

**FIREHOUSE SUPPLEMENT**

# Cardiovascular & Chemical Exposure Risk Considerations During Training



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# Research Highlights the Health Impacts of Fire Service Training Activities & Exposure

The fire service has come to understand that, in addition to elevated temperatures and related heat stress, members may be occupationally exposed to a number of airborne pollutants and contaminants during emergency fire responses, including polycyclic aromatic hydrocarbons (PAHs), volatile organic compounds (VOCs) and other respirable particulates. Some of these compounds may also be produced during live-fire training and may contribute to firefighters' exposure over their career. The magnitude of exposure can vary depending in part on the relative amount of time spent in training versus emergency responses. Occupational exposure during training may also depend on the fuel package used in training fires, number of exposures (as instructor or student) and the way PPE is donned, doffed and cleaned before and after the training scenarios. As a fire instructor, training officer or line firefighter, you may be asked (or may be asking yourself) several important questions about training scenarios that can expose firefighters to hazardous levels of heat and carcinogenic chemicals. For example, you may be asked what can be done to reduce risks during training—a time when we have a professional responsibility to ensure as much safety as feasible while properly preparing firefighters for the work they must do. You may also be interested in incorporating best practices and control measures to reduce risk during training that will also reinforce muscle memory for use during fireground responses.

This supplement is designed to provide some insight into several of these questions based on evidence from a series of studies led by the Illinois Fire Service Institute (IFSI), the UL Firefighter Safety Research Institute (FSRI), and National Institute for Occupational Safety and Health (NIOSH), along with partners from Skidmore College. With funding support from the Department of Homeland Security's Fire Prevention & Safety (FP&S) Grant program, along with additional support from the CDC Foundation and the National Toxicology Program and support from Globe, we have conducted three studies as part of our Cardiovascular and Chemical Exposure Risk Project:

- **Fireground study**—Using a full-scale residential style test structure, teams of 12 firefighters responded to typical room and contents fires in a coordinated response to better understand how operating in an environment typical of today's fireground impacts cardiovascular strain and chemical exposures related to carcinogenic risk.
- **Training Fires study**—Using three common training environments (fires involving 1. natural wood (pallet) or 2. oriented strand board (OSB), or 3. obscuration through theatrical smoke) groups of firefighter trainees conducted a coordinated fire attack scenario in common training structures (concrete building, metal structure). Before and after the training scenarios, concentrations of airborne contaminants (i.e., PAHs, VOCs, acid gases, isocyanates and aldehydes), biological exposure to PAHs and VOCs, and physiological responses of firefighters and fire instructors were evaluated so that we could compare the training scenarios.
- **PPE Cleaning study**—Our most recent study focused on characterizing the impact of repeated smoke exposures and/or cleaning techniques on select performance characteristics of NFPA 1971 compliant PPE. We also carefully tracked the pathway whereby fireground contaminants may lead to exposure of firefighters' skin.

In the pages that follow, we address questions that we frequently have been asked about data that have been produced by this project. The format of this document is to 1) Present the challenge that exists, 2) Describe what we did to further understand the concern, 3) Summarize what we found, and 4) Provide relevance/context to the fire service in terms of lessons that we learned which may be implemented by those who are charged with delivering safe and effective training. As with the application of any research finding to the real problems we face, consideration and interpretation of your operational reality will be necessary and the guidance provided here is certainly not definitive. We hope, however, that this discussion provides you with material on which to build.

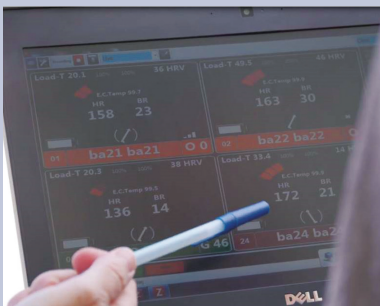
*By Gavin Horn, Kenneth Fent, Denise Smith and Stephen Kerber*

## CONTENTS

- A4 Section 1: Training Fuel Considerations**
- A7 Section 2: PPE Cross Contamination Considerations**
- A11 Section 3: FAQs from the Fireground Study That Can Be Applied to Training**
- A14 Concluding Messages—and What's Next**



# Section 1: Training Fuel Considerations



In our Training Fires study, we compared two training methodologies in two similar training structures. Firefighters' heart rates and core temperatures were measured throughout each scenario and blood drawn shortly after completing the scenarios.

Photos courtesy of IFSI, UL-FSRI, NIOSH

*The Training Fires study provided several new results that can be considered by training officers and academies when selecting the training environment for a given scenario. There are many important, and sometimes conflicting, issues that must be taken into account during training when attempting to provide the best and most useful training conditions for the students, while balancing the risks that are inherent in this critically important activity.*

## 1 Is The Heat Of The Fire The Most Important Factor In Creating Heat Stress?

**CHALLENGE:** Most firefighters understand that heat stress leads to fatigue and can impair performance, and many realize that it also exacerbates cardiovascular strain. But, the assumption that the thermal load from a fire is a primary determinant of heat stress deserves scientific attention. This is particularly important in the fire training environment (what we consider here as training fuel load and training structure design), where scenarios must be designed with consideration for how the ambient conditions support the training objective as well as how they may potentially influence the firefighter's physiology related to health and safety. For example, it has been proposed that conducting simulated training in a thermoneutral environment with a "realistic" visual atmosphere may provide firefighters with the opportunity to learn and practice skills more safely. The most commonly available simulation technologies used to create this kind of atmosphere include theatrical smoke or pepper fog for visual obscuration and a visual display to simulate fire glow. On the other hand, some fire instructors believe that live-fire conditions are necessary to properly acclimatize firefighters to the heat stress of the real fireground.

**WHAT WE DID:** In our Training Fires study, we compared two training methodologies in two similar training structures. In the first scenario, "Pallet," live fire was created using pallets and straw. In the second scenario, "Fog," fire was simulated using theatrical smoke. In both scenarios, the dimensions of the room,

location of the 'fire' and position of simulated trapped occupants was identical. Temperature was measured in each room along the walls and chemical sensors were installed throughout the structure. Firefighters' heart rates and core temperatures were measured throughout each scenario and blood drawn shortly after completing the scenarios.

**WHAT WE FOUND:** In the Pallet scenarios, peak temperatures in the fire rooms reached more than 400 degrees F at the 3-foot level (estimated height of a firefighter crawling). Room temperature remained at ambient temperature for the Fog scenarios. Despite significant differences in ambient conditions between the Fog and Pallet training scenarios, the peak core temperatures and heart rates and the blood clotting potential of firefighters were not significantly different.

Firefighting involves strenuous physical (aerobic and anaerobic) work, in part because of the nature of the job and in part because of the use of heavy, insulative gear. The gear adds to the metabolic work that is performed and interferes with heat dissipation, thus exacerbating heat stress.

**LESSONS LEARNED:** The assumption that performing firefighting activity in ambient (or thermoneutral) conditions leads to lesser physiological strain compared to live-fire activity is not supported by this study. It is important that firefighters training in fully encapsulating personal protective equipment (PPE) be provided rest, recovery and rehab based on the intensity and duration of work, regardless of the apparent safety risk from ambient conditions alone.

While the difference in heat stress and cardiovascular strain is minimal between scenarios, the chemical exposure for the Fog scenario is significantly reduced compared to live-fire training scenarios.

## 2 What Are Some Of The Risks And Benefits Of Different Training Fuels?

**CHALLENGE:** Fire instructors often want to create a “realistic” training environment to better prepare trainees for the conditions they will face on actual emergencies. When live-fire training is conducted, the holistic impact of different fuels should be evaluated to understand relative risk. Traditionally, the most common live-fire training scenarios use wood (often from pallets) and another light combustible material to ease ignition (straw or excelsior) and produce a controlled fire. These materials generate relatively light grey or white smoke. In recent years, some training organizations have begun to utilize engineered wood products such as OSB in addition to pallets and straw because the materials produce a darker smoke that more closely replicates fire environments in 21st century structure fires. Furthermore, it has been argued that it is important to expose trainees to a realistic, elevated thermal environment during training to prepare firefighters for real scenarios. There is a belief among some instructors that including engineered wood products like OSB exposes firefighters to temperatures similar to what they would face on today’s fireground.

**WHAT WE DID:** Another aspect of the Training Fires study provided a comparison between two different training structures—one that included two rooms with pallet and straw fires (**Pallet**), and one that utilized OSB sheathing along the structure ceiling with a smaller pallet and straw fuel load (**OSB**). The Pallet scenario was conducted in a traditional concrete and steel structure, while the OSB scenario used a similar-sized but more modern layout in a steel training structure. Temperatures were measured in each room along the structure walls and a wide range of chemical sensors were included in and around the structures. Urine samples were collected from firefighters up to 3 hours after the end of fire training to measure uptake of fireground chemicals.

**WHAT WE FOUND:** While the temperatures observed inside the training structure were higher during the OSB scenario as compared to the Pallet scenario, the temperatures did not approach those measured in the typical residential structure utilized in the Fireground study in a comparable residential structure. Thus, while temperatures are increased using OSB, they are still not similar to those that may be encountered in a structure fire environment. Furthermore, firefighters’ physiological and hematological responses to the OSB and Pallet scenarios were not significantly different.

Live-fire training scenarios using OSB fuels, however, resulted in greater chemical exposures for firefighters and instructors compared to those only incorporating pallet and straw fuels (particularly for one type of OSB ... see the next consideration). On a per-training fire basis, exposures were generally below what was measured from attack and search firefighters during the Fireground study for all training scenarios (except for one type of OSB ... see the next consideration).



Another aspect of the Training Fires study provided a comparison between two different training structures—one that included two rooms with pallet and straw fires (**Pallet**), and one that utilized OSB sheathing along the structure ceiling with a smaller pallet and straw fuel load (**OSB**).

**LESSONS LEARNED:** It has long been understood that the fire instructor’s choice of live-fire training fuel package can have an important impact on the conditions within the structure, but this study provides a direct comparison between two common fuel types and a similar residential fireground environment. Incorporating engineered wood products increases the ambient temperatures over only using pallets and straw, but did not approach thermal conditions in residential fires with the fuel loads used in this study. At the same time, the chemical exposures experienced by the firefighters and instructors can increase to levels that were similar to the Fireground study and even exceeded on a per-fire basis. Training academies should consider exposure risks as well as instructional objectives when designing training exercises.

## 3 What Does ‘Formaldehyde-Free’ OSB Mean When It Is Burning?

**CHALLENGE:** The term ‘formaldehyde-free’ OSB is sometimes used to describe sheets of OSB that are suggested for use in training fire scenarios. This terminology is often referring to the hazardous “free formaldehyde” that can be measured in standardized testing of formaldehyde emissions. Such testing is focused on formaldehyde off-gassing during use in buildings, not necessarily the formaldehyde that is chemically bound in the OSB, nor related to formaldehyde that maybe released or produced during combustion as a training fuel.

**WHAT WE DID:** In the Training Fires study, the OSB scenarios were conducted with two different types of commercially available ‘formaldehyde-free’ OSB sheets. According to their safety data sheets (SDS) one type (we will refer to as ‘alpha’) reported <0.1 percent of free formaldehyde, while the second type (referred to as ‘bravo’) reported <0.01 percent of free formaldehyde. Both OSB sheathing materials contained



There are concerns for fire instructors at training academies who may conduct multiple scenarios in a given day, including excessive increases in core temperature, cardiovascular strain, and exposures to fireground contaminants.

phenol formaldehyde adhesive and polymeric methylene bisphenyl diisocyanate (pMDI) adhesive, but the exact volume percentage of each is unknown. Chemical samplers focused on measuring aldehydes and isocyanates were included in and around the structures. Urine samples were collected from firefighters up to 3 hours after the end of fire training to measure uptake.

**WHAT WE FOUND:** The median air concentrations of formaldehyde, acrolein, and acetaldehyde during the training fire scenarios with the bravo OSB were above applicable ceiling limits and were also 4.8 to 12-fold higher than what was measured during the alpha OSB scenarios. Isocyanate concentrations were also highest during the bravo OSB scenarios. These results suggest that bravo OSB may have contained higher amounts of MDI-based adhesives than the alpha OSB. Combustion of these adhesives could have also contributed to higher airborne concentrations of the aldehydes and other combustion byproducts. Looking at what compounds reached the firefighter, PAH and benzene exposures from the bravo OSB exercises were consistently higher than the alpha OSB exercises.

**LESSONS LEARNED:** Based on these findings, utilizing 'formaldehyde-free' OSB for live-fire training does not suggest that there will not be formaldehyde present during the training scenario. Combustion of these products can still produce quantities that may exceed ceiling limits. Furthermore, other materials that are used in the binding agents for these materials may combust and react to produce airborne compounds with important health implications in the training environment.

These results once again highlight the importance of firefighters and fire instructors protecting their airway as much as possible by donning SCBA and breathing from a controlled air source on the training ground as often as possible, regardless of the type of OSB utilized in training scenarios. Additionally, when OSB is to be used for live-fire training burns, OSB with the least amount of synthetic adhesives should be selected when possible. It is, however, important to note that this information is not always readily available from the suppliers.

## 4 What Are Some Of The Risks For Instructors Who Conduct Multiple Scenarios Per Day?

**CHALLENGE:** There are important concerns for fire instructors at training academies who may conduct multiple scenarios in a given day, oftentimes several more than the students themselves. Health and safety concerns include excessive increases in core temperature, cardiovascular strain, and exposures to fireground contaminants.

**WHAT WE DID:** Throughout the Training Fires project, firefighters participated in a single training exercise per day, while the instructors supervised three exercises per day. We

measured heart rate, core temperature, and uptake of fireground chemicals before and after training was completed for both firefighting students and instructors.


**WHAT WE FOUND:** Instructors had lower peak heart rates than firefighters, but similar peak core temperatures due to the prolonged and repeated nature of their activities. Even though instructors where involved in multiple evolutions during the day, they had smaller increase in blood clotting potential compared to firefighters. On the other hand,

we found significantly elevated metabolite levels of the PAHs pyrene, phenanthrenes, and fluorenes in instructors at the end of the workday compared to firefighters after a single scenario. These findings suggest instructors experience cumulative exposures to PAHs from overseeing multiple training exercises in a day.

**LESSONS LEARNED:** Overall, this study reinforces that live-fire training may expose firefighters and instructors to hazardous airborne chemicals. Exposure depends on the number of training fires and the type of fuel package. Likewise, training fires will result in the uptake of benzene and other VOCs. Exposures from training fires over time could increase firefighters' and instructors' risk of developing certain types of cancer.

Efforts should be taken to reduce these exposures, including donning SCBA when working or teaching in smoke, cleaning the skin as quickly as possible after exiting the structure, laundering turnout gear after live-fire training as soon as feasible (or field decontamination if laundering cannot be done), showering as soon as possible following training, and selecting training environments that support realistic, objective-based training while limiting unnecessary exposures for firefighters and instructors.





The interface between the hood and SCBA facepiece is a crucial location to further control exposure risks. It is recommended departments provide as much training opportunities as possible that focus on getting the interfaces sealed in addition to getting the PPE donned quickly.

## Section 2: PPE Cross Contamination Considerations

*The modern firefighting turnout ensemble provides state-of-the-art protection from the heat and smoke faced on today's fireground and training ground. However, the firefighters' actions in donning, doffing and cleaning their ensemble can also influence the protection provided by the gear. Fire training provides an important opportunity to teach and reinforce good habits regarding how to handle PPE — building muscle memory during scenarios we are in control of, for application on the dynamic and potentially hectic fireground.*

### 5 Mind The Gap: Do You Teach Careful Hood Donning Practices To Reduce Contamination Through Interfaces?

**CHALLENGE:** Firefighters have recognized the value of wearing a hood in reducing exposure and many have sought increased levels of protection. Consequently, manufacturers have made great progress in developing hoods with particle-blocking capabilities that reduce the penetration of fireground products of combustion. In laboratory tests, these hoods have been shown to improve skin protection by greatly reducing the likelihood for particulate contamination through the hood. The improve-

ments in hood design alone may not be enough to eliminate contamination reaching your neck. Procedures matter. If these new hoods are not donned and doffed carefully and appropriately, there are other ways for contamination to reach the skin.

The interface between the hood and SCBA facepiece is a crucial location to further control exposure risks. While recent SCBA facepiece designs have begun to incorporate a larger interface area with ample room for the rubber seal to make skin and hood contact, older designs are not as easy to don rapidly AND effectively. These legacy designs may have short interface areas and/or utilize straps that connect to the lens itself, creating a situation where it is easy for the hood to be held away from the facepiece seal. Even in newer designs, there is potential for long harness straps to become caught between the hood and the mask. When this occurs, it is often difficult, if not impossible, for the person wearing the mask to see these gaps in protec-

# Cardiovascular & Chemical Exposure Risk Considerations During Training



Manufacturers have made great progress in developing hoods with particle-blocking capabilities, but the improvements in hood design may not be enough. In several scenarios, contamination was found on the skin even when particle-blocking hoods were worn.



Reduce the risk of particle exposure by checking your interface between hood and mask. Facepiece straps can create a gap allowing soot to reach inside the hood.



By controlling the doffing process, it may be possible to more carefully control where the contamination can contact the skin.

tion. Furthermore, donning PPE at a fire scene will often have to be done in a rapid manner which may limit opportunity for inspection prior to entry into the structure.

**WHAT WE DID:** Throughout this series of research projects (Fireground study, Training Fires study, PPE Cleaning study), we have been working on tracking the pathway that contamination takes to get to the firefighter's skin. Pictures of contamination reaching the skin were compared to pictures of the firefighter's gear configuration after donning their PPE.

**WHAT WE FOUND:** In several scenarios, contamination was found on the skin even when particle-blocking hoods were worn. Other situations emerged where uneven contamination was found on the skin despite relatively uniform exposure. Photographic evidence showed that – in some cases – these patterns of contamination could be tied back to gaps that were found in the hood to SCBA facepiece interface. In some cases, these exposures may be attributed to design of the facepiece (e.g. straps that connected to the lens instead of the facepiece seal, no overlap between facepiece seal and hood) while other cases may be attributed to straps caught between hood and facepiece.

**LESSONS LEARNED:** Based on these concerns, the following suggestions are provided to reduce the risk of particle exposure:

- Reinforce the importance of donning the hood properly for protection from both heat and smoke. Provide as much training opportunities as possible that focus on getting the interfaces sealed in addition to getting the PPE donned quickly.
- Check your partner after donning your full PPE ensemble to ensure a complete facepiece-to-hood seal. This activity can again be reinforced during training so that it becomes muscle memory.
- Keep the harness straps as short as possible to reduce the chance of them getting caught when pulling the hood over the harness to create a seal.
- When spec'ing new hoods and facepieces, carefully study how well your hood will be able to seal on the facepiece so that this interface can be easily closed by a single person.

## 6 Are You Defeating The Protection Your Hood Provides?

**CHALLENGE:** Even if a firefighter's hood is based on the newest technology of particle protection, donned without gaps, and securely sealed throughout a firefight, doffing without care and consideration can expose his or her neck to the same contaminants from which it was initially protected. The traditional manner in which firefighters are trained to doff their PPE will typically result in the hood's facepiece opening being pulled over the head and placed down around the neck to allow the firefighter to access the facepiece straps. With this procedure, the firefighter will be exposing his or her skin to the contamination on the hood. Furthermore, heavy sweat and elevated skin temperatures may increase the speed of chemical absorption.

**WHAT WE DID:** The research team began studying the process of hood doffing from the perspective of removing contaminated PPE similar to hazmat suits. By controlling the doffing process, it may be possible to more carefully control where the contamination can contact the skin. The less time that the contamination is in contact with the skin, the less time is available for contaminants to be absorbed.

**LESSONS LEARNED:** While not always feasible on the fireground, firefighters might consider alternative means of removing hoods, particularly in the case where the firefight has ended and a firefighter is reporting to rehab. One possible approach might be to leave the hood and facepiece on until after the coat has been removed, then pull the hood up from the shoulder area, over the facepiece netting. The hood and facepiece can then be removed together. A demonstration of this technique can be found at [www.youtube.com/watch?v=9uYp0ZQP158](https://www.youtube.com/watch?v=9uYp0ZQP158). Other approaches may



Leave the hood and facepiece on until after the coat has been removed.



Pull the hood up from the shoulder area, over the facepiece netting.



The hood and facepiece can then be removed together.

be developed - for example, to roll the hood off the head or to provide other means to reduce contact between the hood and neck skin. These techniques for contamination control can be integrated with a standardized process for cleaning the neck skin once the hood has been doffed. An opportune time to develop, test and implement these techniques is during training scenarios. The more these approaches are practiced, the more likely they will be performed—and performed correctly—on the fireground.

## 7 Do You Doff Your EMS Gloves With More Care Than Your Fire Gloves?

**CHALLENGE:** A lot of well-deserved attention has been paid to the soot contamination that firefighters find on their neck after a firefight, but less effort has been focused on the firefighters' hands. In the Fireground study, we found that contamination levels on firefighters' hands can be considerably higher than on the neck after structural firefighting. While there is typically thicker skin on the hands than the neck, any skin exposure can still provide a path for absorption. Furthermore, the hands provide a highly mobile route for spreading contamination to other body sites. Consider how often you wipe the sweat out of your eyes or mucus from your nose after just completing a firefight. How often do you eat food with your hands on the fireground or rehab? Ever think about the contamination on your hands before you go to the bathroom? Finally, hands can further cross contaminate other parts of your PPE, apparatus cab, and station just to name a few.

**WHAT WE DID:** The research team began studying the process of glove doffing from the perspective of removing contaminated EMS gloves. The fire service is comfortable with controlled doffing of contaminated EMS gloves, often using the same process even when the gloves are not contaminated.

**LESSONS LEARNED:** While it may be impossible to fully eliminate the hand contamination that you encounter while crawling a hallway, advancing a line, removing an occupant or conducting overhaul, this is not the only place hands are exposed to contamination. Your PPE protects you during a firefight but doffing this same gear could expose you to the very contaminants from which you were protected. Gloves are among the most contaminated items of PPE and little attention is paid to the process of taking them off. Consider the care you take in removing EMS gloves to ensure contact is not made with any potential body substance contamination on the outside. A similar approach to touching only the inside of firefighting gloves can be implemented and trained. One approach, demonstrated at [www.youtube.com/watch?v=QyAt5WHf5uM](https://www.youtube.com/watch?v=QyAt5WHf5uM), shows how firefighters can work their hands out from the gloves in a manner that skin only contacts the interior of the glove. This type of an approach will only require a few additional seconds during the doffing process. Once the gloves have been removed, don EMS gloves and avoid carrying contaminated fire gloves around in your hands. Consider a discussion of glove doffing in future training evolutions, such as during SCBA donning practice where PPE might be donned and doffed frequently in a single training session.



A firefighter can remove PPE similar to medical glove removal. With this approach, firefighters work their hands out from the gloves in a manner that skin only contacts the interior of the glove.

## Cardiovascular & Chemical Exposure Risk Considerations During Training



In this example, both firefighters completed the same assignment under the same conditions. The difference is that the firefighter on the left removed their own gloves while the firefighter on the right had help.



Gloves are among the most contaminated items of PPE. Avoid carrying contaminated fire gloves around in your hands.

### 8 Laundering Is Important, But Have You Managed Cross Contamination?

**CHALLENGE:** The fire service continues to evolve its understanding of PPE cleaning techniques. While hood exchange programs and ‘Wash your hood Sunday’ messages are now widespread in the fire service, it is acknowledged that there still exist challenges for getting hoods fully laundered due to the many different chemicals that may be deposited after a fire. While typical laundering appears to remove most of the soot and PAH contamination, some residual amounts of certain flame retardants have been found on the hoods even after thorough laundering. There is additional concern that some of these materials may cross contaminate other cleaner items in the wash load.

**WHAT WE DID:** As part of the PPE Cleaning study, heavily contaminated hoods from the Fireground study were laundered

in the same load as new hoods. After laundering was complete, pieces of each of the hoods were cut out and sent to the lab to determine what residual compounds were in the hood fabric.

**WHAT WE FOUND:** This study showed that some highly contaminated hoods may not only remain contaminated after laundering, but also spread contamination to other relatively cleaner hoods (including the brand-new hoods with no fire-ground exposure). Ongoing studies are working to determine if a firefighter’s sweat might extract some of these contaminants from the hoods and make them available for uptake by the firefighter even after they have been laundered. Initial results suggest that these materials do not easily transfer away from the hoods in sweat, but more work is needed.

**LESSONS LEARNED:** Until we know more about the transfer of this residual contamination to the firefighter, the following best practices are suggested for your consideration:

- Continue to launder hoods after each fire as this process is effective at removing a large portion of PAH contamination that is among the most abundant contaminant on the hoods. PAH contamination is likely after both fireground and training fire responses, while flame retardant exposure is much less likely on the training ground.
- Consider segregating firefighter hoods by contamination level to reduce the potential for cross-contamination. If a firefighter responds to a call but is exposed to low levels of contamination compared to the rest of the crew, it may be beneficial to avoid washing with other crew members’ hoods. Again, this process is particularly important after fires with typical room and contents combustibles but can be reinforced after training fire scenarios as well.
- Do not launder hoods with base layers or station wear to reduce the risk for cross contamination.
- Get in the practice of laundering hoods and segregating by contamination level after training fires whenever feasible. The reduction in PAH contamination is an important contamination control process after training and can build good habits in department membership.



Continue to launder hoods after each fire as this process is effective at removing a large portion of PAH contamination that is by far the most abundant contaminant on the hoods.

# Section 3: FAQs from the Fireground Study That Can Be Applied to Training

*As researchers continue to study the questions asked by the fire service, our collective knowledge continues to evolve. Several key considerations provided in 2017 have been implemented on the fireground, training ground and in studies across the country. Over this time, our understanding has advanced as questions continue to be asked and recommendations begin to be implemented. These considerations build on themselves—we have more analysis to conduct and will have more research to complete as results are implemented in the fire service—and more questions are asked. Here are just a few examples of frequently asked questions (FAQs) we have come across since the first 10 Considerations found at [Firehouse.com/12361314](https://www.firehouse.com/12361314).*

## 9 Preliminary Exposure Reduction FAQs From The Street

**CHALLENGE:** As part of our Fireground study, we provided the first measurement of the effectiveness of gross on-scene decontamination techniques. The wet soap decon method was shown to remove approximately 85 percent of PAH surface contamination from the bunker gear. While the evidence is clear, implementation of the practice has sometimes been met with challenges, resistance and questions.

**WHAT WE DID:** In recent years, many departments have been implementing on-scene decon, also now known as a Preliminary Exposure Reduction (PER), and we have learned a lot about field implementation. Best practices are evolving so that we can address some of the frequently asked questions. A few FAQs and responses are included below.

### LESSONS LEARNED:

#### Do I need a garden sprayer to apply soap?

- While our initial application utilized this approach to apply a soap and water solution to the pre-rinsed gear, it is not a requirement. Several departments have experimented with other approaches including using an in-line eductor on a garden hose and—quite frequently—mixing the soap and water in a bucket and applying directly with the brush. It does appear that utilizing a soap or surfactant is important to removing some of the ‘sticky fat soluble’ contamination, but the method of doing so can be flexible. It may also be prudent to have a couple buckets with brushes that could be used separately depending on the contamination level in order to minimize the risk of cross contamination from a heavily exposed firefighter to a less exposed member. Incorporating the decon step during training would allow fire departments to test what approach works best for them prior to the incident scene.

#### How much water do you need to apply?

- Water application will depend on contamination level but should mostly be used to pre-wet the gear, then rinse off the soap solution. With proper technique, water should not contact



**The wet soap decon method was shown to remove approximately 85 percent of PAH surface contamination from the bunker gear.**

the firefighter through PPE interfaces. Anecdotally, excessive water has been found to be used to remove large pieces of debris from the turnout gear. This can be a difficult task if large amounts of drywall or insulation materials are on the gear, which can result in overly soaking the gear and increased possibility for wetting interfaces and skin. Consider balancing wet and dry methods when large pieces of debris are present (see consideration #10).

- As with any fireground function, training is important to learn and improve technique. It is suggested that wet soap decon/PER be included during live-fire training evolutions so it can be more efficiently and effectively implemented on the fireground.

#### What should we do with PPE after decon now that it is wet?

- A recurring concern about wet decon or PER that has been voiced by firefighters across the country is ‘what to do with PPE after it is deconned, now that it is wet?’ A great resource for this question will be the next edition of the NFPA 1851 standard, which will contain a decision support tool. Until this is officially released, you might consider current department SOPs for how to handle gear that has been wetted by environmental conditions or hose overspray. In other words, take similar precautions that you would if you had been caught in a rainstorm and your outer shell has been wetted by rain.

# Cardiovascular & Chemical Exposure Risk Considerations During Training

## Can I conduct wet soap decon in below freezing conditions?

- While the ability to implement gross on scene decon with water will depend on environmental conditions, the process has been utilized in the cold on many occasions. Chief Frank Leeb from FDNY shared a great video with several important considerations that you can view at [www.youtube.com/watch?v=kA7TbIqoueQ](http://www.youtube.com/watch?v=kA7TbIqoueQ). Wet soap decon in the cold is certainly feasible, but it is important to realize the firefighter being deconned should be prioritized based on conditions. Be sure to be cognizant and address cold stress as part of an integrated rehab program. When feasible, provide warming stations for the deconner and deconnee as quickly as possible. Make ice melt available to reduce slip and fall risk. Deconning firefighting PPE is an important risk reduction process but should be balanced with the other risks that may be uniquely present on each fireground.

## What should I think about when conducting wet soap decon in the heat?

- It is important to remember the firefighter inside their PPE, waiting to be deconned cannot cool down or recover from the thermal and cardiovascular stress of firefighting as easily as if PPE were immediately removed. Thus, it is important to balance the risk of heat stress for the member with the risk for additional chemical exposure. Address heat stress concerns as part of integrated rehab and prioritize firefighter order based on availability of air and their physical and psychological stress level. Provide hydration where feasible — this may be possible while still wearing an SCBA mask using a squeeze bottle with a straw. Consider the benefit of temporarily unzipping the coat to allow airflow around the firefighter's core. It may be beneficial to establish multiple decon lines/stations to move firefighters through more rapidly based on numbers and conditions.

## 10 Dry Decon FAQs From The Street

**CHALLENGE:** While dry decon techniques such as dry brush and air brush have been found to be less effective at reducing surface PAH contamination than the wet soap technique, there may be several reasons why a department or individual would implement these approaches. Fire departments might consider the balance between wet and dry techniques.

### LESSONS LEARNED:

#### When might dry decon be a technique to consider?

- There will be cases when environmental conditions (cold, snow, wind, etc.) do not allow wet soap approaches. While less effective than wet soap decon, the dry brushing technique can reduce the casual contact transfer of contaminants and be a step toward reducing cross-contamination risk.
- As mentioned earlier, the dry technique may be more effective at removing large, solid debris like drywall or insulation. When these materials get wet, they can become difficult to remove and potentially spread out and cover



The dry decon technique may be more effective at removing debris like drywall or insulation that may become difficult to remove when wet. Be sure to use proper PPE and precautions!

other contamination. A quick brush may help reduce the time in wet decon and improve efficiency.

- Dry decon techniques can be implemented in locations where there is limited water supply. While wet soap approaches do not utilize a large amount of water, there are situations where strict limitations are present. Alternate approaches to preliminary cleaning should be balanced with any increased risk.

#### What personnel protection should be considered during dry decon?

- When dry decontamination techniques are used, it is important to consider where the contamination ends up. With a water-based technique, most of the contamination will run off of the gear onto the fireground. Dry techniques will likely reintroduce the contamination into the air and potentially spread them to other unwanted locations (particularly if a forced air approach is used). As such, it is important to consider appropriate airway protection for not only the person being decontaminated, but the decon staff themselves and other 'downwind' personnel. The relative location of the dry decon site and the rehab station as well as other members on the fireground should be carefully planned.

#### How else might dry decon spread contamination?

- It is also important to clean the brush or other tools used during dry decon to reduce transfer of contamination to the staff, apparatus, station or possibly other firefighters. Wet soap decon will tend to clean the tools at the same time as the firefighter, so an extra step will likely need to be taken with the dry decon techniques.

## 11 Interior Vs Transitional Attack FAQs And Continued Analysis

**CHALLENGE:** A primary goal of firefighting is to extinguish fire in order to protect life and property. Based on an accumulating body of evidence, many fire departments are emphasizing the need to apply water to the fire as soon as possible to improve conditions inside the structure. While there are many possible means for accomplishing rapid water application, two distinct approaches have been debated in recent years. For this discussion we will define: 1) "interior attack" where firefighters immediately enter the structure through the front door with a charged hose line and 2) "transitional

attack” where firefighters apply water through a window to initially suppress the fire before they enter the building to completely extinguish the fire.

An important aspect of the decision-making process in selecting one suppression technique versus the other is how employing such a tactic may impact tenability for trapped occupants. Secondary considerations may include how tactical choice impacts risk for compromising firefighting PPE and how fireground operations may impact firefighters’ chemical exposures. It has been proposed by some that transitional attack could lessen exposures by reducing the production of smoke prior to firefighter entry. On the other hand, some have suggested that this tactic might cool the hot upper gas layer and reduce its buoyancy, thus increasing the concentration of smoke in the area where firefighters would be working. Measurements were made to directly address the complex interplay that exists in this question.

**WHAT WE DID:** In the Fireground study, we measured temperatures throughout the structure during fire attack to estimate risk for displacing fire from the burn rooms to areas where trapped occupants may be found as well as estimate risk for damage to firefighting PPE. To better understand impact on the firefighter, we measured skin and core temperature on the participants as well as performed biological monitoring (breath and urine) on firefighters to measure the absorption of combustion byproducts during firefighting.

#### LESSONS LEARNED:

##### Did you find any indications of ‘pushing fire’ in this study?

- As described in the first 10 Considerations document, the data from thermocouples just outside of the fire rooms and heat flux gauges at the end of the hallway outside of the fire rooms showed no large increases in temperature immediately after water application. Data collected near a simulated trapped occupant outside a bedroom at a distant location from the fire rooms did not indicate any substantial differences based on water application.

##### How did the tactical choices impact rescue conditions of the simulated trapped occupants?

- Water application by the fire attack teams resulted in a rapid drop in temperatures throughout the structure, followed shortly afterward by a decrease in the rate of exposure to elevated temperature and gases (as determined by the Fractional Effective Dose (FED) approach). There was no significant difference between the magnitude of the temperature decrease or the time until the inflection point in the FED curve between transitional attack and interior attack. For more information on this analysis, download *Effect of Firefighting Intervention on Occupant Tenability during a Residential Fire* paper from the online toolkit at [www.fsi.illinois.edu/research/cardiochem/#!/tools/science](http://www.fsi.illinois.edu/research/cardiochem/#!/tools/science).

##### Did your study show that tactic impacted firefighter heat stress?

- The transitional attack scenarios resulted in significantly lower ambient temperatures throughout the structure while firefighters were operating compared to the interior attack,

which resulted in lower peak and average temperatures measured at the firefighter’s helmet. However, this did not translate to a significant reduction in firefighter’s heat stress. The PPE worn by firefighters was sufficient to protect them from the elevated ambient conditions where they worked, but it also kept in much of the metabolic heat generated by the heavy exertion.

- A further, somewhat surprising finding from this study was the core temperature of the firefighters conducting outside vent and overhaul can be as high or higher than those on the attack and search crews working in active fire conditions. Similar to consideration #1 (see page A4), heat generated inside the bunker gear can be as important as the ambient conditions when determining firefighter heat stress. For more detail on this component of the study, download *Thermal response to firefighting activities in residential structure fires: impact of job assignment and suppression tactic* paper from the online toolkit at [www.fsi.illinois.edu/research/cardiochem/#!/tools/science](http://www.fsi.illinois.edu/research/cardiochem/#!/tools/science).

##### Was there any difference in chemical exposure between the two tactics?

- The personal air concentrations of PAHs and benzene (concentrations in the air surrounding the firefighter) were slightly higher for interior attack, but there was not a statistically significant difference by attack tactic. We found no statistical differences in skin exposures to PAHs by attack tactic; however, median values measured on firefighters’ hands and necks were slightly higher for interior attack. At the same time, peak neck skin temperatures in the attack and search firefighters were slightly but significantly higher during interior attack compared to transitional attack. Higher skin temperatures may increase transdermal absorption rate of some chemicals. However, the biological monitoring results are the most important in determining differences in exposure. The urine measurements from these firefighters indicate that transitional attack resulted in 20 percent, 36 percent, and 50 percent lower metabolite levels of the following PAHs: fluorenes, phenanthrenes, and pyrene. For more information on these findings, download *Firefighters’ absorption of PAHs and VOCs during controlled residential fires by job assignment and fire attack tactic* and *Airborne contaminants during controlled residential fires* papers from the online toolkit at [www.fsi.illinois.edu/research/cardiochem/#!/tools/science](http://www.fsi.illinois.edu/research/cardiochem/#!/tools/science).

Overall, our findings indicate that, while there was no significant impact of tactic on firefighters’ heat stress, transitional attack could be used as an administrative control to reduce firefighters’ exposures to PAHs when it may be appropriate considering the entirety of the fireground needs present at a scene. It is important to note, that selection of fire attack tactics must consider a broad range of factors in addition to firefighters’ exposures. Providing members with training on how and when to use a different tactics based on a wide range of factors can allow firefighters to best adapt to conditions present on the fireground.

# Concluding Messages—and What's Next

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We now know much more about risks facing firefighters — on the training ground, on the fireground, and at the fire station — than at any time in the fire service history. We are, however, only scratching the surface of fully understanding risks, and most importantly, evaluating these risks in the greater context of the needs of the fire service to properly prepare for and execute its critically important mission for the citizens each department is sworn to protect. While live-fire training carries certain risks — some we understand and others where knowledge is evolving — an untrained and unprepared fire department is vulnerable to a variety of other hazards. In this context, we suggest a holistic view of these results as they apply to your local fire department.

As we continue to analyze samples, perform statistical tests and publish our results, we will continue to share the lessons learned with the fire service. But, even our early findings clearly point to the need for increased understanding of the risks firefighters face. For example while the use of engineered wood products as training fuels increases exposure risk for firefighters and fire instructors, its value in providing high-fidelity training should also be considered. Instructors and training academies can determine if the potential increase in exposure is worth the risk for the potential increase in fidelity. Furthermore, we present a few important PPE lessons that we have learned which may reduce risks on the training ground. Reinforcing the importance of properly donning, doffing and cleaning PPE during training can reinforce this important lesson and assist firefighters in creating muscle memory for application on the fireground.

As a follow-up to the information presented here, we plan to continue to investigate fuel loads that may be introduced in live-fire training that may provide realistic instruction with reduced exposure risks. As PPE continues to evolve, such as through interfacial elements designed to block smoke, so too does the balance of risk posed by chemical exposure and heat stress. And as we learn more about the need to maintain PPE cleanliness, new tools and techniques continue to be introduced and will need to be validated. Stay tuned for future results that come out of this project and the many other outstanding research projects around the country.

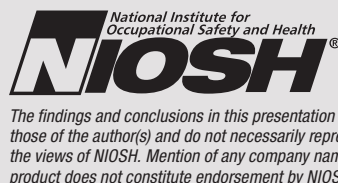
### About the Researchers/Authors

**Kenneth Fent** is a research industrial hygienist at NIOSH and head of the National Firefighter Registry program. Much of his research has focused on characterizing firefighters' exposures to chemical agents and evaluating practices intended to reduce exposures and lessen firefighters' risk of cancer.

**Stephen Kerber** is vice president of research for Underwriters Laboratories and director of the UL Firefighter Safety Research Institute (FSRI). He has led research and education in ventilation, structural collapse and fire dynamics.

**Denise Smith** is a professor at Skidmore College and a senior research scientist at the Illinois Fire Service Institute (IFSI). She conducts research on the heat stress and cardiovascular strain associated with firefighting, pathoanatomic cause of firefighter fatalities, and strategies to increase performance and decrease cardiovascular events in the fire service.

**Gavin Horn** is a research engineer with the UL FSRI and served as the director of IFSI Research until summer 2019. His research focuses on firefighter health & safety and first responder technology development.





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