DEPARTMENT OF HEALTH AND HUMAN SERVICES Public Health Service

National Institute for Occupational
Safety and Health
1090 Tusculum Avenue
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April 6, 2018
HHE 2016-0200

Chief Jacob King
Fire Chief
Wright-Patterson Air Force Base Fire Department
5180 Skeel Avenue, Building 146
Wright-Patterson Air Force Base, Ohio 45433

Dear Chief King:

In July 2016, the International Association of Fire Fighters Local F-88 requested a health hazard evaluation (HHE) for the Wright-Patterson Air Force Base (WPAFB) Fire Department in Wright-Patterson Air Force Base, Ohio. The request concerned fire fighters' exposures to aqueous film forming foam (AFFF), specifically their potential exposure to perfluourochemicals (PFCs). The request was submitted following an accidental release of AFFF into the cab of fire truck A on October 19, 2015, reportedly causing permanent eye damage in one fire fighter. Prior to our visit, union and management representatives voiced concern over workplace relationships, trust, and job stressors. In August 2016, we visited WPAFB and sent a letter to the employer, union, and employee representatives discussing our initial findings and recommendations. This final letter summarizes our evaluation and recommendations.

Background

The WPAFB Fire Department is an organization within the U.S. Department of the Air Force (USAF) Air Force Materiel Command. The WPAFB Fire Department conducts training and incident response activities throughout WPAFB, and responds to mutual aid requests from the surrounding community. The fire department may respond to residential fires, aircraft fires, and hazardous materials spills. The WPAFB Fire Department primarily works out of three fire stations, identified as station one, station two, and station three.

During a training exercise in October 2015, response vehicles deployed to the fire department's training site on base. Immediately after one of the three fire fighters operating fire truck A engaged the water turret a failure occurred. Pressurized water was released into the cab, followed by a release of AFFF into the cab. The pressurized AFFF stream struck one fire fighter directly in the eyes. Two other fire fighters in the cab were exposed to large amounts of AFFF. The fire fighters immediately sought care at the base hospital, where their eyes were flushed.

Fire fighting foams are routinely classified as Class A and Class B foams. Class A foams are used in wildfire, structural, and other fires, and aid firefighting water to better penetrate combustible materials [FFFC 2014; MPCA 2009]. Class B foams, including AFFF, are used on flammable petroleum fires and petroleum spills. Some Class B foams contain PFCs, in particular

perfluorooctanate sulfonate (PFOS) and perfluorooctanoic acid (PFOA), which is also called C8. American manufacturers ceased production of Class B foams that contain PFCs prior to 2003 [MPCA 2009]. However, workers may come into contact with foams containing C8 if they remain from prior stockpiles or are purchased from international manufacturers. In addition to PFCs, AFFF contain hydrocarbons, salts, solvents and water.

Evaluation

In order to best understand potential fire fighter exposures to AFFF, we evaluated the potential for exposures within the context of the WPAFB Fire Department's health and safety program. During our visit to WPAFB, we met with employees, management, union representatives, and safety and health representatives. We conducted a walk-through survey of station one, the chemical storage facility, and the fire department's training site. We spoke with employees about work processes including the use and storage of AFFF. We observed how AFFF was stored and mock demonstrations of how AFFF was used during routine operations at station one, including transferring AFFF from storage containers to the truck and vice versa. We also observed mock demonstrations on how AFFF would be utilized during an emergency response. Mock demonstrations utilized fire truck A when possible.

We reviewed local operational guidelines and management plans, a USAF health-risk assessment for AFFF change-out procedures, e-mail communication between staff, training records, AFFF inventory and safety data sheets (SDS), and documents relevant to the October 2015 incident. We performed an extensive literature search on acute and chronic health effects of PFCs and acute health effects from the ingredients of AFFF used during the incident in October 2015.

We held voluntary, confidential medical interviews with employees to discuss health and safety training, work history and practices, personal protective equipment (PPE) availability and use, medical history, and perceptions of the work environment. We reviewed medical documentation for three employees, and the fire department's 2015 OSHA Form 300 Log of Work-Related Injuries and Illnesses logs and reports. At the conclusion of our visit, we held an open meeting with employees, managers, union representatives, and health and safety representatives to summarize our activities, share preliminary observations and recommendations, and answer questions.

Results

Document Review and Workplace Observations

The WPAFB Fire Department used operating guidelines and management plans to outline standard operating procedures. We reviewed the plans pertaining to the safe handling of chemicals and appropriate responses during a hazardous material spill or inadvertent exposure. These plans also included SDSs for all available firefighting foams, detailed standard operating procedures, and health and safety information.

An e-mail to staff regarding PPE use during the transfer of AFFF stated that fire fighters were required to use "at a minimum eye protection, N95 mask, and gloves." The e-mail instructions did not specify what type of eye protection or gloves were needed. During the mock demonstrations of transferring AFFF, we asked what type of PPE and clothing the fire fighters wore during AFFF transfers. Firefighters reported wearing eye protection (safety glasses or prescription glasses with side shielding), respiratory protection (N95 filtering facepiece respirator), and gloves, but use of PPE varied. Clothing worn ranged from short-sleeve shirts, shorts, and open-toe shoes to long-sleeve shirt, long pants, and work shoes.

Fire fighters stated that respiratory protection was available if needed; however, fire fighters also responded that they do not always wear N95 respirators per previous instructions. Manufacturer SDS respiratory protection recommendations for AFFF available on base ranged from "not normally necessary" to half-mask or full facepiece elastomeric respirators with organic vapor cartridges. Due to the use of self-contained breathing apparatus for firefighting purposes, the department had a written respiratory protection program. Some fire fighters were unsure if N95 or other respirators not used in traditional firefighting duties were fit tested under the program.

During our walkthrough of the chemical storage facility, we spoke with the inventory manager and reviewed the available inventory of AFFF. Following the October 2015 incident, drums known to contain PFCs were set aside on the warehouse floor, with a notification sign specifying they were not for use. The inventory manager reported that these drums had been removed from the available online inventory, so they could not be inadvertently ordered.

Medical Record and OSHA 300 Log Reviews

We reviewed OSHA 300/300A Logs for documentation of work-related injuries and illnesses for the fire department during 2015. The WPAFB Fire Department reported three injuries requiring job restriction or job transfer. Two cases were from back strains resulting in 36 total days requiring job restriction or job transfer. The third case was related to the accidental release of AFFF, which was recorded as 63 days requiring job restriction or job transfer. At the time of our visit, the third case had not returned to work following the onset of his symptoms.

We reviewed SDSs for each manufacturer's AFFF product used at the facility. In particular, we focused our evaluation on the ingredients of the C8-containing AFFF used during the incident, which were potentially capable of causing acute injuries to the skin and eyes. These ingredients included diethylene glycol mono butyl ether (DGBE), magnesium sulfate, ethylenediaminetetraacetic acid (EDTA) tetrasodium salt, a proprietary hydrocarbon surfactant, and a proprietary fluorosurfactant [Chemguard 2006].

We reviewed medical documentation for two current fire fighters. One fire fighter exhibited persistent eye pain following AFFF exposure. The other fire fighter showed local skin irritation that resolved. In December 2015, three fire fighters had their blood tested for PFCs by an outside laboratory. Table 1 shows fire fighters' blood PFC results in comparison to the 2013–2014 National Health and Nutrition Examination Survey (NHANES) data for a representative sample

of the U.S. population [CDC 2017a]. Values that are bolded represent levels above the upper confidence limit for the 95th percentile of males aged 20 years or older.

Table 1. Range of PFC levels in tested WPAFB fire fighters and in NHANES, in µg/L

PFC Name*	Range in fire fighters	95th percentile (confidence interval) in U.S. male population
PFOS	5.68 – **30.8**	22.1 (16.7 – 26.9)
PFOA	1.78 – 3.05	5.67 (4.67 – 6.27)
PFNA	0.23 – 1.09	2.2 (1.80 – 2.40)
PFHxS	4.63 – **10.1**	6.30 (5.20 – 8.80)
PFOSA†	< LOD – 0.06	< LOD
PFDeA	< LOD – 0.13	0.80 (0.60 – 1.00)
PFUA	0.03 – 0.15	0.60 (0.40 – 0.90)
Me-PFOSA-AcOH	0.73 – 0.13	0.50 (0.40 – 0.70)

*PFOS (perfluorooctane sulfonate); PFOA (perfluorooctanoic acid); PFNA (perfluorononanoic acid); PFHxS (perfluorohexane sulfonate); PFOSA (perfluorooctane sulfonaminde); PFDeA (perfluorodecanoic acid); PFUA (perfluoroundecanoate); Me-PFOSA-AcOH [2-(N-methyl-perfluorooctane sulfonamide) acetic acid

†NHANES samples taken 2011–2012

Note: Bolded numbers are greater than what you would expect to see in 95% of the average U.S. male population (20 years or older)

Employee Interviews

We conducted voluntary, confidential medical interviews with 16 of 21 employees working on site during the day of our visit. Five of the 21 employees were off-site and unavailable for interview. The median age of these employees was 39.5 years (range: 33–47). Five (30%) of these employees were supervisors. The median length of employment at WPAFB was 13.5 years (range: 2.5–20 years). Fifteen (94%) employees reported handling AFFF at some point during their fire fighting career, with 12 of 15 (80%) reporting actively working with AFFF.

We asked employees about medical conditions potentially associated with PFC and solvent exposure. Employees were asked if they had been diagnosed or treated for a number of conditions over the last five-year period. Four employees reported abnormal cholesterol, and three employees reported an eye injury or eye disease. Two or fewer employees reported thyroid disease, skin disease, miscarriage in self or spouse, or liver disease or dysfunction. All employees responded negatively to the following conditions: cardiovascular disease, abnormal blood sugar, diabetes, metabolic syndrome, hepatitis, jaundice, abnormal kidney function tests, kidney disease, blood disease, immune dysfunction, gout, low testosterone, infertility, kidney cancer, prostate cancer, and testicular cancer. We also offered open-ended responses regarding health concerns, or medical conditions not previously addressed.

We asked about psychosocial factors at work pertaining to trust in management, workplace relationships, and job stressors. Nearly all employees reported enjoying their work (94%), with

many citing variation (88%) and clear responsibilities (88%) as positive organizational aspects of their job. Most employees reported that their work was usually well-organized (81%) and that they were well-trained (81%) for their positions. Employees reported that they had the tools necessary to complete their tasks (75%), and that they were well-informed about the goals and the results of their work (75%).

Fourteen of 16 (88%) respondents reporting that their working conditions could be improved. Fourteen (88%) employees also reported that there are sometimes accidents or near misses in the workplace. Eleven (69%) employees reported experiencing an injury on the job. Similarly, eleven (69%) of employees reported concerns about workplace safety. Of the employees ever reporting an injury on the job, all eleven (100%) required treatment by a healthcare provider, with 10 (91%) of 11 resulting in a lost-time injury. Eight (73%) of these eleven employees required a temporary reassignment or restriction during their recovery. Only nine (56%) employees reported that enough attention was paid to preventing accidents, mishaps and near misses. Full questions and response are included in Table 2 below.

Table 2. Frequency of affirmative responses for job stress and psychosocial working conditions, n = 16

Question	Frequency of "Yes" responses (%)
Is your work made more difficult due to other people being absent?	15 of 15 (100%)
Do you normally enjoy your work?	15 (94%)
Do you have any work-related health concerns?	15 (94%)
Do you have enough variation in your work?	14 (88%)
Is it clear what your responsibilities are at work?	14 (88%)
In your department, are there sometimes accidents or near misses?	14 (88%)
Do you think your work or working conditions need to be improved?	14 (88%)
Is work usually well organized?	13 (81%)
Do you believe you were trained well for your job?	13 (81%)
Do you feel free to report health and safety concerns at work?	13 (81%)
Does your employer encourage you to stay home if you are ill?	13 (81%)
Do you always have the tools necessary to complete your work?	12 (75%)
Are you well informed about the goals and results of your work?	12 (75%)
In your department, is there enough attention paid to preventing accidents, mishaps and near misses?	9 (56%)
Do you trust your employer to look out for your well-being?	8 of 15 (53%)
Do you have poor relations with your supervisors?	8 (50%)
Do your supervisors listen to what you have to say?	8 (50%)

Is your work made more difficult due to other people not doing their job properly?	8 (50%)
Do you have poor relations with your coworkers?	7 (44%)
Do you often have to do something that is not part of your job description?	7 (44%)
Do you have a lot of say or get to make many decisions as a part of your job?	6 (38%)

All 16 employees reported that they were aware of health and safety management plans, and stated they received training through a number of mechanisms, including the Health and Safety committee, formal training sessions, online reference material (including through e-mail and the department's Microsoft SharePoint webpage), hardcopy documents, and word of mouth.

All 16 employees reported regular use of PPE while on the job; however, some employees reported that they did not use PPE when performing training or live exercises with AFFF.

Discussion

Perfluorochemicals are a large group of manufactured chemicals used to make a wide range of products from non-stick cookware to industrial products like firefighting foam [NIEHS 2016]. People may also be exposed to PFCs by drinking contaminated water or ingesting contaminated food (such as fish), hand-to-mouth transfer from surfaces treated with PFCs, or working in and/or living near industries that manufacture, manipulate, or use products containing PFCs [ATSDR 2017a]. Due to their widespread distribution and persistence in the environment, there has been increasing concern about exposure to PFCs. PFCs have been found to stay in the human body for several years. The range of half-lives, or time it takes half the substance to be broken down and eliminated, for common PFCs range from two to nine years [ATSDR 2017a].

The greatest exposures for PFCs has generally occurred in those with occupational exposures, primarily those in manufacturing PFC-containing products [ATSDR 2017b]. These workers showed blood levels far greater than the public, often more than ten times that of the general population [ATSDR 2017b]. Some studies have specifically identified fire fighters using AFFF as having high levels of PFCs [Laitinen et al. 2014; Rotander et al. 2015a,b]. Fire fighters in Australia and Finland have been shown to have elevated levels of PFCs in their blood, in particular PFOS, PFHxS, and PFNA [Laitinen et al. 2014; Rotander et al. 2015a,b].

The Centers for Disease Control and Prevention (CDC) administers the NHANES every year to a representative sample of the U.S. population, aged 12 or older. This survey aims to assess the health and nutritional status of adults and children in the United States. In 2013–2014, NHANES measured levels of PFCs in the blood of its participants. When we compare the NHANES results to the laboratory results for the three fire fighters exposed to the October 2015 accidental release of AFFF, these fire fighters' blood levels of PFCs are generally consistent with levels encountered in the general population [CDC 2017a]. However, one individual's measurements exceeded the upper confidence limit for the 95th percentile for PFOS and PFHxS. All other

measured values fell below this upper confidence limit. At this time, we do not have information to say what the level of PFCs in the blood mean for resulting health problems. We do not generally recommend for individuals to have PFCs tested in their blood. Studies have evaluated numerous health effects potentially associated with PFC exposure. However, these studies have not shown a consistent relationship with specific health outcomes.

Some employees reported conditions that have been associated with PFC exposures in some studies. A total of 4 of 16 participants (25%) reported high cholesterol. However, approximately 30% of adults in the United States also have high cholesterol [CDC 2017b]. Other employees reported eye disease or injuries. Fluorosurfactants, including PFCs, may be irritating to the eyes in high-doses, but are not typically associated with permanent eye damage [ATSDR 2009].

In 2016, the Environmental Protection Agency (EPA) issued a lifetime health advisory for PFOA and PFOS in drinking water of a combined 70 parts per trillion (ppt) [EPA 2018]. This measure does not directly correlate with health effects, but offers a margin of protection for all Americans throughout their lifetime from adverse health effects [EPA 2018]. The EPA based this limit on animal studies and populations studied for those exposed to PFCs.

In May 2016, the Ohio EPA issued an advisory to WPAFB, that PFC measurements in drinking water exceeded the EPA lifetime health advisory level of 70 ppt [Barber 2016a]. The following month, the city of Dayton shut down drinking water wells near WPAFB as a precaution [Barber 2016b]. These potential exposures are of note, as it is unclear if fire fighter exposures would be ongoing from environmental contamination or persistent from prior exposure to AFFF. Future occupational exposures are unlikely, considering base management had taken steps to remove PFC-containing AFFF from circulation.

In addition to work exposures, people living near areas where PFCs are manufactured, manipulated, or used have been shown to have higher levels of PFCs in their blood than the general population [Frisbee et al. 2009]. The largest study was the C8 Health Project, which was a large epidemiological study that looked at health effects from a population known to have drinking water contaminated with C8 from the 1950s until 2002. The C8 Health Project was initiated in an effort to study health effects from drinking water contaminated with PFOA in the Ohio River Valley, and aimed to determine if there was a probable link between exposure and a resulting health effect. The C8 Health Project identified some conditions as having a probable link to PFOA exposure, including high cholesterol, thyroid disease, testicular cancer, and kidney cancer.

A review of the SDSs for all AFFF available revealed many ingredients that cause a wide range of potential adverse health effects. We focused our evaluation on the ingredients for AFFF involved in the October 2015 incident. Studies for the health effects of DGBE show that it can cause dermal irritation, but systemic toxicity is not readily apparent. Along with dermal irritation, ocular irritation is likely to occur with direct contact, though this was not directly studied in animal trials. Ocular changes were not noted from systemic toxicity in animals exposed to DGBE [Johnson et al. 2005]. Magnesium sulfate, though an ingredient listed in the

AFFF, is a medication used for numerous medical conditions under controlled settings. It has a well-established toxic profile, and can cause short-term changes to the neurologic, cardiac, and respiratory systems [FDA 2013]. It can cause visual changes, accommodation issues, and abnormal pupillary responsive; however, we did not identify any circumstances in which direct contact with magnesium sulfate caused permanent eye or skin damage [Digre et al. 1990; FDA 2013].

Tetrasodium EDTA is a diamine salt that has been widely used in cosmetics, oral care products, and many other consumer products [Lanigan and Yamarik 2002]. Animal studies have shown variability in the effects of EDTA, with some showing pain, redness, swelling and bleeding when directly applied to the eyes of rabbits, and others describing nonirritating effects [Lanigan and Yamarik 2002]. Researchers administered low-doses of EDTA on the corneas of people over 15-minute periods, which did not show damage to the human cornea. EDTA may increase or decrease other chemicals ability to damage the eye, though we did not identify any information about other chemicals contained in the AFFF formulation [Lanigan and Yamarik 2002].

Hydrocarbons most frequently cause immediate ocular discomfort, with limited corneal damage [Chernow 1992]. For some chemicals classified as hydrocarbons, contact with the corneal epithelium can cause moderate to severe damage. However, this is typically the exception and not the rule. Cases involving severe damage may have an asymptomatic, or latent period, with little evidence of damage at the time of injury. This period usually ends within 12 hours of the injury [Chernow 1992]. We could find no further information about AFFF ingredients that could present with ocular damage months after initial injury.

The United States Air Force School of Aerospace Medicine health-risk assessment outlined the USAF's policy to transition from using both C6- and C8-based formulations of AFFF, to exclusively using C6-based formulations. C6 formulations do not contain significant quantities of PFCs [FFFC 2014]. NIOSH emphasizes a hierarchy of controls as a means of determining how to implement feasible and effective control solutions. Eliminating or substituting hazardous processes or materials reduces hazards and protects employees more effectively than other approaches. The United States Air Force School of Aerospace Medicine health-risk assessment aims to reduce potential exposures to C8-containing AFFF through substitution. This change-out process was completed prior to December 15, 2016. With the shift from C8- to C6-based formulations, the potential for exposure to PFCs is significantly reduced, and ideally controls exposures, thereby preventing future potential adverse health effects.

Nearly all employees we spoke with reported enjoying their work, with the majority of employees noting variation, good training, organization, and clear responsibilities as positive factors. Employee responses indicated that "trust in management" and "accident prevention" were potential areas for improvement. Trust in management is important because it has been shown to improve job performance, job satisfaction, organizational commitment, commitment to management decisions, and decreased turnover intentions [Dirks and Ferrin 2002]. Employees' raised concerns regarding the safety climate of the workplace as well. Managerial emphasis on a climate of safety has been shown to increase safe behaviors and reduce workplace accidents

[Johnson 2007]. This can, in part, be accomplished through strong communication between management, employees, the union, and the safety department. Sharing incident reports and information on decision-making, to the greatest extent possible, may increase employees' trust in management and coworkers, enhance a climate of safety, and improve organizational outcomes [Thomas et al. 2009].

Conclusions

The WPAFB Fire Department's health and safety program includes training, incident response procedures, SDSs, standard operating procedures for handling chemicals safely, and the use of PPE. All employees reported receiving training on handling hazardous materials, though training on PPE use specific to AFFF occurred only following the October 2015 incident. Some employees reported distrust in management; poor relations with supervisors and coworkers; and the need to pay more attention to accident prevention. Direct contact with AFFF to the skin and eyes, particularly under high pressure, can result in skin and eye irritation. The actions of WPAFB to remove AFFF containing PFCs and the USAF's policy to exclusively use C6-based formulations will eliminate or significantly reduce potential exposures to PFCs.

Recommendations

After reviewing information obtained before and during our site visit, we provide the following recommendations to improve workplace safety and health.

- Ensure all formulations of C8-based AFFF have been discarded in accordance with USAF policy.
- When transferring AFFF, employees should wear a face shield or eye protection with side shielding, long cuff nitrile gloves, long sleeve shirts, long pants, and closed toe shoes to minimize potential dermal exposure.
- Any dermal or eye contact with AFFF should be flushed with large amounts of water as soon as possible.
- Update all standard operating procedures to include new safe work practice guidance and PPE information including respirator usage.
- Ensure each employee is fit tested for each respirator that is required.
- Share reports about safety and health incidents with supervisors, employees and union officials, to the greatest extent possible. Sharing incident reports may increase employees' trust in management and coworkers, which may improve workplace morale and organizational outcomes.

This letter serves as a final report and concludes this health hazard evaluation. According to federal regulation (42 CFR 85.11), the employer must post a copy of this letter for 30 days at or near work areas of affected employees. We are sending a copy of this letter to the Occupational Safety and Health Administration Region VII Office and the Ohio Department of Health.

Thank you for your cooperation with this evaluation. If you have questions, please call Dr. Reed Grimes at 513-841-4426 or Dr. James Couch at 513-841-4318.

Sincerely,

George R. Grimes -S5

Digitally signed by George R. Grimes -S5
Date: 2018.04.06 14:06:08 -04'00'

George Reed Grimes, MD, MPH
Epidemic Intelligence Service Officer

James R. Couch -S

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cc: Mr. Brian Grubb, President, IAFF Local F-88
Occupational Safety and Health Administration Region VII Office
Ohio Department of Health

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