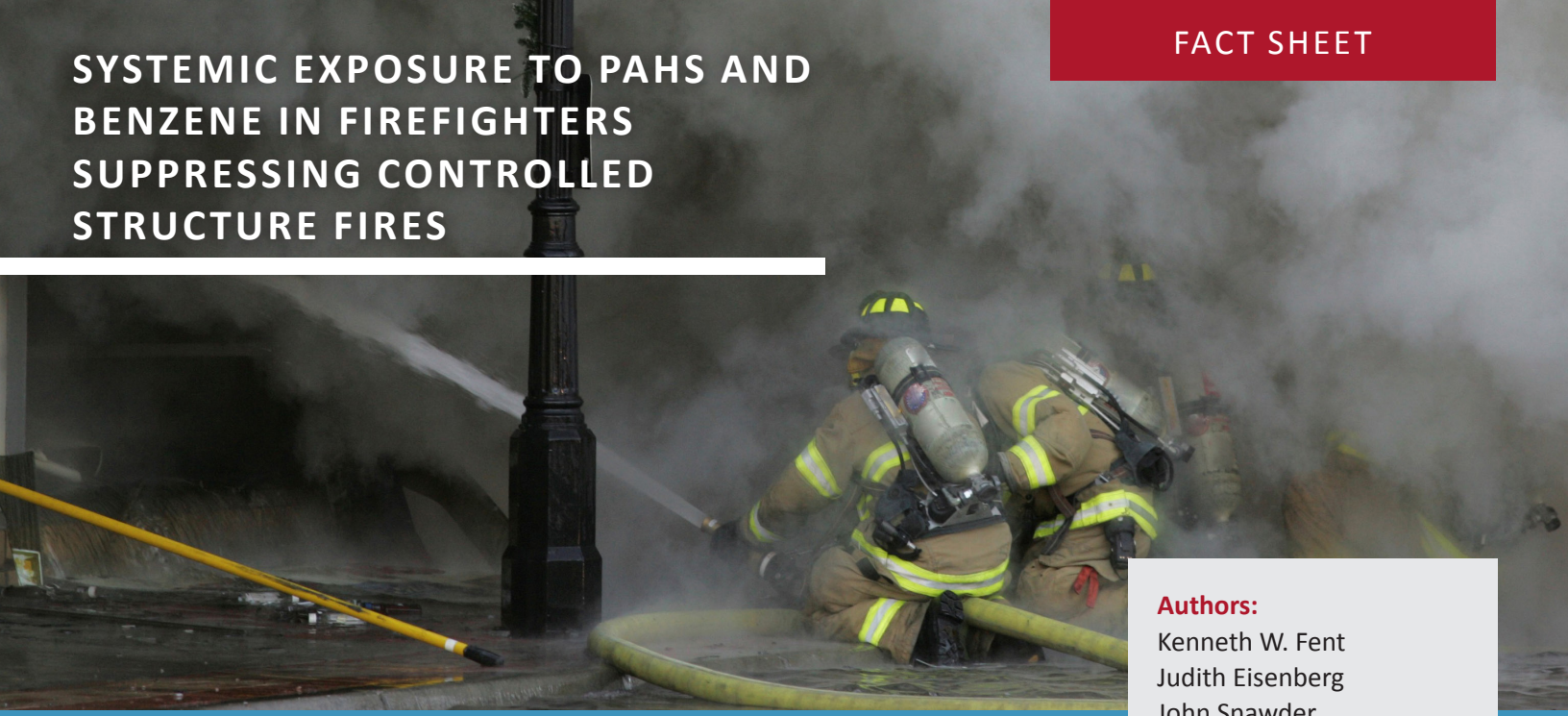
FACT SHEET

SYSTEMIC EXPOSURE TO PAHS AND BENZENE IN FIREFIGHTERS SUPPRESSING CONTROLLED STRUCTURE FIRES



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SUMMARY

Turnout gear provides protection against dermal exposure to contaminants during firefighting; however, the level of protection is unknown. This study explored the dermal contribution to the systemic dose of polycyclic aromatic hydrocarbons (PAHs) and other aromatic hydrocarbons in firefighters during suppression and overhaul of controlled structure burns.

Polycyclic aromatic hydrocarbons (PAHs) are components of incomplete combustion that can exist in both particle and gas phase. “Of the 18 PAHs that are commonly produced during fires, the International Agency for Research on Cancer (IARC) classified benzo[a] pyrene as carcinogenic to humans (Group 1) and eight others as probably or possibly carcinogenic to humans (Group 2A or 2B) (IARC 2002 , 2010). In addition to PAHs, nearly all fires will produce other potentially carcinogenic aromatic hydrocarbons such as a benzene (IARC, 2012)”.

The results of this study found:

- Firefighters wearing full NFPA compliant protective ensembles (recently washed or brand new) absorbed combustion products into their bodies.
- Statistically significant positive correlations between personal air concentrations of PAH (external exposures) and :
  - Change in urinary PAH metabolite levels (biomarkers) in Round 1, and
  - Change in breath concentrations of benzene in Round 2.

Combined, these results suggest that firefighters, wearing full protective ensembles, may still absorb combustion products into their bodies. The PAHs most likely entered firefighters’ bodies through their skin, with the neck being the primary site of exposure and absorption due to the lower level of skin protection afforded by hoods.

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FSTAR is managed by the International Association of Fire Chiefs and is funded by a FEMA/AFG/Fire Prevention and Safety grant award.

FINDINGS

Key findings of this study include:

- Significantly elevated ($P < 0.05$) post-exposure breath concentrations of benzene compared with pre-exposure concentrations for both rounds.
- Statistically significant positive correlations between external exposures (personal air concentrations of PAHs) and biomarkers (pre- to post-exposure change in urinary PAH metabolite levels in Round 1 and breath concentrations of benzene in Round 2).
- The dermal exposure data suggest that the neck skin was the most exposed part of the firefighters' bodies.
- Across firefighters, a ranking of the change in PAH levels on the neck from lowest to highest corresponds with the same ranking of the change in urinary PAH metabolite levels.
- Aromatic hydrocarbons can be:
  - absorbed through the skin during firefighting,
  - inhaled due to poor adherence in wearing full protective ensembles too close to exposure site, or
  - inhaled from off-gassing contaminated gear as this can occur for several minutes after a response.

The chart below explains the firefighter exposure times for each of the controlled burns. Each burn simulation looked at the total time of each scenario, including active fire, fire control, and overhaul operations. The period of active fire was intended to simulate a typical interior attack where firefighters would be exposed to products of combustion. For the first set of fires, firefighters took a stationary position (standing or squatting) in the target room. In the second set of fires, firefighters were mobile and rotated working positions during the burns. The simulated activities included searching for victims, pulling down a ceiling, and taking a break at the back of the structure.

Round/fire scenario	Day/ burn	Exposure times by response phase (min)			
		Active fire	Knock down	Over haul	Total
ROUND 1. Timber-framed structure, drywall interior, 33 m^3 burn room, 33m^3 target room, firefighters wre mostly stationary, hoods shorter than in round 2, exercises involving wood smoke also took place at the training facility.	1	10	1	4	15
	2	11	3	16	30
	3	15	7	7	29
ROUND 2. Intermodal metal container, drywall interior, 15 m^3 burn room, 35 m^3 target room, firefighters were mobile and rotated positions (except for nozzle-man and company officer)	1	10	2	8	20
	2	10	3	5	18
	3	10	4	4	18

Source: www.ncbi.nlm.nih.gov/pmc/articles/PMC4124999/#CIT0005

TAKEAWAYS

- PAHs and benzene generated by the fires were absorbed into the firefighters' bodies even when wearing NFPA compliant structural firefighting PPE throughout the scenarios.
- Material of hoods provides less protection than bunker coat and pants. Furthermore, the neck has some of the thinnest skin on the body. Thinner skin absorbs contaminants faster than thick skin.
- Overall, higher external exposures (measured in air or on skin) appeared to be related to higher biological levels (measured in breath or urine) of combustion byproducts.
- Further study on hood design, turnout gear decontamination methods, and firefighters' absorption of combustion products through the skin during fire responses is warranted.
- This study used clean gear. If the gear had been unclean, it is likely that there would be higher dermal exposure levels to the hands and arms.
- To lessen exposure:
  - Wear SCBA throughout external suppression and overhaul.
  - Doff SCBA last after firefighting.
  - Keep contaminated/off gassing gear segregated from firefighters during rehab.
  - Air out gear before return trip to station and do not transport contaminated gear in apparatus or POV passenger compartment during return to station.
  - Air out structures before overhaul or investigation, and wear SCBA while exposures are likely.

FIRE STATION TALK

Firefighters need to understand the benefits of receiving annual physicals. Annual fire service specific medicals can provide a baseline for comparison in the event that an exposure was suspected. Firefighters should also consider self-documenting construction type, materials, actions, and conditions during the fire response. This may be the only information available to isolate an exposure that causes injury of illness in the future.

- All PPE has limitations. Do you understand the function and necessary maintenance of your PPE?
  - How often do you check the fit of your turnouts to reduce your exposures?
  - How well do the interfaces in your PPE overlap? Particularly your hood and bunker coat?
- In this study, PAH levels on the neck corresponded to a change in urinary PAH metabolite levels.
  - Does that change your perception about how toxins in the air can be metabolized into your body?
  - Knowing that hoods provide less protection and that some of the thinnest skin on the body is at the neck, a clean hood should be used every shift and/or after a major exposure. How clean is your hood?
  - The study found that hoods that were longer or secured down provided better protection. Are you taking the necessary time to making sure your hood is securely tucked down and not leaving points of exposures? Is your hood long enough?
- Contaminated gear is a concern due to both transfer/dermal absorption and off-gassing/inhalation of aromatic hydrocarbons. What can you do, as a crew, to reduce these exposures?
  - How conscious are you about how close to the incident you are before removing your protective gear?
  - Knowing that gear can off-gas after exiting a scene, always keep your gear in open ventilated area.
  - Never bring your gear into station living areas, to your home, or store in your personal car unless it has been decontaminated and cleaned.
- Participants of the study had lower PAH readings than in other studies because they had to avoid second-hand tobacco smoke and abstain from eating char-grilled foods for two days prior to the start of the study, and had at least one day off from firefighting activities.
  - Does this information change your perceptions of what your PAH readings might be based on your lifestyle and number of fire responses?
  - Do you understand NFPA 1500 and 1851? What is your responsibility?

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CONSIDERATIONS FOR CHIEFS

Department leaders should consider the following:

The results of this study suggest that firefighters, wearing full protective ensembles, may still absorb combustion products into their bodies. Develop procedures to help firefighters manage and limit these exposures.

- There are multiple NFPA guidelines to assist with use and care of PPE
  - NFPA 1500, Standard on Fire Department Occupational Safety and Health Program - Chapter 7 Protective Clothing and Protective Equipment
  - NFPA 1851, Standard on Selection, Care, and Maintenance of Protective Ensembles for Structural Fire Fighting and Proximity Fire Fighting
  - NFPA 1852, Standard on Selection, Care, and Maintenance of Open-Circuit Self-Contained Breathing Apparatus (SCBA)
  - NFPA 1971, Standard on Protective Ensembles for Structural Fire Fighting and Proximity Fire Fighting - Chapter 8
  - NFPA 1981, Standard on Open-Circuit Self-Contained Breathing Apparatus (SCBA) for Emergency Services
- PPE Safety and Training: Does your department conduct regular inspections of turnouts for possible rips and tears that could provide sources of exposure?
  - NFPA 1851, Chapter 6 provides inspection requirements
  - Set up turnout inspections at the start of each shift.
  - To better understand the limitations of PPEs, every firefighter should receive a copy, or have one made available electronically, of the manufacturer's PPE Usage Instruction and Safety Guide.

CONSIDERATIONS FOR CHIEFS (continued)

- Are there protocols for washing protective gear on a regular basis – especially after possible high exposure incidents?
  - NFPA 1581, Chapter 7 provides cleaning requirements.
  - Set up protocols to wash hoods after responses or at least at the end of shift.
  - Is there a way to provide everyone more than one hood to reduce re-exposures to the neck, which has been shown to be one of the highest exposure sites?
  - Can your department support a hood exchange program?
- Review your protocol for rehab placement to include exposure due to off-gassing.
  - Is there ongoing training to ensure members do not remove gear (face piece, helmet, hood, gloves) too soon after after they exit the IDLH?
  - Consideration of a rehab location, even during simple training exercise, needs to be addressed to help reinforce the importance of exposure prevention.
  - Stress the importance of skin cleaning during rehab. Contaminants can be removed from the neck with skin wipes. Hands should be thoroughly cleaned, particularly if eating hand-held items such as fruit, sandwiches, snack bars or other common rehab foods.
  - Share and emphasize new research regarding the need for full protective gear during all phases of an incident, including post-incident (fire watch/overhaul), to your members.
- Based on possible accumulative PAH levels in firefighters (as well as other potential carcinogens), and the known links to cancer, should the number of consecutive shifts be a staffing consideration?
  - Are fire-hours and fire-runs being tracked to mitigate possible overexposures?
  - Is exposure reporting an easy process for your members?
  - What can be done to support firefighters proactively tracking their fire-hours and fire-runs?

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TERMS

Metabolite - usually refers to small molecules produced during metabolism; also represents building block of a larger structure or a degraded product destined for excretion.

PAHs - Polycyclic Aromatic Hydrocarbons - are a group of semi-volatile organic compounds from products like heavy oils, coal tar, roofing tar, or creosote.

Benzene - is a colorless, flammable liquid with a sweet odor.

Aromatic Hydrocarbons - a hydrocarbon that contains one or more benzene rings that are characteristic of the benzene series of organic compounds.

Benzene, benzine, benzol - a colorless liquid hydrocarbon; highly inflammable; carcinogenic; the simplest of the aromatic compounds.

Biomarkers - are key molecular or cellular events that link a specific environmental exposure to a health out come.

Overbreathing - overbreathing occurs when the firefighter requires more air than the SCBA's regulator can supply. When the inhalation rate exceeds the supply rate, the pressure in the mask can temporarily become negative, and combustion products could enter through any leaks (see Burgess)

STAY IN THE KNOW

Read the research, start the discussion.

Additional resources and tools for this study can be found at www.fstaresearch.org/resource/?FstarId=11476.