COLD FIRE SCENE
Recognizing the Hidden Da

By Jeffrey L. Pauley

THE INTERNATIONAL ASSOCIATION OF ARSON INVESTIGATORS (IAAI) defines a cold fire scene as one that has been fully extinguished for at least 72 hours and not generating detectable or visible dust, fumes, mists, particulates, gases, vapors or aerosols (Photo 1). This article is for those who enter a fire scene days or weeks after the fire has been extinguished (the post-fire environment) who may think that, because it is a cold fire scene it is a safe scene: insurance agents or adjusters, engineers, cleanup crew members, attorneys or others who enter more than a few scenes throughout their lifetime. These individuals may often walk through the scene wearing street clothes and spend time looking around or taking pictures, or spend hours working in the scene without using any PPE, then get in their vehicle and leave. All the while, unbeknownst to them, these people are being exposed to the fire's toxic by-products that are still present. And, just like the several thousand people who die in structure fires each year, these exposed people may well die from being at the fire scenes too. But it could happen many years later and likely no one will know that the post-fire scenes they entered over the years could have contributed to their death.

In the past 10 years, the author has been to hundreds of post-fire scenes as a public or private fire investigator and has seen firsthand the devastation that fires can wreak on families and livelihoods; it can be heart-wrenching. During that time, the author has also been researching and writing about the adverse health effects of post-fire scenes. We know that these scenes can be hazardous to the long-term health of fire investigators. That also means they can be hazardous to anyone else who spends time in them. Knowing that people working in this environment are at risk because they are not adequately protected is disconcerting. IAAI's health and safety committee is working to expand the post-fire environment research and broaden the understanding of the post-fire scene health hazards.

KEY TAKEAWAYS

- With rare exceptions, every post-fire scene contains health hazards that require the use of PPE, including respiratory protection.
- This article discusses the types of hazards that may be present at post-fire scenes and how these hazards can affect workers who enter these spaces, which may include cleanup crews, engineers, insurance personnel and attorneys.
- It also describes protective gear and safety protocols that can be established and followed to help protect those entering post-fire scenes. An N95 filter is not adequate respiratory protection in the post-fire environment.

Post-Fire Scene Hazards

NIOSH's Miriam Calkins (as cited in IAAI Health & Safety Committee, 2020) says, "There are many hazardous chemicals in the post-fire environment, and how they combine to form other hazardous compounds is presently unknown" (p. 10). Some research shows that gases and vapors generally dissipate over time (Weiss & Miller, 2011). Still, time alone is not a good predictor of possible hazards (Nelson, 2011). And while these vapors and gases may go away over time, the particulates do not.

Much has been written in the past few years about the effects of these toxic gases on firefighters, but not enough has been said about their impact on others working in the post-fire environment long after the fire trucks have left, or about the persistence of particulates. The current research data for the post-fire scene is scant. Along with several research partners, IAAI is working to change that. But there is also much that is unknown.

OSH professionals should all know that the potential exists for physical, environmental and biological hazards from a wide variety of sources at every post-fire scene. These hazards are usually identified by a good scene safety survey upon first arriving at the scene. These hazards can be readily seen, and most are mitigated by using the various hierarchy of control methods. During and immediately after a fire, many fire gases are present. But after the fire and for a considerable time thereafter, particulates,

JEFFREY PAULEY

Photo 1: An example of a cold fire scene.

HEALTH HAZARDS

angers

vapors and gases are present that continue to be a threat to everyone in the vicinity, and they cannot be seen.

Fire smoke is a mixture of particles and chemicals produced by the incomplete burning of carbon-containing materials. All smoke contains carbon monoxide, carbon dioxide and particulate matter (soot). Smoke can contain many different chemicals, including aldehydes, acid gases, sulfur dioxide, nitrogen oxides, polycyclic aromatic hydrocarbons, benzene, toluene, styrene, metals and dioxins (NYSDOH, n.d.). This is what stains the walls and covers surfaces at the post-fire scene. These particulates remain in the scene until cleanup or demolition is finished, and they can be stirred up by merely walking through the scene, moving objects or digging. And the most harmful ones cannot be seen.

The content and type of particulate matter found in the post-fire environment are varied and complex. These particulates are made up of the combustion residue from whatever burned. Think about all the things this could include at a residential structure: plastics and other synthetic materials, cleaning products, solvents, insecticides and more. The number of plastics alone in homes today is nearly unquantifiable, as are the glues used in laminated furnishings and construction materials (Bolstad-Johnson, 2018).

There are more than 100 known carcinogens in fire smoke and many different toxic gases. It is known that during the fire and for an undetermined time after, harmful gases, including carbon monoxide, hydrogen cyanide and formaldehyde, are present (Bolstad-Johnson et al., 2000). They likely dissipate over time, but it is suspected that gas and vapor molecules can also be trapped in fire debris and released when the debris is moved.

A study found that "97%+ (of particulates) were too small to be visible by the naked eye suggesting that 'clean' air was not really that clean" (Fabian et al., 2010, p. 256). These are the nanoparticulates. The ones that are 5 microns and smaller can travel to the farthest depths of the lungs when inhaled (Figure 1, p. 22). They are not visible to the human eye, but they are present at every fire scene. The polycyclic aromatic hydrocarbons in this post-fire scene residue can exist as particles and gas so they can be inhaled and absorbed. Of the 18 polycyclic aromatic hydrocarbons commonly produced in fires, nine are known carcinogens (Fent et al., 2013).

One particulate hazard of note is asbestos. From the 1930s to the 1970s, U.S. manufacturers added asbestos to a wide range of products to make them more durable. Although asbestos is now regulated in the U.S., it is found in many older structures. However, the substance is still used in some new products today so it could be present after any structure fire. Asbestos regulations in other countries vary greatly, so asbestos exposure at a post-fire scene is possible anywhere. When inhaled, asbestos can lead to "several very serious . . . pulmonary conditions" (Brantom et al., 2018, p. 5). Brantom et al. further note that "the very nature of the work of firefighter will inevitably expose them to asbestos" (p. 5). Therefore, it is a logical extension that anyone else working in the post-fire scene could also be exposed.

Scott and Scott (2019) enumerate a broad range of lead-containing household items, including jewelry, pipes, stained glass, antiques, electronics and toys. During a structure fire, lead fumes are produced from these items when heated to at least 932 °F. The average house fire burns at a temperature between 1000 and 2000 °F. At these temperatures, the lead releases highly toxic lead oxide fumes. When they cool, these fumes condense into solid particles that are released into the atmosphere and become part of the nanoparticulates present in the post-fire scene. While lead oxide is hazardous to adults, it poses the most significant risk to young children, infants and unborn babies in the form of damage to the central and peripheral nervous systems, learning disabilities, impaired hearing, and impaired formation and function of blood cells (CDC, n.d.). If a worker is not adequately protected while working in the post-fire scene, these particulates can be transported home on clothing and the body, exposing family members.

Exposure hazards can be from ingestion, injection, absorption or inhalation. Differences in gender, weight, age and even genetic sequences can alter the concentration at which they react and the reaction level. There are also other variables. Concentration and duration play a role in the effects of any exposure. There is also the body's natural defense mechanisms and the fact that susceptibility varies by person (Mangelsdorf et al., 2014; Roberts et al., 2015). All of this means that every exposure is different for each person. Because of these many unknowns, the best practice is to protect oneself every time.

The two most common entry routes for these hazards in the post-fire environment are inhalation and dermal absorption. Not coincidentally, the body's two largest organs are the lungs and skin. Semple (2004) notes that "many chemicals can cross the unbroken skin" (p. 381).

The use of proper respiratory protection helps with the inhalation hazard. But unlike for inhalation exposure, there are no U.S. occupational exposure limits for dermal exposure (Semple, 2004). The regular removal of soot and unseen particulates from the skin helps limit the absorption of the many harmful chemicals found in the post-fire environment. There is some movement in the EU to define dermal occupational exposure limits (Mangelsdorf et al., 2014). However, knowledge of the compound's hazardous characteristics is necessary. This could be done in a facility where a known material is being used. This is impossible to determine in the post-fire environment where many harmful substances are likely present.

A related factor that everyone working in the post-fire environment should also take into consideration is heat. The skin is highly porous, with many potential pathways for toxins to enter the body. Skin permeability increases as skin temperature increases. The hotter the temperature, the more the skin perspires and the faster toxins permeate into the body (Park et al., 2008).

Why Is All of This a Problem?

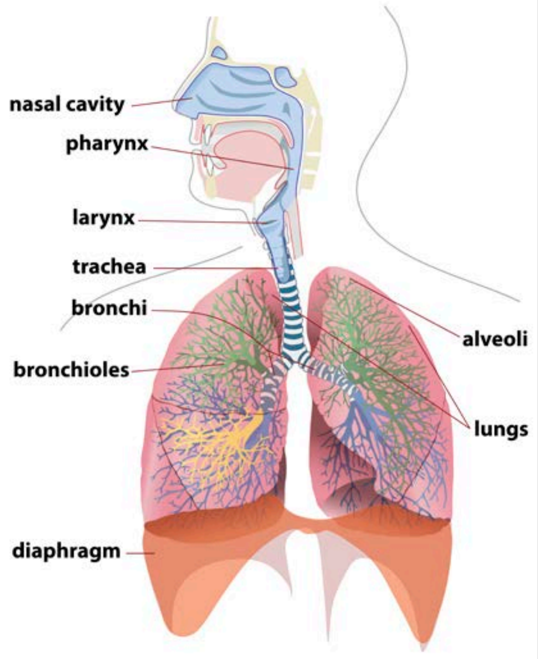
Even though many workers spend time in and around fire debris that contains particulates or that can release toxic gases, or the gases ride along on the particulates on their trip into unprotected lungs, the culture is often to think, "It hasn't hurt me yet so why should I change?" or "That's the way we have always done it." Unfortunately, this mentality is exacerbated by the fact that, absent something bad (acute) happening at or immediately after being at a scene, workers go home feeling OK and do not think about the cumulative effects of these exposures. So, when medical issues develop years later, it is too late to go back and change things. This is an inherently dangerous attitude that must change.

With the understanding that nanoparticulates cannot be seen when a worker enters the warm or hot zone of any cold fire scene (Figure 2), these nanoparticulates will be stirred up. They will attach to whatever the worker is wearing and, unless protected, the worker will also breathe them in. Another point to understand is that these nanoparticulates are present not only inside the structure. As the smoke from a fire rises, it cools and condenses into particulates, and they fall to the ground. As shown in Figure 2, the area of this warm zone varies depending on the wind speed and direction and includes the surrounding outdoor areas that are covered with these particulates.

By simply walking into the warm or hot zones of a cold fire scene, workers collect nanoparticulates on their clothing, exposed skin, footwear and in their hair. Unless protected, workers can then spread the nanoparticulates into their vehicle when leaving and at the next destination. This exposure continues and exposes family members, coworkers and others. This continued exposure is demonstrated in the video, "Bunker Gear Transfer: The Invisible Danger" (Harrison, 2018; **https://youtu.be/UFzP1rQJWSQ**).

When someone breathes in particulates, the larger ones (generally 10 microns or larger), are captured by the body's natural defenses and expelled. The smaller particulates are inhaled into the lungs and, therefore, can be a health hazard. The smallest particulates can penetrate deep into the lungs, all the way into the alveoli, and are potentially highly problematic for human health (Cimbala, 2014). Unfortunately, on average, most people can only distinguish objects down to about 70 microns with the naked eye, which is about the size of a single strand of hair. If the particulate reflects light, one might be able to see it down to about 10 microns (Cimbala, 2014). So, the most hazardous

FIGURE 1
RESPIRATORY SYSTEM



Note. Adapted from "Respiratory System Complete," by M.R. Villarreal [LadyofHats], 2007.

FIGURE 2
FIRE SCENE ZONES

Every fire scene is divided into zones.

Note. Adpated from *Fire Investigator Health and Safety Best Practices* (2nd ed.), by IAAI Health and Safety Committee, 2020. Photo from Google Earth.

particulates, the nanoparticulates, cannot be seen. But they are present nonetheless and are dangerous to human health.

Chronic exposure symptoms of disease typically do not present themselves for years. Leukemia can occur in as little as 3 years, while lung cancer can take as long as 30 years to appear (Burgess & Calkins, 2020). This is known as latency and is the reason that it is important to protect workers now to prevent illness that could arise in the future. When a person feels fine after an exposure, recognizing this danger and being proactive can be difficult.

The Solution

Establishing, following and enforcing scene safety protocols today can save lives in the future. The best way to accomplish this is through the proper use of PPE, especially respiratory protection, by every person entering the cold fire scene.

As discussed, walking through the scene, touching or moving any fire debris, digging or cleaning stirs up particulates and creates a health hazard for everyone present. The NIOSH (n.d.) hierarchy of controls is an approach to controlling exposures to occupational hazards that is the fundamental method of protecting workers. Unfortunately, most of these control methodologies are not adequate in the post-fire environment. As stated in the current edition of National Fire Protection Association 921 (2021), "Although generally considered one of the least effective control measures, wearing proper PPE may be one of the only available control measures due to the nature of fire investigations." This would apply to everyone else working in the post-fire scene as well.

Therefore, every person in the post-fire scene for any reason should wear the following PPE:

•Coveralls (preferably disposable and with a hood) that completely cover the arms, legs and head. Some variations are acceptable, but the goal is to cover as much of the body as possible.

•Disposable nitrile gloves and covered with disposable leather-palm gloves if the worker is touching or moving anything. These are single-use.

•Boots or shoes with a steel toe and puncture-resistant sole.

•Proper respiratory protection equipment, as further discussed below.

•Goggles or similar PPE to reduce the possibility of ocular absorption.

•Helmet with chin strap if there is any chance of material falling.

All of this PPE should be donned and doffed in the cold zone (Figure 2), away from any area where particulates may be, and packaged and sealed after use. The sealed package should be placed in the worker's trunk or truck bed so that nothing contaminated is in the vehicle's passenger area. There are two categories of contaminated items: those that go in the trash and those that are to be cleaned and reused. Disposing of the trash bag is simple, but it should not be left at the scene. However, when opening the bag containing items to be cleaned and reused, the worker must wear at least a respirator and nitrile gloves to protect themselves from the

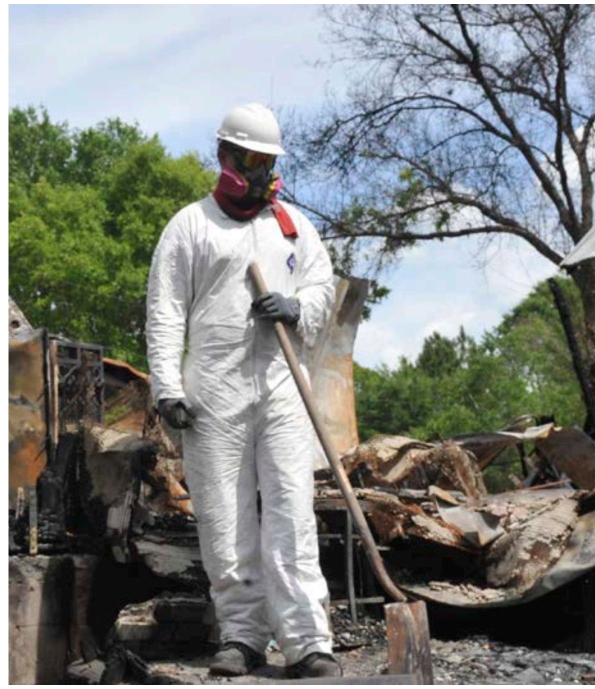

KEVEN B. HAYS FIRE CONSULTING LLC. USED WITH PERMISSION.

Photo 2: An example of a properly attired worker at a post-fire scene.

nanoparticulates that will be expelled. Detailed information on this process, as well as detailed decontamination and washing procedures, can be found in the IAAI (2020) white paper, "Fire Investigator Health and Safety Best Practices."

Respiratory Protection

In the U.S., OSHA regulations govern the need for and use of proper respiratory protection equipment. Respirators are required when adequate engineering controls are not feasible, while they are being instituted, or when controls cannot be effectively used to eliminate the hazard. OSHA also requires employers to provide employees with respirators that are applicable and suitable for the purpose intended when such equipment is necessary to protect the employee's health.

OSHA provides an online tool to help determine the proper respiratory equipment needed. One of the information subsets offered with this tool discusses the employer's responsibility to conduct an exposure assessment. Employers must make a reasonable estimate of the employee exposures anticipated to occur due to those hazards, including those likely to be encountered in reasonably foreseeable emergencies, and must also identify the physical state and chemical form of such contaminants. This includes identifying the respiratory hazards that could be present.

However, to use the OSHA respirator selection advisor software, it is imperative to know several workplace parameters, two of which are the OSHA permissible exposure limit and the maximum exposure level in the workplace of a single contaminant and its physical state. This, of course, requires identifying specific hazards, which, as discussed, is impossible in the post-fire environment. IAAI has identified the best level of respiratory protection in the cold post-fire scene. An N95 dust mask is not sufficient.

The IAAI-recommended respirator assembly for everyone while in the hot and warm zone of a cold post-fire scene is a half-mask facepiece that has a P100 particulate filter and goggles. For additional protection, or if a worker is there within 2 hours after extinguishment, an organic vapor/acid gas/formaldehyde gas/vapor cartridge should be added. Photo 2 (p. 23) shows a properly attired worker at a post-fire scene.

If the premise presented here—that a post-fire scene contains known respiratory hazards—is accepted, then all private employers in the U.S. are required by OSHA to have a written respiratory protection program and provide employees with proper respiratory protection equipment. A medical evaluation and fit test are necessary before use.

Conclusion

According to data from the U.S. Fire Administration, more than 1.3 million fires occurred in the U.S. in 2018. If we assume that three-quarters of these fire scenes receive one visit from one insurance agent or adjuster and two cleanup or demolition workers, that equates to nearly 3 million annual exposure episodes. How many of these are performed by the same people? How long do these people remain in each post-fire scene? How well protected were they?

The post-fire health hazards are real and present at every fire scene. Just because the hazard is not visible does not mean it is not there, so it is important to protect oneself and workers accordingly. When we know better, we need to do better. The life saved might be your own. **PSJ**

The post-fire health hazards are real and present at every fire scene. Just because the hazard is not visible does not mean it is not there, so it is important to protect oneself and workers accordingly.

References

Bolstad-Johnson, D.M. (2018). *Exposed: Carcinogenic exposures on the fireground and 11 work practices to minimize the risk.*

Bolstad-Johnson, D.M., Burgess, J.L., Crutchfield, C.D., Storment, S., Gerkin, R. & Wilson, J.R. (2000). Characterization of firefighter exposures during fire overhaul. *American Industrial Hygiene Association Journal, 61*(5), 636-641. https://doi.org/10.1080/15298660008984572

Brantom, P.G., Brown, I., Baril, M. & McNamee, R. (2018). Epidemiological literature review on the risk of cancer among firefighters (R-1012). Institut de recherche Robert-Sauvé en santé et en sécurité du travail (IRSST).

Burgess, J. & Calkins, M. (2020, Feb. 28). *Topic 4: Per- and polyfluoroalkyl substances (PFAS) in the fire service* [Conference session]. National Firefighter Cancer Symposium, Miami Gardens, FL, U.S.

CDC. (2020). Health effects of lead exposure. www.cdc.gov/nceh/lead/prevention/health-effects.htm

Cimbala, J. (2014, Feb. 28). Particles [Presentation slides]. Penn State University. www.me.psu.edu/cimbala/me405/Lectures/Slides_Particles.pdf

Fabian, T., Borgerson, J.L., Kerber, S.I., Gandhi, P.D., Baxter, C.S., Ross, C.S., Lockey, J.E. & Dalton, J.M. (2010). Firefighter exposure to smoke particulates. Underwriters Laboratories Inc. https://ulfirefightersafety.org/assets/EMW-2007-FP-02093-cef37283b5f736fe7dd535dcf26382e5b5b5d5e9118b28af6fed60ad0b6e6a.pdf

Fent, K.W., Eisenberg, J., Evans, D., Sammons, D., Robertson, S., Striley, C., Snawder, J., Mueller, C., Kochenderfer, V., Pleil, J., Stiegel, M. & Horn, G.P. (2013). Evaluation of dermal exposure to polycyclic aromatic hydrocarbons in fire fighters [Report No. 2010-0156-3196]. U.S. Department of Health and Human Services, CDC, NIOSH.

Harrison, T. (2018, Feb. 15). *Bunker gear transfer: The invisible danger* [Video]. YouTube. https://youtu.be/UFzP1rQJWSQ

International Association of Arson Investigators (IAAI) Health and Safety Committee. (2020). Fire investigator health and safety best practices (2nd ed.). www.iaaiwhitepaper.com

Mangelsdorf, I., Schröder, K. & Pinheiro, N.C. (2014). Environmental health criteria 242: Dermal exposure. World Health Organization, International Program on Chemical Safety. www.who.int/ipcs/publications/ehc/ehc_242.pdf

National Fire Protection Association (NFPA). (2021). Guide for fire and explosion investigations (NFPA 921). www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards/detail?code=921

Nelson, W. (2011). *Respiratory protection for fire investigators* [Capstone project]. Northern Arizona University.

New York State Department of Health (NYSDOH). (n.d.). Exposure to smoke from fires. https://health.ny.gov/environmental/outdoors/air/smoke_from_fire.htm

NIOSH. (2020). Hierarchy of controls. www.cdc.gov/niosh/topics/hierarchy/default.html

Park, J.-H., Lee, J.-W., Kim, Y.-C. & Prausnitz, M.R. (2008). The effect of heat on skin permeability. *International Journal of Pharmaceutics, 359*(1-2), 94-103. https://doi.org/10.1016/j.ijpharm.2008.03.032

Roberts, S.M., James, R.C. & Williams, P.L. (2015). *Principles of toxicology: Environmental and industrial applications* (3rd ed.). John Wiley and Sons.

Scott, B. & Scott, S. (2019). Lead contamination in structure fires. *Restoration and Remediation.* www.randrmagonline.com/articles/88641-lead-contamination-in-structure-fires

Semple, S. (2004). Dermal exposure to chemicals in the workplace: Just how important is skin absorption? *Occupational and Environmental Medicine, 61*(4), 376-382. https://doi.org/10.1136/oem.2003.010645

Villarreal, M.R. [LadyofHats]. (2007). Respiratory system complete. https://commons.wikimedia.org/wiki/File:Respiratory_system_complete_en.svg

Weiss, D.C., & Miller, J.T. (2011). A study on chemicals found in the overhaul phase of structure fires using advanced portable air monitoring available for chemical speciation. State of Oregon Governor's Fire Service Policy Council and Tualatin Valley Fire and Rescue.

Jeffrey L. Pauley is a nationally recognized expert on fire investigator safety and health. He is a partner and fire group manager at Pacific Pointe Consulting Inc., where he provides corporate training and policy development assistance regarding the post-fire environment. He also works as a fire investigator at EFI Global Inc. Pauley is chair of the IAAI Health and Safety Committee. He holds a B.S. in management studies from the University of Maryland and is pursuing an M.S. in Occupational Safety and Health from Columbia Southern University.