

Field Exposure Assessment Design: Ambient Distribution of Toxic Metal Aerosols in Firefighter Live-Fire Training Structures

Yi-Hsuan (Amelia) Chen, PhD, Juan M. Alvarez, Xinyi Niu, Jooyeon Hwang, PhD*, UTHealth Houston, School of Public Health

Take Home Messages:
Severe Particle Exposure
Upper-Floor Toxic Metal Risk
Unprotected Exterior Inhalation Hazard

"We cannot protect what we do not measure"
Exposure assessment reveals the unseen toxic hazards firefighters breathe, transforming hidden fireground risks into actionable strategies to prevent occupational cancer.



Background and Rationale

- Evaluating acute firefighter toxicant exposure in real-world emergencies is severely limited by unpredictable fire dynamics and baseline chronic exposure clutter (Fent et al., 2022; Goldfarb et al., 2023).
- Firefighting smoke contains complex aerosol mixtures including heavy metals classified as **IARC Group 1, 2A, and 2B** human carcinogens.
- Live-fire training creates a **controlled, reproducible setting** to examine ambient aerosol movement and airborne exposure limits.
- This study aims to **characterize ambient heavy metal aerosol distributions** across a live-fire training structure to identify peak inhalation hazard zones and establish a biobanking framework to link external particle exposures with internal dose kinetics.

Study Design - Field Setting

- Location:** Houston Fire Department Val Jahnke Training Facility (VJTF)



Figure 1. Two-Story Concrete Live-Fire Building.



Figure 2. Live-burn material: wood and pallet

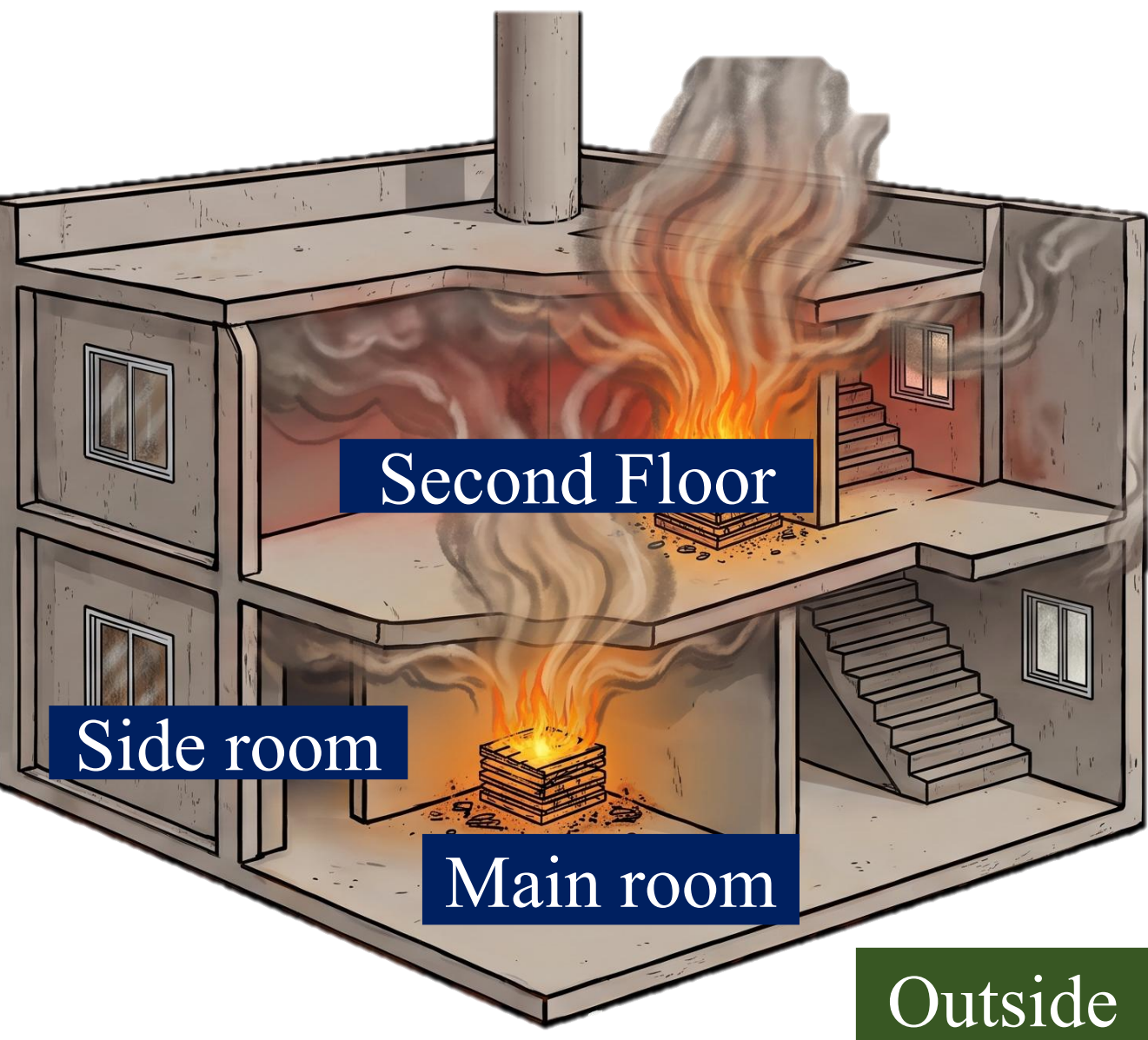


Figure 3. Four sampling area (1st Floor Main Room, 1st Floor Side Room, Second Floor, and Outside)

Reference

- Fent, K. W., et al. (2019). *Journal of Exposure Science & Environmental Epidemiology*.
- Goldfarb, D. G., et al. (2023). *Occupational and Environmental Medicine*, 80, 104–112.

Study Design – Aerosol Exposure Investigation

Exterior Monitoring



Figure 4. Outdoor: Direct-reading real-time instruments. The location was selected with the on-site HFD commander to minimize training disruption and identify the downwind direction.

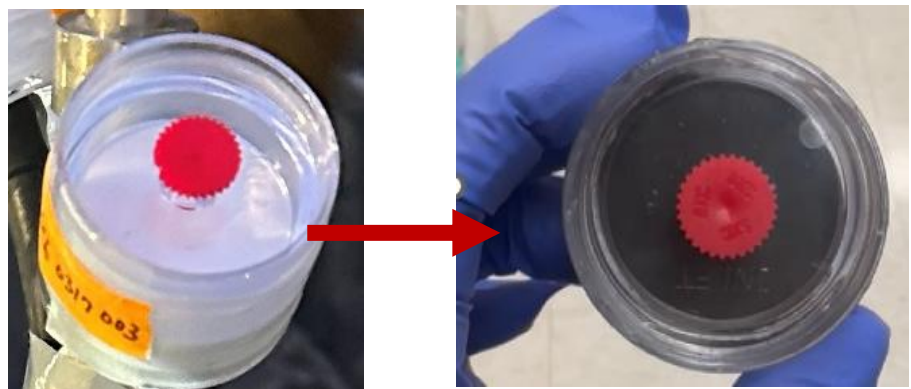
Indoor Monitoring



Figure 5. Indoor: Mixed Cellulose Ester (MCE) membrane samplers. The stations were positioned approximately 200–250 cm from the fire source. Each sampler was covered with turnout gear to protect it from high temperatures.

Filter Sample Analysis

- MCE membrane: gravimetric + toxic metals analysis
 - ✓ Inductively coupled plasma mass spectrometry (ICP-MS) analysis for toxic metals.
 - ✓ 25 elements were analyzed via ICP-MS and grouped according to IARC classifications.
 - ✓ Group 1 (Cr, Ni, As, Cd), Group 2A (Pb, Co), and Group 2B (V, Ti) metals.



- Rapid Particulate Loading:** Membranes exhibited heavy, dark particulate accumulation within just 10 minutes of live-fire exposure.

Results and Key Findings

- Live-fire training causes extreme particle spikes:** dust mass concentrations peaked at 225.8 mg/m³ on the second floor, exceeding OSHA and ACGIH limits by up to 45 ×.

Figure 6. Filter-based particle mass concentrations by location during live-fire training vs. occupational exposure limits.

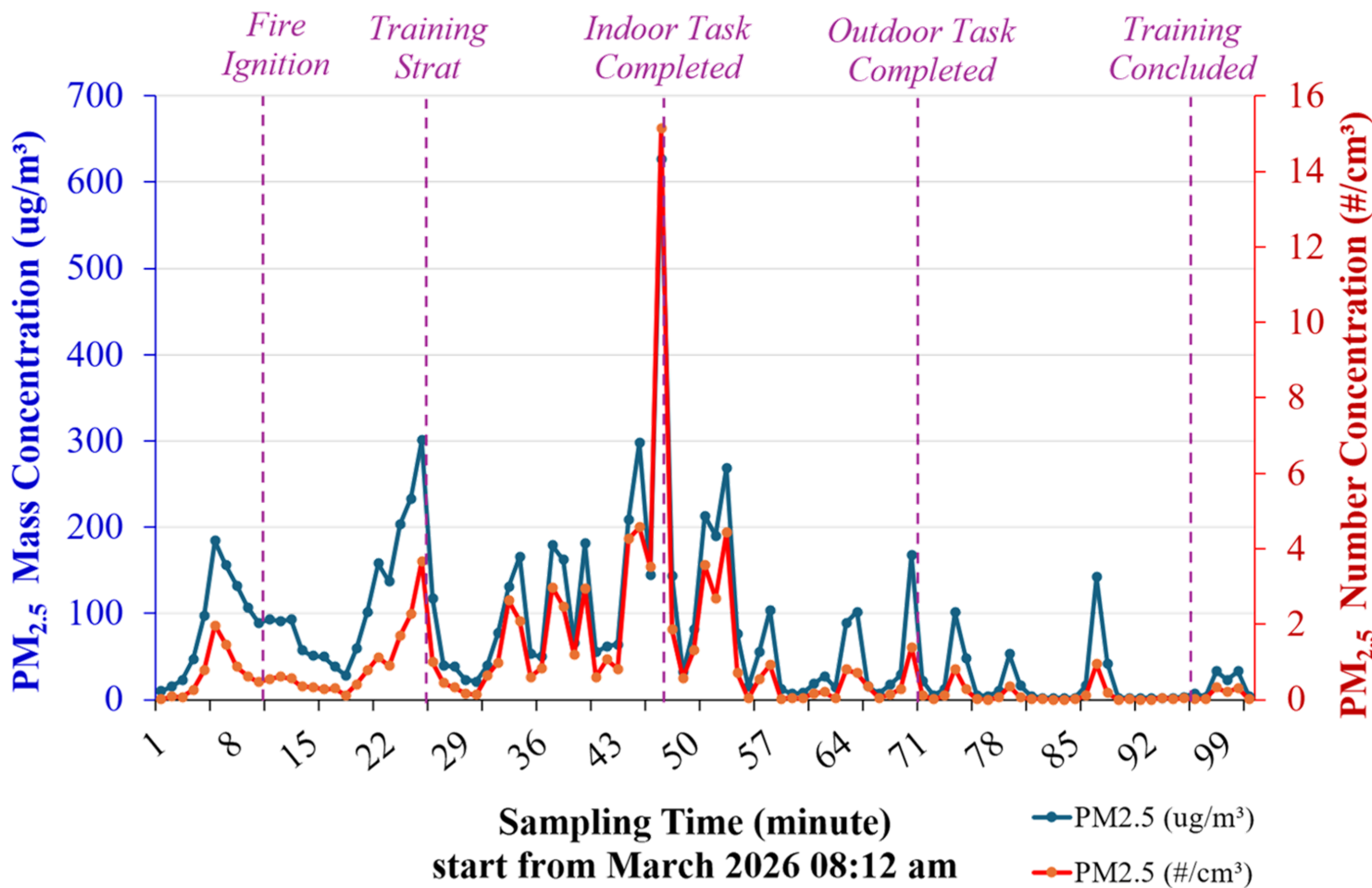
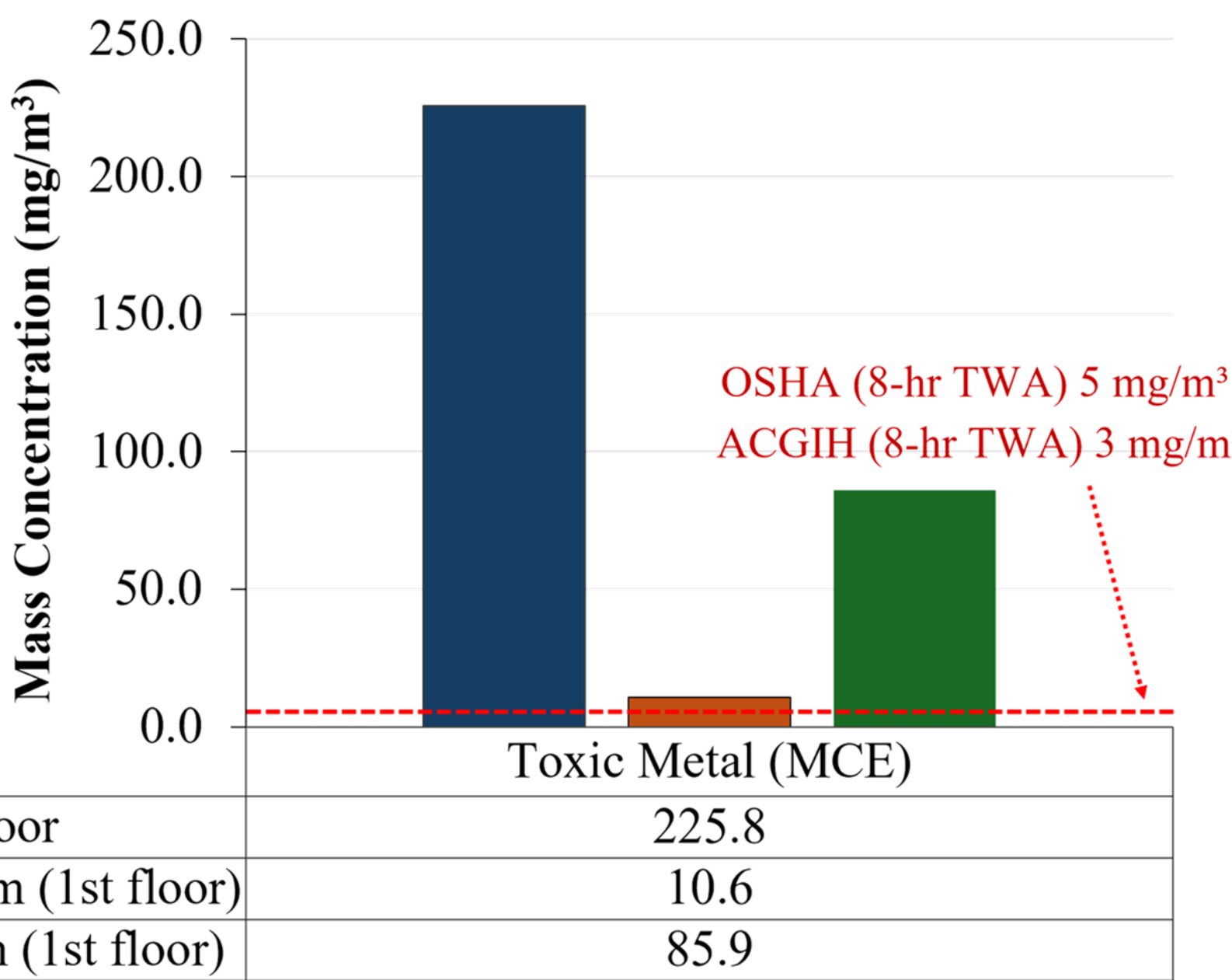
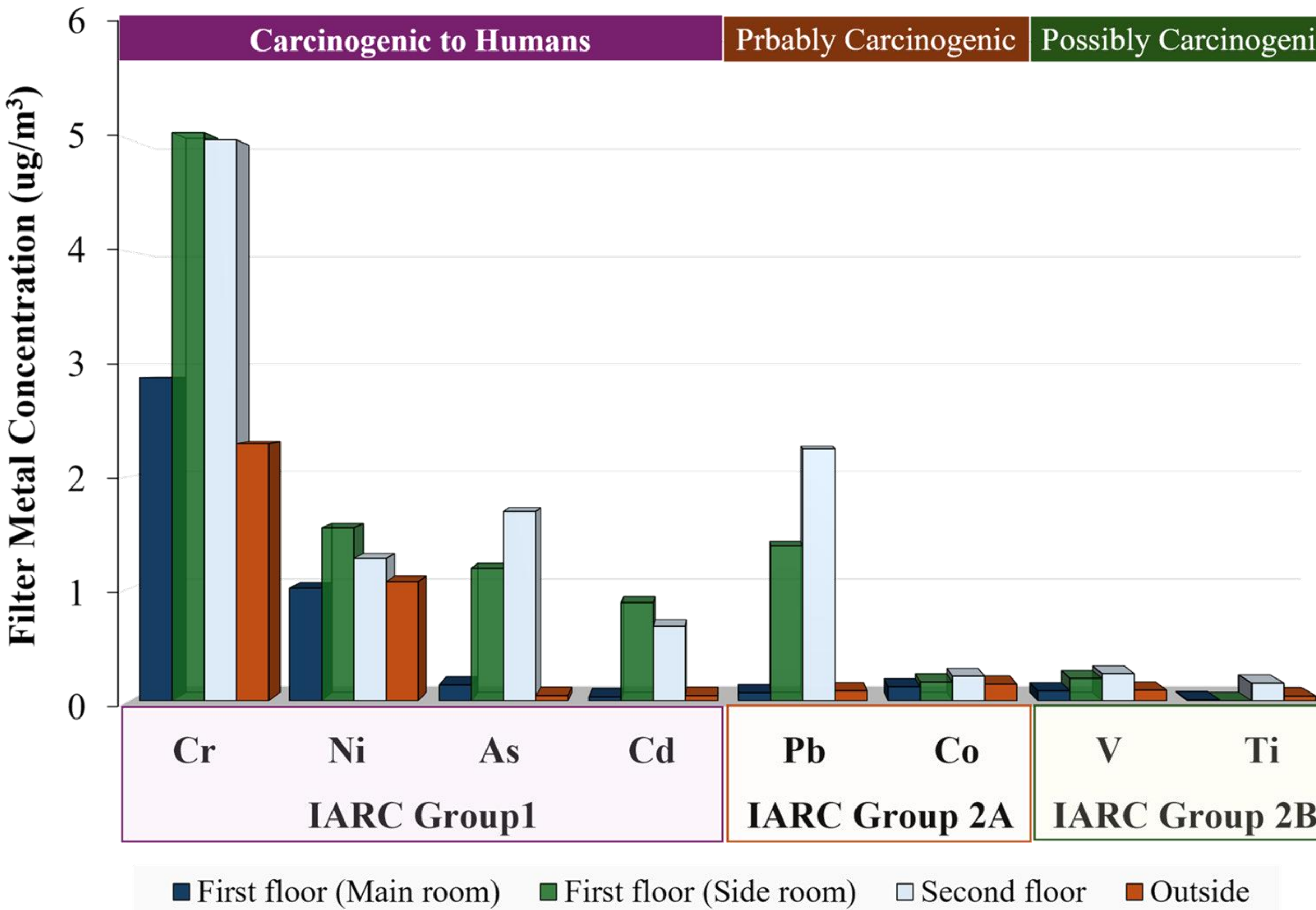


Figure 7. Real-time exterior PM_{2.5} mass (mg/m³) and particle number (#/cm³) concentrations during HFD VJTF live-fire training evolutions.

- Real-time exterior monitoring** reveals sharp PM_{2.5} spikes (300 μg/m³) outside the structure, posing acute inhalation hazards to staging personnel and cadets without SCBA during active burn phases.

Figure 8. Airborne metal levels across sampling locations by IARC carcinogen group



- Toxic Metal Accumulation:** Live-fire smoke drives high levels of **IARC Group 1 carcinogens**, dominated by Cr (~5 μg/m³) and causes second-floor peaks in Pb (~2.3 μg/m³) and As (~1.7 μg/m³), significantly exceeding outdoor and main-room baselines.

Acknowledgement



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