Comparison of Use, Storage, and Cleaning Practices for Personal Protective Equipment Between Career and Volunteer Firefighters in Northwestern Kentucky in the United States

Abstract

Most occupational research on firefighter exposure in the U.S. has been conducted in large urban cities with career firefighters. Over 70% of U.S. firefighters, however, are volunteers, a population overrepresented in small rural fire departments and thus under studied. We conducted three focus groups with individuals from eight fire departments in the Green River Firefighters Association fire protection district in northwestern Kentucky. Based on these focus groups, we developed a survey and administered it to 43 career and 187 volunteer firefighters at their annual fire training school. Based on their responses, we identified significant variables related to existing personal protective equipment (PPE) use, storage, and cleaning practices of firefighters. Except for storage, work practices related to the use of turnout gear (coats and pants) showed no significant difference between the two groups of firefighters. A majority of both career firefighters (85%, n = 16) and volunteer firefighters (59%, n = 57) stored their gear at the fire department (p < .05). Although turnout gear is the core component of PPE, 11% of the volunteer firefighters did not own turnout gear. Both firefighter groups have a substantial challenge with respect to PPE practices. Career firefighters deal with more frequent exposures to fire-related contaminants during training and while on duty. In contrast, volunteer firefighters lack the resources needed to properly maintain, clean, and store their PPE, concerns that are not addressed by National Fire Protection Association recommendations.

Introduction

Research interest in the health of firefighters in the U.S. increased in the 1980s. Over the following decades, a series of investigations in the U.S. has examined the adverse acute and chronic health effects related to firefighter occupational exposures (Fent et al., 2018; Gold, Burgess, & Clougherty, 1978). Most of the studies on firefighter occupational exposures have focused on career firefighters in densely populated urban cities (Dahm, Bertke, Allee, & Daniels, 2015; Daniels et al., 2014, 2015; Fent et al., 2018; Sparer et al., 2017). In particular, there are few, if any, studies on occupational exposures that focus on firefighters in small rural fire departments in the U.S.

Most firefighters in small rural fire departments are volunteers (Easterling & Prince, 2007) and are more likely to be vulnerable to carcinogenic exposures (Hwang, Taylor, Cann, Golla, & Gilbert, 2019; Hwang, Taylor, Cann, Norris, & Golla, 2019). Some of the heightened vulnerability of volunteer firefighters to occupational exposures can be attributed to a lack of respiratory protection standards, as volunteer fighters are not subject to Occupational Safety and Health Administration (2011) standards that are in place for career firefighters. The carcinogenic toxin benzo[a]pyrene, for example, is associated with lung, bladder, and kidney cancers; diesel exhaust is associated with rectal cancer, lung cancer, and leukemia (International Agency for Research on Cancer, 2010, 2013).

In the U.S., 89.2% (N = 25,604) of all fire departments employ mostly or all volunteers, and 69.0% (N = 788,250) of all firefighters are volunteers (Haynes & Stein, 2017). In Kentucky specifically, 75.7% of firefighters across nearly 700 fire departments are volunteers. The national average is 70.9% (U.S. Fire Administration, 2018). This pattern of
predominantly volunteer firefighters is commonly observed in the smaller rural communities in northwestern Kentucky.

Small rural fire departments do not have as high of a call volume as large urban fire departments or as large of a budget for employing career firefighters. Thus, volunteer firefighters are likely to be residents of the community who have committed to serve in an emergency, as needed in a part-time capacity or for a single shift, in addition to their separate primary job. Furthermore, volunteer firefighters in Kentucky do not receive direct financial benefits, although they can claim a $1,000 refundable income tax credit.

By contrast, career firefighters are full-time responders who are compensated accordingly. In terms of tasks, volunteer firefighters mainly perform response, training, and maintenance activities, whereas career firefighters do these tasks plus perform administrative and medical fitness activities, such as medical evaluation and respiratory protection programs (Easterling & Prince, 2007).

The occupational health risks faced by firefighters are exceptional. To manage these risks, firefighters depend heavily on personal protective equipment (PPE), including turnout gear (coats and pants), hoods, gloves, helmets, eye protection, masks, footwear, and self-contained breathing apparatuses (SCBA). Therefore, identifying existing PPE practices for maintaining, cleaning, and storing firefighter gear is essential.

In a recent study of firefighters in Kentucky, Lesniak (2017) examined how the use of some PPEs can affect their performance. The firefighters participating in that study, however, were from a large urban fire department staffed by career firefighters, a scenario that precludes any personal information.

Methods

Study Design

Our study design used both qualitative and quantitative methods and was approved by the institutional review board (IRB) of Western Kentucky University (IRB code number: 16-446). Specifically, we developed and tested the survey instrument through focus group interviews, and then we administered the survey instrument to firefighters at the fire training school, each of whom signed an informed consent form. We followed this two-phase approach for three reasons: 1) our goal was to develop a systematic survey instrument, 2) we wanted to identify the PPE concerns of different groups of firefighters, and 3) we needed to build a sustainable relationship with the firefighters for the purpose of the larger study.

Focus Groups

We conducted three focus groups for fire departments in the local Green River Firefighters Association (GRFA) fire protection district to develop the survey instrument. The district staffs 70 municipal fire departments in 8 counties in northwestern Kentucky, which represents 10% of the fire departments in the state. The participants in the first and second focus groups were leaders, such as fire chiefs and directors. The participants in the third focus group were frontline individuals, such as firefighters and instructors. For all three focus groups, we held meetings for approximately 90 min. We kept all discussions strictly confidential and did not collect or record any personal information.

In the first focus group, eight firefighter leaders discussed questions relating to occupational exposures in their working environments, including PPE practices. Based on that discussion, we developed a survey instrument that emphasized the use, storage, and cleaning practices for PPE. In the second focus group, the same eight leaders provided feedback on the resultant survey instrument and discussed logistics for administering the survey. We then revised the survey instrument based on their feedback.

For the third focus group, the leaders from the first two focus groups sent an invitation to participate in the survey. From the survey results, we extracted 31 questions related to a variety of firefighter PPE work practices for data analysis. For seven participants who indicated they were both a career and a volunteer firefighter, we incorporated their employment status and job titles for classification. If the participant was a full-time firefighter (e.g., an assistant chief), then he or she was classified as a career firefighter (n = 4). If the participant was working part-time (e.g., retired), then he or she was classified as a volunteer firefighter (n = 3).

We recorded all completed survey instruments using survey software and compared PPE practices between career and volunteer firefighters with chi-squared tests using SAS version 9.4 with significance levels determined by p ≤ .05.

Results

Demographic Information

The response rate for the survey instrument was 53% (121 of 230 firefighters). The respondents represented 24 counties in northwestern Kentucky, only one of which was an urban city, as defined by a population ≥ 50,000 (U.S. Census Bureau, 2018). A total of 19 career and 102 volunteer firefighters participated in the study (Table 1).

The demographics of the career and volunteer firefighters were similar (p > .05) but the participating career firefighters tended to be younger and more experienced. Two of the survey questions asked the total number of years as a firefighter and the number of years at the current fire department. The difference between those two numbers was 3 times higher for career firefighters than volunteers (3.3 years for the career firefighters versus 1.1
years for the volunteer firefighters), indicating that career firefighters have a faster turnover rate from one fire department to another.

**Personal Protective Equipment Gear**
Due to the unique environmental conditions of fire suppression operations, firefighters depend on PPE. Thus, respondents were asked to identify the types of PPE worn (Table 2). The firefighters relied heavily on all types of PPE except for hearing protection at a fire scene (range 78–100%). Additionally, we found that 100% of career firefighters were issued turn-out gear, compared with 89% of the volunteer firefighters. Overall, 17% of the firefighters had more than one set of turnout gear; career firefighters had an average of 1.5 sets of gear, whereas volunteer firefighters had only one set.

Although the fire departments participating in this study provided full monetary support to purchase new turnout gear for 78% of career firefighters and 67% of volunteer firefighters, our study found that 22% of the career firefighters and 41% of the volunteer firefighters replaced their gear longer than every 10 years. The maximum age of the newest and oldest sets of turnout gear ranged from 12–15 years and 20–37 years, respectively. Both the oldest and newest sets of turnout gear owned by volunteer firefighters were at least 1.6 times older than those of the career firefighters; however, there was no statistically significant difference between the career and volunteer firefighters ($p > .05$, Table 3).

**Personal Protective Equipment Storage Practices**
The PPE storage practices of career firefighters differed significantly from volunteer firefighters ($p < .05$, Table 4). Most career firefighters (85%, $n = 16$) stored gear at the fire department (e.g., in a locker or fire truck) versus 59% ($n = 57$) of the volunteer firefighters. Only 21% ($n = 4$) of the career firefighters stored their gear in personal vehicles compared with 53% ($n = 51$) of the volunteer firefighters.

The firefighters were also asked about container usage or portable storage practices. Most volunteer firefighters (63%, $n = 58$) stored their turnout gear in a container such as a zipper bag or airtight container. Only 13 volunteer firefighters (14%) stored their gear in a mesh container as recommended by the National Fire Protection Association (NFPA, 2014).

**Personal Protective Equipment Cleaning Practices**
We also evaluated cleaning practices of the firefighters, including cleaning determination, frequency of cleaning, and type of washer used for cleaning. Overall, the two groups had similar cleaning practices ($p > .05$, Table 5) but volunteer firefighters tended to wash gear less frequently than career firefighters. Most firefighters had not performed advanced cleaning of their turnout gear. An extractor, which is a high-performance
industrial washer, was more accessible to the career firefighters (42%, \( n = 8 \)) than to the volunteers (12%, \( n = 11 \)) because it is usually located in the fire department.

### Discussion and Conclusion

#### Personal Protective Equipment Gear Replacement

Career and volunteer firefighters in small rural communities in northwestern Kentucky face different challenges with respect to PPE use, storage, and cleaning practices. Volunteer firefighters find it challenging to meet PPE requirements due to fewer resources. In particular, turnout gear loses protective functions, such as fire and chemical resistance, as it ages and has a maximum life span of 10 years from the date of manufacture (NFPA, 2014). Yet we found that volunteer firefighters tended to have older turnout gear that was less frequently replaced (>10 years) than career firefighters. Additionally, one of the volunteer firefighters in our survey did not possess turnout gear at all. Although most small rural fire departments provide monetary support for the purchase of turnout gear, and in our survey 67% of volunteer firefighters had full monetary support for turnout gear, a full set of gear on a limited budget still might not be affordable for all firefighters (Green River Firefighters Association [GRFA], 2016).

#### Training and Personal Protective Equipment Gear

Career firefighters in Kentucky must complete a minimum of 100 training hours annually, while volunteer firefighters need only 20 hours (Kentucky Fire Commission, 2017). Training covers subjects such as fire behavior, first aid, and communication. Specific fire-related training operations can cause exposure to residual smoke off-gassing from PPE and occupational air contaminants on PPE. For example, career firefighters routinely train for aircraft emergencies in which the primary threat is petroleum. Typically, volunteer firefighters only encounter petroleum when they fight crude oil tank fires at a fire scene. Thus, the chance of being exposed to smoke and air contaminants from burnt petroleum likely is higher for career firefighters because they are exposed not only at fire scenes but also during required training.

Another difference between career and volunteer firefighters relates to the training requirements for PPE. Specific PPE criteria are established by NFPA’s Standard 1851: Standard on Selection, Care, and Maintenance of Protective Ensembles for Structural Fire Fighting and Proximity Fire Fighting (NFPA, 2014). The basic section on PPE is part of the required training for both career and volunteer firefighters; however, career firefighters undergo more hours of training. This difference in training hours could explain our finding that nearly twice as many career firefighters were familiar with the NFPA standards as were volunteers.

#### Personal Protective Equipment Gear Storage

Except for storage location, we did not identify any differences between career and volunteer firefighters in the use, storage, and cleaning of turnout gear (\( p > .05 \)). In a previous study, nearly half (47%) of the firefighters reported storing their turnout gear in personal vehicles (Fent et al., 2013). In this study, the volunteer firefighters were more likely than the career firefighters (53% and 21%, respectively) to store their turnout gear in a personal vehicle, a tendency that might be due to the size and dispersal of the response area for small rural fire departments. Given the large area covered by rural departments and the high likelihood that vol-

### Table 3

<table>
<thead>
<tr>
<th>Turnout Gear Set</th>
<th>Career</th>
<th>Volunteer</th>
<th>( p )-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Minimum</td>
</tr>
<tr>
<td>Newest set</td>
<td>3.3</td>
<td>3.8</td>
<td>0.1</td>
</tr>
<tr>
<td>Oldest set</td>
<td>6.1</td>
<td>3.5</td>
<td>1.5</td>
</tr>
</tbody>
</table>

### Table 4

<table>
<thead>
<tr>
<th>Storage Practices*</th>
<th>Career</th>
<th>Volunteer</th>
<th>( p )-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%</td>
<td># of Responses/ # of Participants</td>
<td>%</td>
</tr>
<tr>
<td>Location</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Locker at fire department</td>
<td>74</td>
<td>14/19</td>
<td>50</td>
</tr>
<tr>
<td>Fire truck</td>
<td>11</td>
<td>2/19</td>
<td>9</td>
</tr>
<tr>
<td>Personal vehicle</td>
<td>21</td>
<td>4/19</td>
<td>53</td>
</tr>
<tr>
<td>Home</td>
<td>0</td>
<td>0/19</td>
<td>9</td>
</tr>
<tr>
<td>Container type</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zipper bag</td>
<td>44</td>
<td>8/18</td>
<td>58</td>
</tr>
<tr>
<td>Mesh container</td>
<td>11</td>
<td>2/18</td>
<td>14</td>
</tr>
<tr>
<td>Airtight container</td>
<td>0</td>
<td>0/18</td>
<td>5</td>
</tr>
</tbody>
</table>

*Based on multiple answers (more than one answer).
Volunteer firefighters have other jobs, they often respond to calls by driving their personal vehicles to the scene of an emergency (GRFA, 2016). Therefore, volunteer firefighters tend to store their turnout gear in their vehicles. Storing PPE in vehicles and moving contaminated gear in and out of personal vehicles can increase the risk of residual exposure to contaminants, such as polycyclic aromatic hydrocarbons (Baris et al., 2001; Dahm et al., 2015; Fabian et al., 2014), polychlorinated dibenzo-p-dioxins and dibenzofurans, and polybrominated dibenzo-p-dioxins and dibenzofurans (Shaw et al., 2013).

Whether firefighters are exposed to accumulated contaminants in their vehicles is a relevant question and the possibility of take-home contamination from previous fires should not be ignored (Du Plessis et al., 2010; Hwang, Taylor, Cann, Norris, & Golla, 2019). In terms of container type, the NFPA (2014), recommends that turnout gear be stored in breathable mesh unless the gear is new. We observed, however, that firefighters more often than not stored unlaundered gear in an airtight container in a personal vehicle or at the fire department.

### Personal Protective Equipment Gear Cleaning

NFPA discusses two processes for cleaning PPE: routine cleaning and advanced cleaning. Routine, light cleaning is often performed by a firefighter and consists of brushing off dry debris, rinsing with a water hose, and spot cleaning. Advanced gear cleaning refers to thorough cleaning by hand or machine, with cleaning agents, and often by contracted companies. NFPA mandates advanced cleaning of all personal turnout gear at least once every 6 months or whenever routine inspections indicate a problem with the gear. We found that the advanced cleaning practice, however, is not followed in small rural fire departments, which are mainly staffed by volunteers and have budget constraints.

The volunteer firefighters surveyed in this study had limited access to cleaning equipment, including extractors for routine gear cleaning. An extractor is a high-functioning washer that controls water temperature, chemical injection, and extract speed. Most of the firefighters we surveyed air-dried turnout gear in direct sunlight, which is not recommended by NFPA, and a few firefighters used clothes dryers. Furthermore, firefighters reported washing gear with mild detergents, regular laundry detergents, and turnout gear cleaners. The type of washer, dryer, and detergent can affect how quickly turnout gear degrades.

<table>
<thead>
<tr>
<th>Cleaning Practice*</th>
<th>Career</th>
<th>Volunteer</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cleaning determination</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>After fire</td>
<td>53</td>
<td>10/19</td>
<td>39</td>
</tr>
<tr>
<td>Visibly dirty</td>
<td>37</td>
<td>7/19</td>
<td>54</td>
</tr>
<tr>
<td>Following SOP</td>
<td>42</td>
<td>8/19</td>
<td>22</td>
</tr>
</tbody>
</table>

| Frequency of routine cleaning | | | |
| None | | 11 | 2/19 | 4 | 4/95 | .295 |
| After each use | | 37 | 7/19 | 31 | 29/95 |
| ≤ Every 6 months | | 37 | 7/19 | 24 | 23/95 |
| > Every 6 months | | 5 | 1/19 | 23 | 22/95 |

| Frequency of advanced cleaning | | | |
| None | | 83 | 15/18 | 71 | 65/92 | .152 |
| After each use | | 6 | 1/18 | 0 | 0/92 |
| ≤ Every 6 months | | 6 | 1/18 | 7 | 6/92 |
| > Every 6 months | | 6 | 1/18 | 14 | 13/92 |

| Washer type** | | | |
| Hose or hose with brush | | 31 | 6/19 | 40 | 36/89 | .095 |
| Top- or front-load washing machine | | 21 | 4/19 | 51 | 45/89 |
| Extractor | | 42 | 8/19 | 12 | 11/89 |

*Based on multiple answers (more than one answer).
**Types of dryer and cleaning solutions are not shown.

SOP = standard operating procedure.
Personal Protective Equipment Gear as Control
Industrial hygiene lists protection methods from most to least effective in a standard hierarchy of control: hazard elimination, substitution, engineering control, administrative control, and PPE. The standard hierarchy does not apply to firefighters, however, due to a unique working environment, namely intermittent risk, on-call work, and responses outside the workplace. Consequently, firefighters must rely on PPE, the least effective method of control.

We found that firefighters depend heavily on all PPE at a fire scene, except for hearing protection, which interfered with vital communication with fellow firefighters, dispatchers, and other emergency response workers. Firefighters, then, are not protected from the other noise sources that are present such as sirens, ventilation fans, extraction equipment, operating equipment for fire suppression, and SCBA equipment. Although these other noise sources are intermittent and usually short, accumulated exposure can lead to hearing loss (Hong, Samo, Hulea, & Eakin, 2008).

Limitations

This study has several limitations. The ratio of career to volunteer firefighters in our study was unbalanced, reflecting the composition of the surveyed fire district, in which 81% of firefighters were volunteers (GRFA, 2017). The selection of volunteer firefighters could be more discriminating, thereby limiting participation to those with less experience. Volunteer firefighters with less than 3 years of experience cannot contribute to focus groups because they have not completed the required NFPA training hours. We found that many volunteer firefighters had less than 3 years of experience. We further compared the types of firefighters enrolled in the fire school (N = 230) with the survey participants (N = 121). Approximately 19% of the students and 16% of our participants were career firefighters, illustrating the imbalance between career and volunteer firefighters in this region.

Other limitations are due to nonresponses, sample composition, participant bias (self-selection and recall), and investigator bias. Due to the moderate 53% response rate in this study, nonresponse bias was unavoidable. To increase response rate, a monetary incentive was randomly offered to the participants.

The unique format of the fire school, however, was not fully explored prior to distributing the survey. During fire school training, firefighters participate in multiple activities on the ground or in the field rather than lectures in a classroom; therefore, potential respondents had insufficient time to respond to the entire survey. To better understand the firefighter cohort in this region, we plan to conduct a follow-up survey at the fire school over an extended period of time using a multimodal approach, such as a combined paper-and Internet-based format.

All respondents voluntarily agreed to participate in the survey. Voluntary responses imply there is possible self-selection bias due to purposive participants, in contrast to a randomized sample (Murray et al., 2014). Additionally, the information provided by the survey participants might have been influenced by recall bias from the focus group. Although focus group discussion data were useful for placing study findings into context, all statements by the focus group participants should have been recorded and fully transcribed to enable a more transparent process. Finally, there could be bias from the investigators who guided the discussion.

Acknowledgements: The authors wish to thank the participating firefighters and the fire departments represented. We are grateful to GRFA for assistance in organizing and implementing the study. We would also like to acknowledge the Western Kentucky University (WKU) graduate students for their assistance. This study was supported by the WKU College of Health and Human Services.

Corresponding Author: Jooyeon Hwang, Assistant Professor, Department of Occupational and Environmental Health, Hudson College of Public Health, University of Oklahoma Health Sciences Center, 801 NE 13th Street, Room 415, Oklahoma City, OK 73104. E-mail: jooyeon-hwang@ouhsc.edu.

References


---

**Did You Know?**

NEHA’s A Day in the Life of an EH Professional blog contains a wide variety of blog posts from NEHA staff and members. The posts cover a broad spectrum of environmental health topics—food safety, climate change, aquatic health, health impact assessments, children’s environmental health, toxic substances, and water quality, to name a few. You can also find posts on NEHA activities, news, and member spotlights. Check them out at www.neha.org/membership-communities/get-involved/day-in-life.