which evaluated these and other compounds, found barium at 38.0 μg/L. This is below the EPA MCLG of 2 mg/L. That water sample also contained methyl tert-butyl ether at 2.69 μg/L. EPA has not established an MCL or MCLG for methyl tert-butyl ether, but the most conservative recommended state guideline in drinking water is 13 μg/L in California, with a secondary MCL for taste and odor at 5 μg/L.

PFAS Exposure to Firefighters

Firefighters may be exposed to multiple types of PFAS during regular tasks at the fire station and response duties. Specifically, during and after fires, first responders may be exposed to PFAS through use of firefighting foams that contain PFAS; through dust containing PFAS (e.g., from combustion of stain-resistant upholstery or carpeting); and, potentially through contact with gear used to protect them from heat-related hazards during emergency response (e.g., turnout or bunker gear) [NIOSH 2024].

PFAS exposure may result from dermal contact with the outer layer and moisture barrier (middle layer) of turnout gear, aqueous film-forming foam (AFFF), and inhalation and dermal contact of combusting materials and particulates containing PFAS [Mazumder et al. 2023]. In addition to these occupationally specific exposures, firefighters are also exposed to the same PFAS sources as the public, such as through dust and indoor air, water, and diet. These exposure sources may even be more amplified for firefighters. Dust and indoor air in fire stations may have elevated levels of PFAS due to storage of turnout gear, past or current use of AFFF, and residual fire debris [Hall et al. 2020].

Multiple studies have found that firefighters have elevated levels of PFAS compared with the general population [Graber et al. 2021; Leary et al. 2020; Trowbridge et al. 2020]. A study of predictors of serum level of PFAS in firefighters [Conner et al. 2026] found several nonoccupational variables associated with increased serum PFAS, including older age, male sex, ethnicity, lower body mass index (BMI), not donating blood or plasma, use of well water as a home drinking water source, diet, and smoke exposure at home.

Occupational variables associated with increased serum PFAS included years of service as a career firefighter, previous or active military service, rank and role, current use of AFFF, and drinking tap water at the station. Additionally, agency policies play a role in lowering firefighter serum PFAS levels: washing gear prior to storing it, having an automatic closing door for the turnout gear storage, decontaminating the interior of fire apparatus, supplying firefighters with gear bags, more frequent dusting of station living quarters, and having reverse osmosis filters in fire stations [Conner et al. 2026].

Due to the cumulative nature of PFAS and firefighters' increased risk for exposure to PFAS and cancer, the literature suggests limiting firefighters' exposures to PFAS as much as possible. The firefighting community has already started using PFAS-free outer shell materials for turnout gear and fluorine-free foams. Several agencies and entities have published general guidance for reducing firefighters' occupational exposure and community exposure to PFAS [ATSDR 2024a; DoD 2024; IAFF 2026].

PAHs in Fire Station Air

Of the PAHs detected in fire station air, only naphthalene (measured at 825 ng/m^3 in the apparatus bay) has health-based guidelines. The EPA's Integrated Risk Information System (IRIS) human health assessment program has a reference concentration for inhalation exposure of 3,000 ng/m^3 for chronic exposure [EPA 2023]. The World Health Organization (WHO) has indoor air quality guidelines of 10,000 ng/m^3 for an annual average [WHO 2010]. For occupational exposures, the NIOSH and OSHA occupational exposure limits are both 50,000,000 ng/m^3 full-shift time-weighted average [NIOSH 2007; OSHA 2026]. Naphthalene is considered the most volatile PAH and is therefore commonly found in the air. In a study evaluating PAH penetration in firefighter PPE, authors found that naphthalene was the most abundant PAH measured [Mayer et al. 2020].

Mold

Mold can be found indoors and outdoors in all climates and during all seasons [CDC 2024]. Visual inspections, along with mold testing on surfaces and air, documented mold growth, water damage, and water intrusion recurring in several areas of the fire station. Deficiencies in HVAC and high relative humidity are also conditions favorable to mold growth. Water and moisture issues favorable for mold growth should be immediately addressed. Currently, no health-based standards exist for mold or biological agents in indoor air. Because of this and because sampling for mold does not represent actual exposures to occupants or employees, public health professionals do not generally recommend routine air sampling for mold. NIOSH has developed the Dampness and Mold Assessment Tool for schools and general buildings. In general, resources are better spent addressing the root cause of water and moisture issues and preventing the conditions in which mold can grow.

Health Symptoms and Concerns

In response to concerns about various health symptoms and conditions and whether they were related to exposures at the station, we reviewed existing information about station firefighters' health and the fire station environment. We also interviewed firefighters who have worked at the station to better characterize their experience of the symptoms and conditions of concern that led to the HHE request. We discuss these separately below.

Symptoms

The interviews helped clarify which symptoms were experienced when a firefighter was working at the station. The symptoms were nonspecific, meaning they have many causes. They could be related or unrelated to exposures at the station, firefighter work, or nonoccupational causes. Each person could have a different set of factors leading them to experience symptoms.

Headaches and nasal or sinus symptoms have been associated with lack of adequate ventilation and water intrusion with resultant microbial growth [Brightman et al. 2008; Malkin et al. 1996]. However, these types of symptoms are also common. Of the general population, 86%–95% have one or more symptoms during any given 2- to 4-week period, and the average adult reports a minimum of one symptom every 4–6 days [Barsky and Borus 1995].

Gastrointestinal symptoms were also reported as station-related, with loose stool or diarrhea being the most common (24%, n = 4). In the United States, the prevalence of chronic diarrhea (defined as mushy or liquid consistency being the usual or most common stool type) was estimated to be 6.6% in adults [Singh et al. 2018] and 8.2% in adults with obesity [Han et al. 2024]. Both studies used data from the National Health and Nutrition Examination Survey (NHANES), a nationally representative sample. Among people with circadian disruption, such as shift workers like firefighters, gastrointestinal symptoms are the most common type of symptoms [Bishehsari et al. 2025]. Gastrointestinal symptoms have been associated with shift work in multiple studies [Alsadah et al. 2021; Chang and Peng 2021; Nojkov et al. 2010; Storz et al. 2022] although shift schedules and the specific types of gastrointestinal symptoms with identified associations varied across these studies. However, circadian rhythm is known to regulate gastrointestinal functions such as motility, secretion, digestion, absorption or metabolism of nutrients, cell proliferation, and tissue repair [Bishehsari et al. 2025; Voigt et al. 2019].

Structural firefighters might be exposed to PAHs through fire suppression activities via the skin or, to a lesser extent, through inhalation [Fent et al. 2014; Hwang et al. 2021; Keir et al. 2017]. Two studies have evaluated the relationship between PAH exposure and diarrhea. Using 2001–2006 data from NHANES, Wu et al. [2021] found a significant association between the presence of PAH metabolites in the urine and diarrhea, defined as three or more liquid or semi-formed bowel movements each day.

Similarly, Zang et al. [2024] found statistically significant associations between higher urinary PAH levels and chronic diarrhea, defined as a predominantly mushy or liquid stool pattern, using machine learning models with 2009–2010 NHANES data. It is unclear how PAHs might lead to diarrhea, but potential mechanisms include changes to the gut microbiota or immune function [Zang et al. 2024]. Since these studies evaluated PAH exposure through their presence in the urine, they do not provide any information about what levels in the air or through dermal exposure might be associated with the risk of developing diarrhea. The PAH area air sampling results we reviewed indicate that firefighters at this station were potentially exposed to PAHs, as expected, and with area air levels comparable with those in other fire stations in the study. However, the results do not necessarily show whether or how much this exposure might contribute to loose stool or diarrhea reported by station firefighters.

Other factors that might contribute to stool consistency include diet, physical activity, and stress levels. In a study of healthy adults in the United States, 24% of participants had soft (mushy or liquid) stool as scored by a technician; only 45% of participants had normal stool consistency [Lemay et al. 2021]. Lower intake of fruits and vegetables and higher intake of saturated fatty acids relative to unsaturated fatty acids were predictive of soft stool; lower cortisol levels were also associated with soft stool [Lemay et al. 2021]. Dietary fiber has been associated with a lower occurrence of diarrhea [Homann et al. 1994; Wang et al. 2024].

Interviewed firefighters reported sharing many meals cooked at the station, suggesting potentially similar dietary exposures. Depending on intensity, duration, and timing, physical activity can improve gut health or aggravate gastrointestinal symptoms. Prolonged or intense physical activity can reduce blood flow to the gut, leading to gastrointestinal symptoms [Al-Beltagi et al. 2025]. Since many factors, including some related to working as a firefighter, can contribute to gastrointestinal symptoms, we cannot definitively link them to exposures at this particular fire station.

Conditions

Toxicity from PFAS is not associated with any characteristic signs or symptoms [ATSDR 2024b]. Instead, research studies have shown that PFAS are associated with a variety of health conditions. The NASEM Committee on the Guidance on PFAS Testing and Health Outcomes (NASEM committee) concluded, based on authoritative reviews and recent epidemiological studies, that there is sufficient evidence of an association between PFAS exposure and dyslipidemia, decreased antibody response, decreased infant and fetal growth, and increased risk of kidney cancer. The committee also found limited or suggestive evidence of changes in liver enzymes and increased risk of breast cancer, pregnancy-induced hypertension, testicular cancer, thyroid disease and dysfunction, and ulcerative colitis [NASEM 2022].

Among these conditions, multiple station firefighters interviewed reported high liver enzymes (41%, n = 7) and dyslipidemia (41%, n = 7). However, these findings do not necessarily mean that there is an occupational or station-specific cause. Dyslipidemia is a relatively common condition. According to recent NHANES data, 35% of U.S. males aged ≥ 20 years have total cholesterol levels > 200 mg/dL, 26% have low-density lipoprotein cholesterol levels > 130 mg/dL, and 22% have high-density lipoprotein cholesterol levels < 40 mg/dL [Palaniappan et al. 2026]. Approximately 20% of U.S. adults have high triglyceride levels [Palaniappan et al. 2026].

Fatty liver was another common condition reported by interviewed station firefighters (35%, n = 6), which we classified as MASLD based on other information from the interview. Moreover, ultrasound findings of fatty liver were observed among 54% of current firefighters throughout the department who participated in the February 2025 health screening. While 10%–20% of the general population have elevated liver chemistry levels [Langan and Hines-Smith 2024; Radcke et al. 2015], elevated liver enzymes can be more common among individuals with fatty liver [Abd El-Kader and El-Den Ashmawy 2015; Ma et al. 2020]. One reason is that elevated liver enzymes often lead to an evaluation for liver disease [Kwo et al. 2017]. MASLD is the most common cause of mildly elevated levels of liver transaminases, which are specific types of liver enzymes [Langan and Hines-Smith 2024]. The estimated prevalence of MASLD is approximately 30% overall [Kalligeros et al. 2024; Lee et al. 2024] and approximately 35% in men [Lee et al. 2024] based on 2017–2020 NHANES data. The incidence of MASLD has been increasing; a modeling study predicted that the prevalence of MASLD among U.S. adults will steadily increase to over 40% by 2050 [Le et al. 2025].

By definition, MASLD is abnormal accumulation of fat within the liver that is strongly associated with metabolic syndrome, a group of conditions that includes hypertension (high blood pressure), hyperglycemia (high blood sugar), abdominal obesity, and dyslipidemia [Chan et al. 2023]. A recent systematic review and meta-analysis estimated the prevalence of metabolic syndrome in firefighters to be 22% [Beckett et al. 2023]. By condition, the estimated prevalence among firefighters was 39% for hypertension, 38% for abdominal obesity, 30% each for abnormal cholesterol and triglyceride levels (dyslipidemia), and 21% for hyperglycemia [Beckett et al. 2023].

The number of station firefighters who underwent cholecystectomy (gallbladder removal) was a concern brought up during this evaluation. Speakers at town halls held by the NASEM committee have also mentioned gallbladder dysfunction as a concern [NASEM 2022]. Among interviewed station firefighters, three (18%) reported gallbladder disease where cholecystotomy was recommended and two (12%) reported undergoing the surgery. Up to 10 cholecystectomies were mentioned in the list provided by the union, which corresponds to 24% of the 41 individuals on the revised list and 18% of the 57 unique individuals on the station assignment reports. The most commonly reported reason for surgery among interviewed firefighters was symptomatic gallstones. One firefighter described persistent right upper quadrant pain. This might be due to gallstones that are too small to detect with ultrasound or a motility disorder of the gut manifested by impaired gallbladder emptying or dysfunction of sphincter of Oddi, the muscular valve where the bile and pancreatic ducts meet the small intestines [Shaffer 2003].

Gallstone disease is one of the most common gastrointestinal diseases in the United States, with 12% of participants in the NHANES 2017–2020 population reporting a history of gallbladder surgery [Unalp-Arida and Ruhl 2023]. Each year, approximately 935,000 cholecystectomies are performed in the United States [Unalp-Arida and Ruhl 2024]. The prevalence of gallstone disease (defined as gallstones or history of cholecystectomy) had approximately doubled between 1988–1994 (7%) and 2017–2020 (14%). This change may possibly be related to the increasing prevalence of metabolic risk factors such as obesity, diabetes, and dyslipidemia. It may also reflect more widespread use of laparoscopic cholecystectomy, a procedure with lower risk than open surgery, which has led to changes in indications for surgery [Unalp-Arida and Ruhl 2023]. In Western countries, 85% of gallstones are cholesterol stones [Zucker 2022]. MASLD is associated with both gallstones and cholecystectomy, but it is unclear whether MASLD is a risk factor for gallbladder disease or vice versa [Corsi et al. 2025; Unalp-Arida and Ruhl 2023]. Dietary risk factors for gallstones include high calorie intake, low fiber intake, high refined carbohydrates, and high glycemic load [Zucker 2022]. In addition, a large study of twins in Sweden demonstrated symptomatic gallstones have heritability of approximately 25% [Katsika et al. 2005].

The relationship between PFAS and gallbladder disease has not been extensively studied. One study found that a history of ever having gallstones was associated with lower levels of four PFAS, considered separately or together [Shi et al. 2024]. The mechanisms underlying this association are not clear, but the study's authors suggest that PFAS might affect enterohepatic circulation. Enterohepatic circulation is the process by which substances like bile salts are secreted by the liver, stored in the gallbladder, released into the intestines, reabsorbed in the intestines, and returned to the liver via the portal vein. When it is impaired, the risk of gallstone formation can increase because bile that is supersaturated with cholesterol spends more time in the gallbladder and PFAS reabsorption decreases. Alternatively, PFAS might affect lipid metabolism in the liver and sex hormones, which are implicated in the higher prevalence of gallstones in females. More research is needed to understand the relationship between PFAS and gallbladder disease; however, the study authors did not evaluate whether PFAS is associated with cholecystectomy status. We were not able to identify any studies on PAHs and gallbladder disease, although PAHs are excreted in feces (via bile) in addition to urine [ATSDR 1995].

Based on the available information, it is unclear whether station-related exposures have led to an excess of station firefighters experiencing the health conditions evaluated. It is also unclear at what levels exposures need to occur in order to lead to health outcomes. While PFAS and PAHs were detected at the station, exposure might also be related to firefighting in general [Arinaitwe and McNamee 2026; Gonzalez et al. 2024; Pálešová et al. 2023]. The fire department was located in a geographic area with PFAS contamination in drinking water sources, suggesting PFAS exposure could also occur outside of work. Responses from interviewed firefighters suggest that tap water use at the station decreased after 2017, when PFAS contamination of well water in the area became known.

PAHs are a class of chemicals created through combustion of organic material. In addition to occupational exposures, people can be exposed to PAHs in their daily life through multiple routes, such as eating contaminated food (e.g., grilled or charred meat, or contaminated cereals, flour, vegetables, pickled foods), inhaling contaminated air (e.g., tobacco smoke, vehicle exhaust, or wood smoke from burning logs), or drinking contaminated water [ATSDR 1995].

Moreover, it is unclear whether more station firefighters were experiencing the conditions evaluated than expected. Conditions such as dyslipidemia, MASLD, and gallstone disease are relatively common in the United States. Small populations can have highly variable disease rates that sometimes do not match the overall rates for a larger population. At any given time, some populations have rates above or below the overall rate. Even when high rates occur, it may still be consistent with the expected random variability. In addition, firefighters face various exposures associated with adverse health outcomes such as cardiovascular disease and cancer [Gonzalez et al. 2024], which might make them at higher risk for some conditions than the general population. For example, associations between cholesterol levels and exposure to a mixture of PFAS and PAHs were observed among Czech firefighters [Pálešová et al. 2023]. Finally, sometimes conditions were diagnosed years after an interviewed firefighter no longer worked at the station. Because some conditions take time to develop, it is not necessary for a condition to be diagnosed while working at the station in order to be related. However, it is unclear how much intervening time and more recent factors might contribute to a condition being diagnosed because age is a strong risk factor for many health conditions.

Limitations

Limitations in the types of information available for the evaluation may have affected our results and should be considered when interpreting the findings presented here. First, we reviewed past water and air sampling records from May 2023 through April 2025. We are not able to determine exposures that might have occurred beforehand or to other substances. Area air sampling for select PFAS and PAHs were collected and can only quantify air concentrations in the area during the duration of sampling. Area sampling cannot determine personal exposures. Second, there was relatively low participation in the interviews, which means we had limited information about firefighters who worked at the station. We do not know if firefighters who participated in interviews differed in exposure or health status from firefighters who did not participate, which might have affected the results. There might also have been firefighters who worked at the station but were not assigned there (e.g., while covering shifts), so their experience or some of the time working at the station might not have been captured. Third, since the interview included questions about symptoms and experiences while working at the station and diagnoses that might have occurred years ago, decreased recall might have affected the information collected through self-report.

Conclusions

This evaluation did not demonstrate a definitive link between health symptoms and conditions of concern with exposures at the station. On the basis of available information, the station had a history of moisture and IEQ issues and is located in a geographic area with PFAS contamination of drinking water sources. Interviewed firefighters reported some symptoms that can be related to the station's IEQ as well as nonspecific, relatively common health symptoms and conditions. These symptoms could be associated with firefighting, nonoccupational exposures, or both. However, it is prudent to continue monitoring environmental conditions at the new station location, take steps to reduce exposures to PFAS and PAHs at the station and in the course of firefighting, and support firefighters in improving their health.

Section C: Tables

Table C1. Records and documents reviewed on water sampling for PFAS and other compounds

Report date	Sample date	Sample locations	Compounds	Conducted by	Conducted for	Results summary
5/25/2023	5/9/2023	Groundwater (pre-treatment)	PFAS	Contractor 1	NCDEQ	See Table C2
5/30/2023	5/4/2023	Groundwater (pre-treatment)	PFAS	Contractor 2	County facilities management	See Table C2
7/12/2023	6/29/2023	Groundwater (pre-treatment), post-treatment	PFAS	Contractor 1	NCDEQ	See Table C3
11/9/2023	10/23/2023	Pre-treatment, mid-treatment, post-treatment	PFAS	Contractor 1	NCDEQ	PFAS in pre-treatment
5/21/2024	4/23/2024	Kitchen sink, bathroom sink	PFAS	Contractor 3	Fire department	No results >DLs
6/19/2024	5/28/2024	Unknown*	PFAS	Contractor 3	Unknown*	No results >DLs
10/15/2024	9/13/2024	Post-treatment	PFAS	Contractor 4	Fire station	No results >DLs
12/2/2024	10/29/2024	Pre-treatment, mid-treatment, post-treatment, sink	VOCs, SVOCs, organochlorine pesticides, dioxins/furans, metals, mercury, general chemistry	Contractor 2	NCDEQ	Methyl tert-butyl ether and barium in pre-treatment; lead in post-treatment
12/3/2024	10/29/2024	Pre-treatment, mid-treatment, post-treatment, sink	PFAS	Contractor 1	NCDEQ	PFAS in pre-treatment; PFBA in mid-treatment; PFMOAA and PFPrA in mid-, post-, and post-filter
3/5/2025	2/27/2025	Groundwater (pre-treatment), post-treatment, bathroom sink	Arsenic, Hexavalent chromium	Contractor 5	Fire station	No results >DLs
4/8/2025	3/17/2025	Post-treatment	PFAS	Contractor 4	Fire station	No results >DLs

PFAS = per- and poly-fluoroalkyl substances
NCDEQ = North Carolina Department of Environmental Quality
DLs = detection limits
VOCs = volatile organic compounds
SVOCs = semivolatile organic compounds
SM = standard method
*Information was not able to be determined from the records

Table C2. PFAS compounds found above reporting or detection limits for groundwater sampling conducted by two contractors in May 2023, in parts per trillion

PFAS compound	Contractor 1 result	Contractor 1 reporting limit	Contractor 1 detection limit	Contractor 2 result	Contractor 2 reporting limit	EPA MCL	EPA MCLG	In consent order
PFOA	3.32†	1.61	0.644	2.1†	2.0	4.0	0	N
PFOS	137*†	1.61	0.644	74*†	2.0	4.0	0	N
PFHxS	18.5*†	1.46	0.531	13*†	2.0	10	10	N
PFNA	0.531	1.61	0.531	NR	2.0	10	10	N
PFO2HxA	0.308	0.402	0.161	NR	2.0	–	–	Y
PFMOAA	1.89	0.402	0.161	NR	2.0	–	–	Y
PFHpA	1.53	1.61	0.531	NR	2.0	–	–	Y
PFBS	1.96	1.43	0.531	NR	2.0	–	–	N
PFBA	2.11	1.61	0.644	NR	5.0	–	–	N
PFHpS	1.2	1.53	0.531	NR	2.0	–	–	N
PFHxA	2.41	1.61	0.644	NR	2.0	–	–	N
PFPeS	2.22	1.51	0.531	NR	2.0	–	–	N
PFPeA	1.56	1.61	0.531	NR	2.0	–	–	N

EPA MCL = Environmental Protection Agency Maximum Contaminant Levels (enforceable)

EPA MCLG = Environmental Protection Agency Maximum Contaminant Level Goals (nonenforceable)

NR = not reportable, result was under the reporting limit

* This value exceeds the corresponding EPA MCL.

† This value exceeds the corresponding EPA MCLG.

Table C3. PFAS compounds found above detection limits for pre- or post-treatment water sampling by Contractor 1 in June 2023, in parts per trillion

PFAS compound	Pre-treatment	Post-treatment	Detection limit	Reporting limit	EPA MCL	EPA MCLG	In consent order
PFOA	2.96†	ND	0.736–1.60	1.84–4.00	4.0	0	N
PFOS	144*†	1.16†	0.736–1.60	1.84–4.00	4.0	0	N
PFHxS	20.8*	ND	0.607–1.32	1.84–3.64	10	10	N
PFMOAA	2.39	1.52	0.184–0.400	0.460–1.00	–	–	Y
PFHpA	1.65	ND	0.607–1.32	1.84–4.00	–	–	Y
PFBS	2.05	ND	0.607–1.32	1.64–3.56	–	–	N
PFBA	1.85	1.13	0.736–1.60	1.84–4.00	–	–	N
PFHxA	2.17	ND	0.736–1.60	1.84–4.00	–	–	N
PFPeS	2.05	ND	0.607–1.32	1.84–3.76	–	–	N
PFPeA	1.99	ND	0.607–1.32	1.84–4.00	–	–	N

EPA MCL = Environmental Protection Agency Maximum Contaminant Levels (enforceable)

EPA MCLG = Environmental Protection Agency Maximum Contaminant Level Goals (nonenforceable)

ND = not detectable, result was under the detection limit

* This value exceeds the corresponding EPA MCL.

† This value exceeds the corresponding EPA MCLG.

Table C4. Criteria for classifying steatotic liver disease (SLD) in participants with fatty liver

Condition	Criteria
Metabolic dysfunction-associated SLD (MASLD)	One or more of the following cardiometabolic risk factors: • High blood pressure or taking medication to lower blood pressure • Body mass index > 25 kg/m^2 • Diabetes • Dyslipidemia or taking lipid-lowering medication
MASLD + increased alcohol intake	Criteria for MASLD **and** Daily alcohol intake of 30–60 grams (men)
Alcohol-associated liver disease	No cardiometabolic risk factors **and** Daily alcohol intake > 60 grams (men)
SLD of specific etiology	No cardiometabolic risk factors **and** *any* of the following: • Wilson disease • Hepatitis B or C • Celiac disease • Taking medications that can affect the liver
Cryptogenic SLD	No cardiometabolic risk factors **and** *none* of the following: • Wilson disease • Hepatitis B or C • Celiac disease • Taking medications that can affect the liver

Adapted with modifications from Rinella et al. [2023] and Sheth and Chopra [2025].

Table C5. Meal practices while working at the station reported by interviewed firefighters (n = 17)

Meal practices*	Participants, no. (%)†
Shared meals with coworkers cooked at [the station]	17 (100)
Cooked own meal at [the station]	13 (76)
Brought food from home	10 (59)
Ate elsewhere	10 (59)

* Responses to the question "What did you usually eat while working at [the station]?"

† Responses do not add to 100% because participants were asked to select all that applied.

Section D: Occupational Exposure Limits

NIOSH investigators refer to mandatory (legally enforceable) and recommended occupational exposure limits (OELs) for chemical, physical, and biological agents when evaluating workplace hazards. OELs have been developed by federal agencies and safety and health organizations to decrease the risk of adverse health effects from workplace exposures. Generally, OELs suggest levels of exposure that most employees may be exposed to for up to 10 hours per day, 40 hours per week, for a working lifetime, without experiencing adverse health effects.

However, not all employees will be protected if their exposures are maintained below these levels. Some may have adverse health effects because of individual susceptibility, a preexisting medical condition, or a hypersensitivity (allergy). In addition, some hazardous substances act in combination with other exposures, with the general environment, or with medications or personal habits of the employee to produce adverse health effects. Most OELs address airborne exposures, but some substances can be absorbed directly through the skin and mucous membranes.

Most OELs are expressed as a time-weighted average (TWA) exposure. A TWA refers to the average exposure during a normal 8- to 10-hour workday. Some chemical substances and physical agents have recommended short-term exposure limits (STEL) or ceiling values. Unless otherwise noted, the STEL is a 15-minute TWA exposure. It should not be exceeded at any time during a workday. The ceiling limit should not be exceeded at any time.

In the United States, OELs have been established by federal agencies, professional organizations, state and local governments, and other entities. Some OELs are legally enforceable limits; others are recommendations.

- OSHA, an agency of the U.S. Department of Labor, publishes permissible exposure limits [29 CFR 1910 for general industry; 29 CFR 1926 for construction industry; and 29 CFR 1917 for maritime industry] called PELs. These legal limits are enforceable in workplaces covered under the Occupational Safety and Health Act of 1970. The Occupational Safety and Health Act requires employers to provide a safe workplace.

- NIOSH recommended exposure limits (RELs) are recommendations based on a critical review of the scientific and technical information and the adequacy of methods to identify and control the hazard. NIOSH RELs are published in the NIOSH Pocket Guide to Chemical Hazards [NIOSH 2007]. NIOSH also recommends risk management practices (e.g., engineering controls, safe work practices, employee education/training, personal protective equipment, and exposure and medical monitoring) to minimize the risk of exposure and adverse health effects.

- Another set of OELs commonly used and cited in the United States includes the threshold limit values or TLVs, which are recommended by the American Conference of Governmental Industrial Hygienists (ACGIH). The ACGIH TLVs are developed by committee members of this professional organization from a review of the published, peer-reviewed literature. TLVs are not consensus standards. They are considered voluntary exposure guidelines for use by industrial hygienists and others trained in this discipline "to assist in the control of health hazards" [ACGIH 2026].

Outside the United States, OELs have been established by various agencies and organizations and include legal and recommended limits. The Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung (Institute for Occupational Safety and Health of the German Social Accident Insurance) maintains a database of international OELs from European Union member states, Canada (Québec), Japan, Switzerland, and the United States. The database contains international limits for more than 2,000 hazardous substances and is updated periodically.

OSHA (Public Law 91-596) requires an employer to furnish employees a place of employment free from recognized hazards that cause or are likely to cause death or serious physical harm. This is true in the absence of a specific OEL. It also is important to keep in mind that OELs may not reflect current health-based information.

When multiple OELs exist for a substance or agent, NIOSH investigators generally encourage employers to use the lowest OEL when making risk assessment and risk management decisions.

PFAS

PFAS are a group of thousands of human-made chemicals that have been used in industry and consumer products since the 1940s [EPA 2026c; NIOSH 2024]. Their useful properties have made them central ingredients in coatings, materials, and textiles that are nonstick or resistant to heat, oil, stains, and water. Some PFAS are more widely used and studied than others; the most studied and well-known are perfluorooctanoic acid (PFOA) and perfluorooctanesulfonic acid (PFOS). Many PFAS are highly persistent in the environment and are removed very slowly from the body, and therefore can build up in people, animals, and the environment over time. Because of this and widespread use in consumer products and manufacturing, PFAS are present in water, soil, air, and food.

Studies suggest that most people in the United States and other industrialized countries have measurable amounts of PFAS in their blood [ATSDR 2024c]. In the general U.S. adult population, most exposures occur through drinking contaminated water, using consumer products containing PFAS, eating food that contains PFAS, or accidentally swallowing contaminated soil or dust. In occupational settings, inhalation is the most likely exposure route. Workers may also be exposed to PFAS by getting them on their skin and by swallowing them [ATSDR 2024a]. Specifically, during and after fires, first responders may be exposed to PFAS through use of firefighting foams that contain PFAS (e.g., AFFF); through dust containing PFAS (e.g., from combustion of stain-resistant upholstery or carpeting); and, potentially through contact with gear used to protect them from heat-related hazards during emergency response (e.g., turnout or bunker gear) [NIOSH 2024].

Research studies have reported a variety of health outcomes associated with exposures to PFAS, including that high levels of certain PFAS may lead to increased cholesterol levels, changes in liver enzymes, small decreases in infant birth weights, decreased vaccine response in children, increased risk of high blood pressure or preeclampsia in pregnant women, and increased risk of kidney or testicular cancer [ATSDR 2024b; NASEM 2022]. Recently, the International Agency for Research on Cancer

(IARC) updated their classification of PFOA to "carcinogenic to humans" (Group 1) and PFOS as "possibly carcinogenic to humans" (Group 2B) [Zahm et al. 2023].

While studies have shown that PFAS exposure is associated with a range of health effects, at this time, there is insufficient toxicological and epidemiological data to fully inform OELs. The ACGIH has established TLVs for three PFAS in air: perfluoroisobutylene (PFIB), perfluorobutyl ethylene (PFBE), and ammonium perfluorooctanoate (AFPO, a form of PFOA) [ACGIH 2026]. However, air monitoring methods for PFAS are limited. Instead, most studies of occupational PFAS exposure rely on biological measures of workers' PFAS exposure using serum blood and urine testing.

PFAS can stay in the body for varying lengths of time ranging from days to years depending on its chemical structure [Christensen and Calkins 2023]. Finding a measurable amount of PFAS in serum or urine means that a person has had past or recent exposure to PFAS [NASEM 2022]. In the absence of biological OELs for PFAS, scientists rely on alternative comparisons to understand workers' PFAS exposure and determine the need for clinical follow-up. In the United States, the NHANES, an ongoing study conducted by the CDC, measures a selected number of PFAS in the blood and urine of people across the country; PFAS concentrations found among adults participating in NHANES represent average levels of exposure in the United States. PFAS have been measured in NHANES participants for more than 20 years and generally show a decreasing trend, meaning that concentrations measured in more recent years are lower than previous NHANES years. Scientists can compare concentrations of PFAS found in the blood and urine of workers with the concentrations found in NHANES to understand if groups of workers have been exposed to higher levels of PFAS than are found in the general U.S. population.

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