Working in Smoke: Protecting Wildland Firefighters in an Extreme Environment

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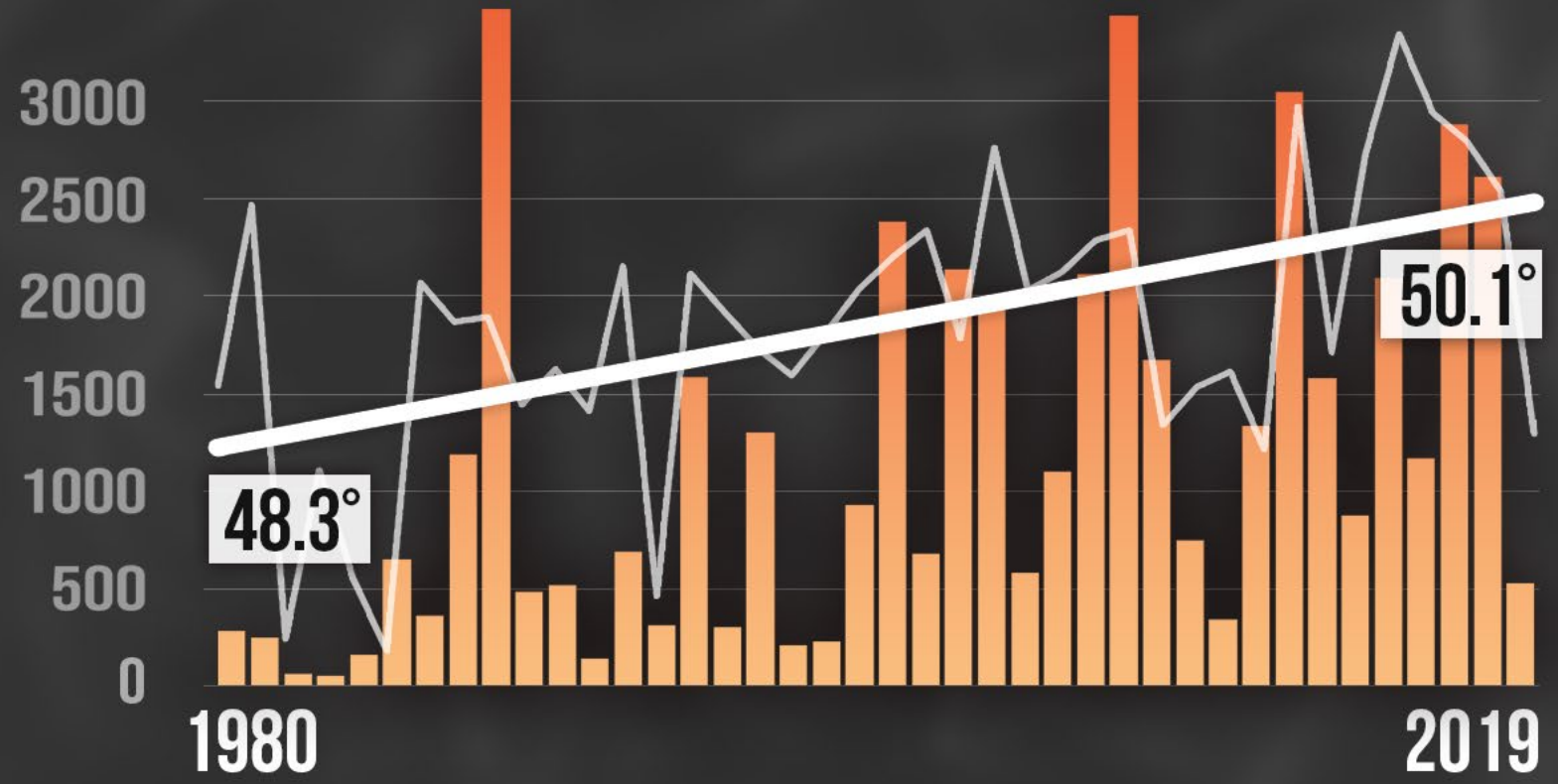
Office of Wildland Fire

HOTTER YEARS, HIGHER FIRE RISK

ACRES BURNED ACROSS WESTERN STATES

(THOUSANDS OF ACRES)

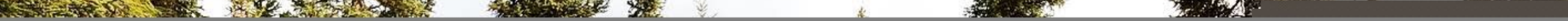


Total acres burned in the west calculated by summing acres burned across 11 states: AZ, CA, CO, ID, MT, NV, NM, OR, UT, WA, & WY. Avg annual temps (1980-2019) calculated by averaging temps across same states. Source: National Fire & Aviation Management FAMWEB Data Warehouse & NOAA/NCEI's Climate at a Glance

CLIMATE CENTRAL

Wildfire

Prescribed Fire (Rx)



Burning out

Mop-up

Routes of Exposure

- Ingestion
- Inhalation
- Absorption

Ingestion

- Mop up – ash
- Dusty hikes
- Ash, dirt, and fuel on hands

Photos by Kari Greer

Inhalation

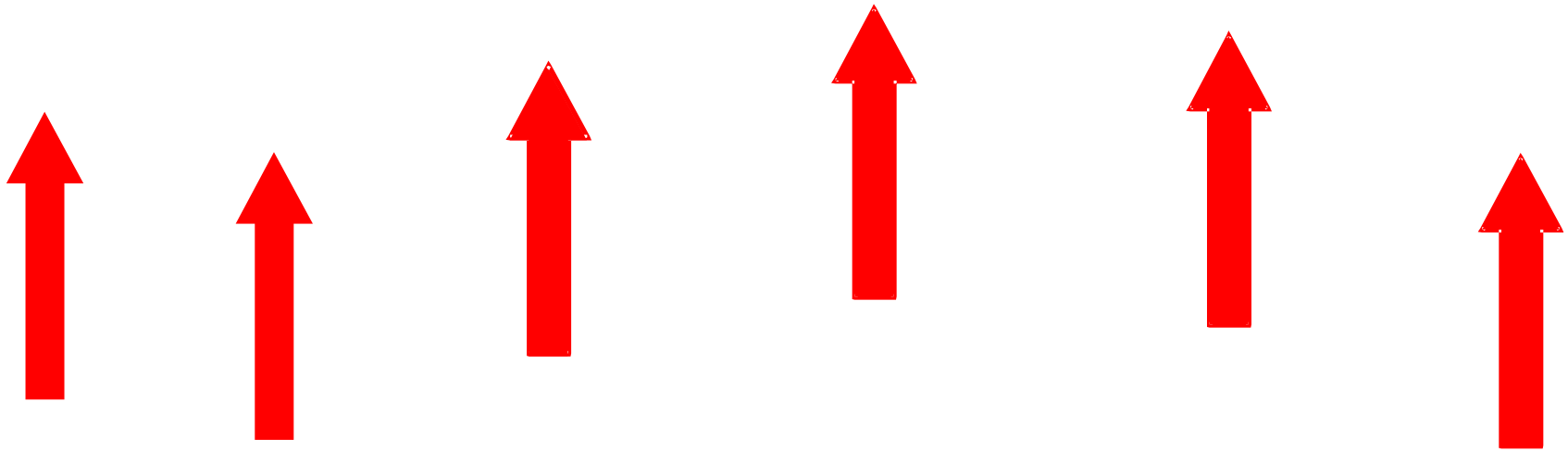
- Burning vegetation
- Smoke from ignition devices
- Dust and ash
- Long duration exposure to smoke in fire camps

Photos by Kari Greer

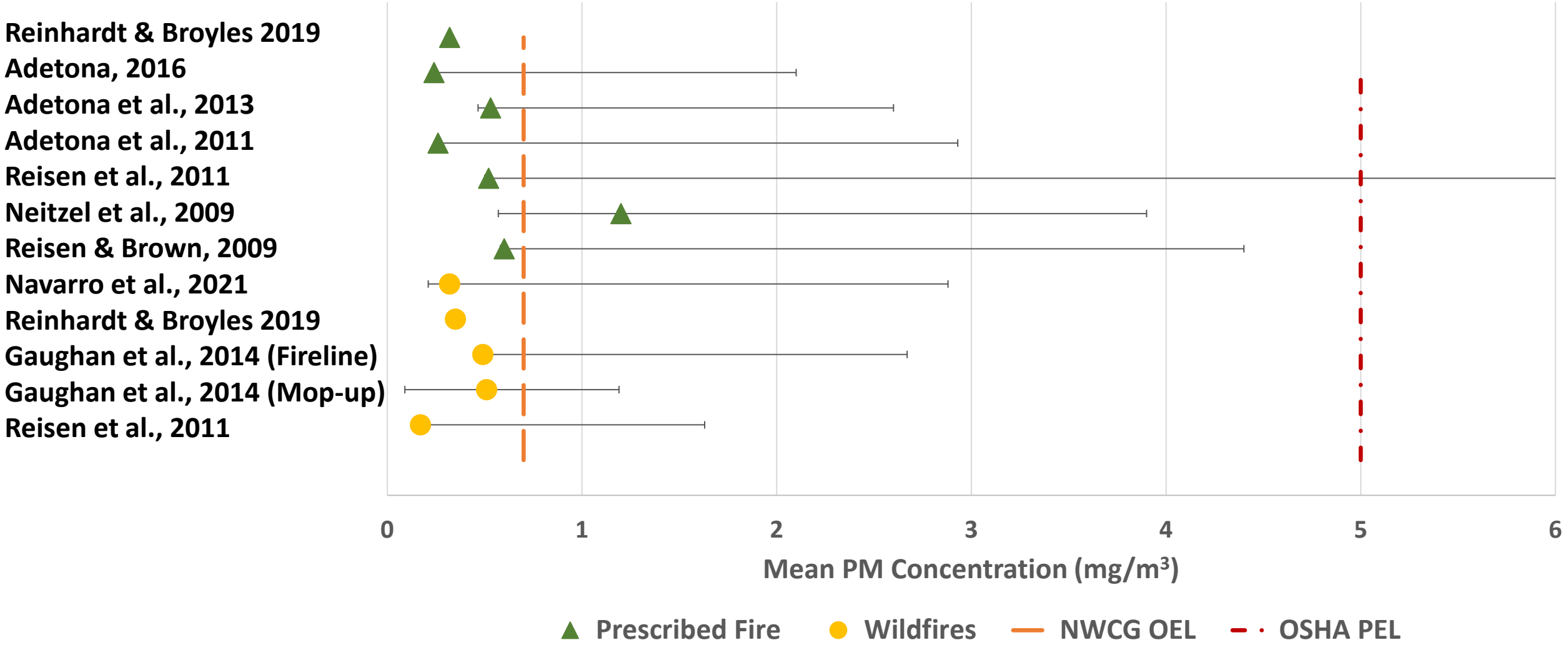
Absorption

- Contaminated fire clothes which can contain oil, gas, smoke and ash particles
- Sooty legs, face/neck, hands/wrists
- Gear stored in vehicles

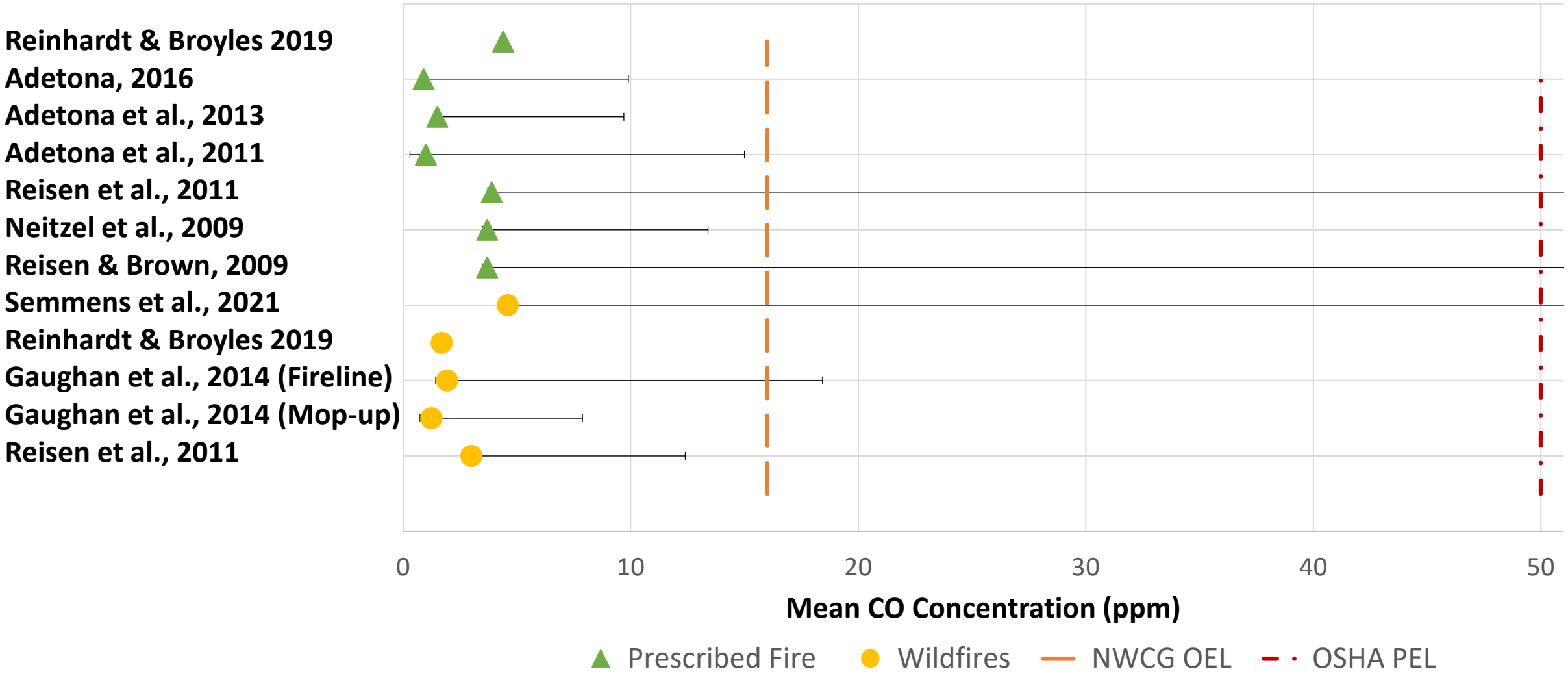
Photo by Kari Greer



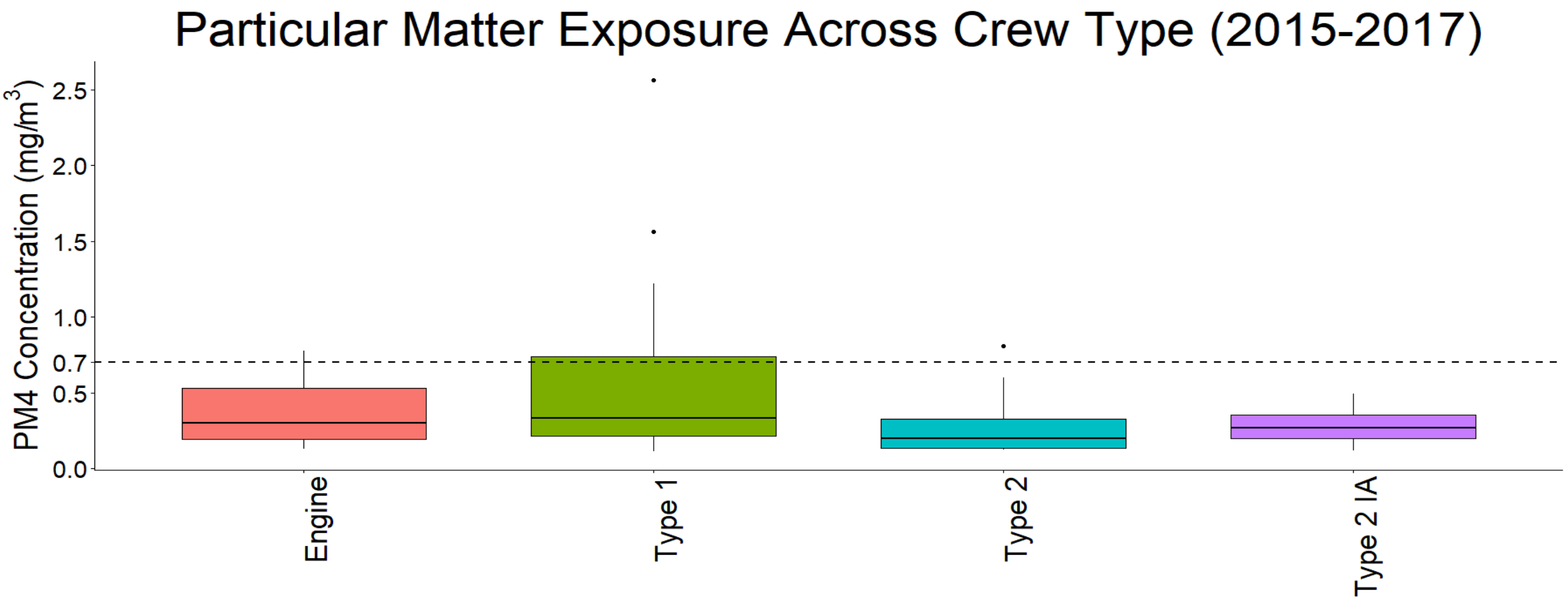
Recent $PM_{2.5-4}$ Exposure Assessments



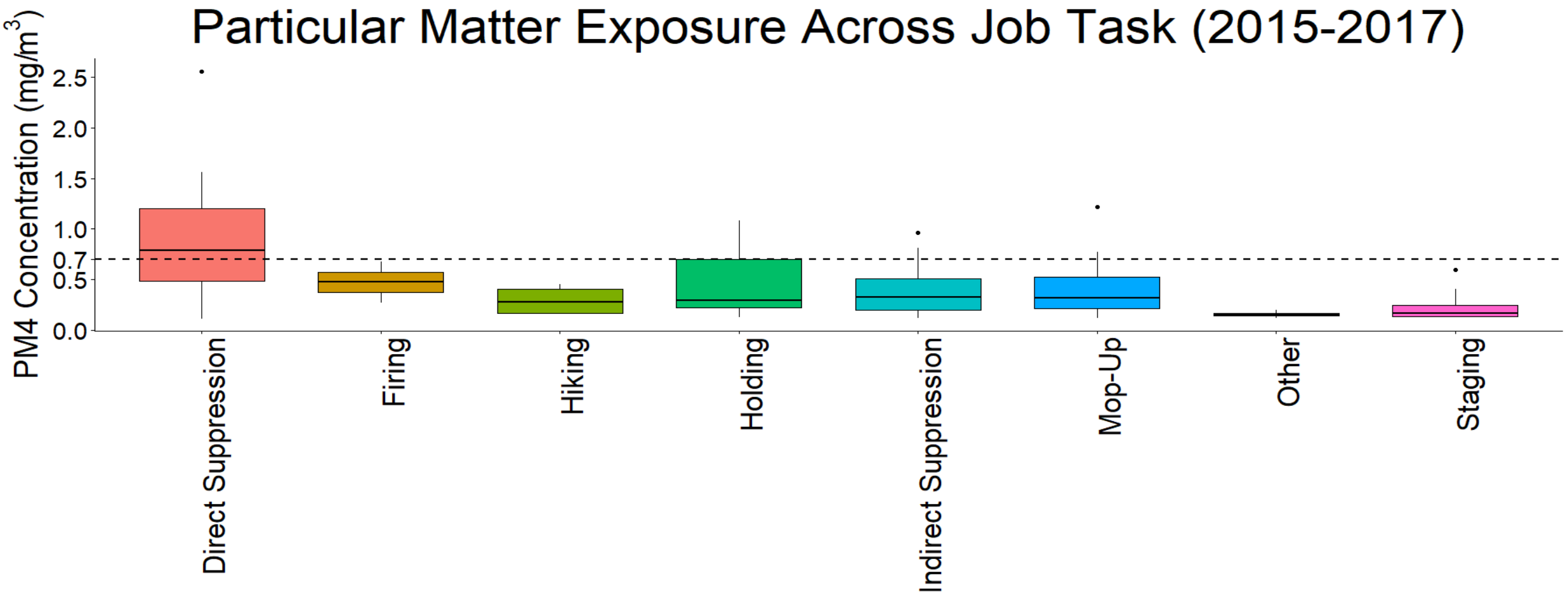
Recent CO Exposure Assessments



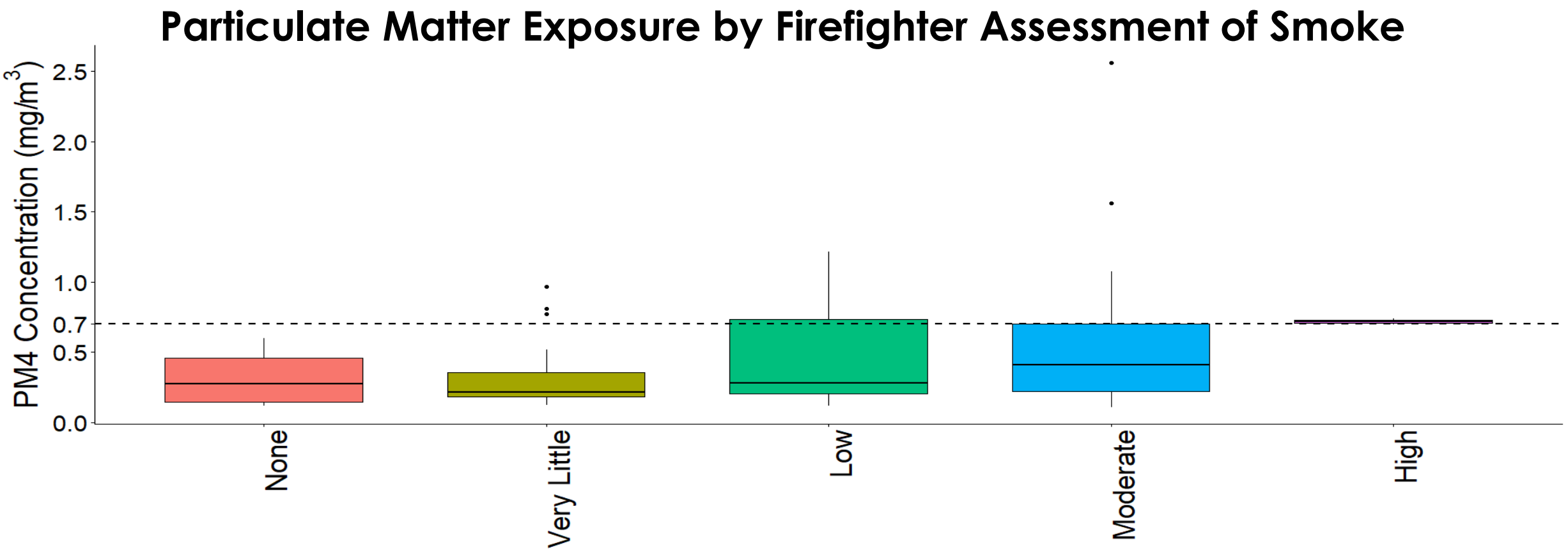
Results - Across Crew Type



Results - Across Job Task



Results - Firefighter Smoke Assessment



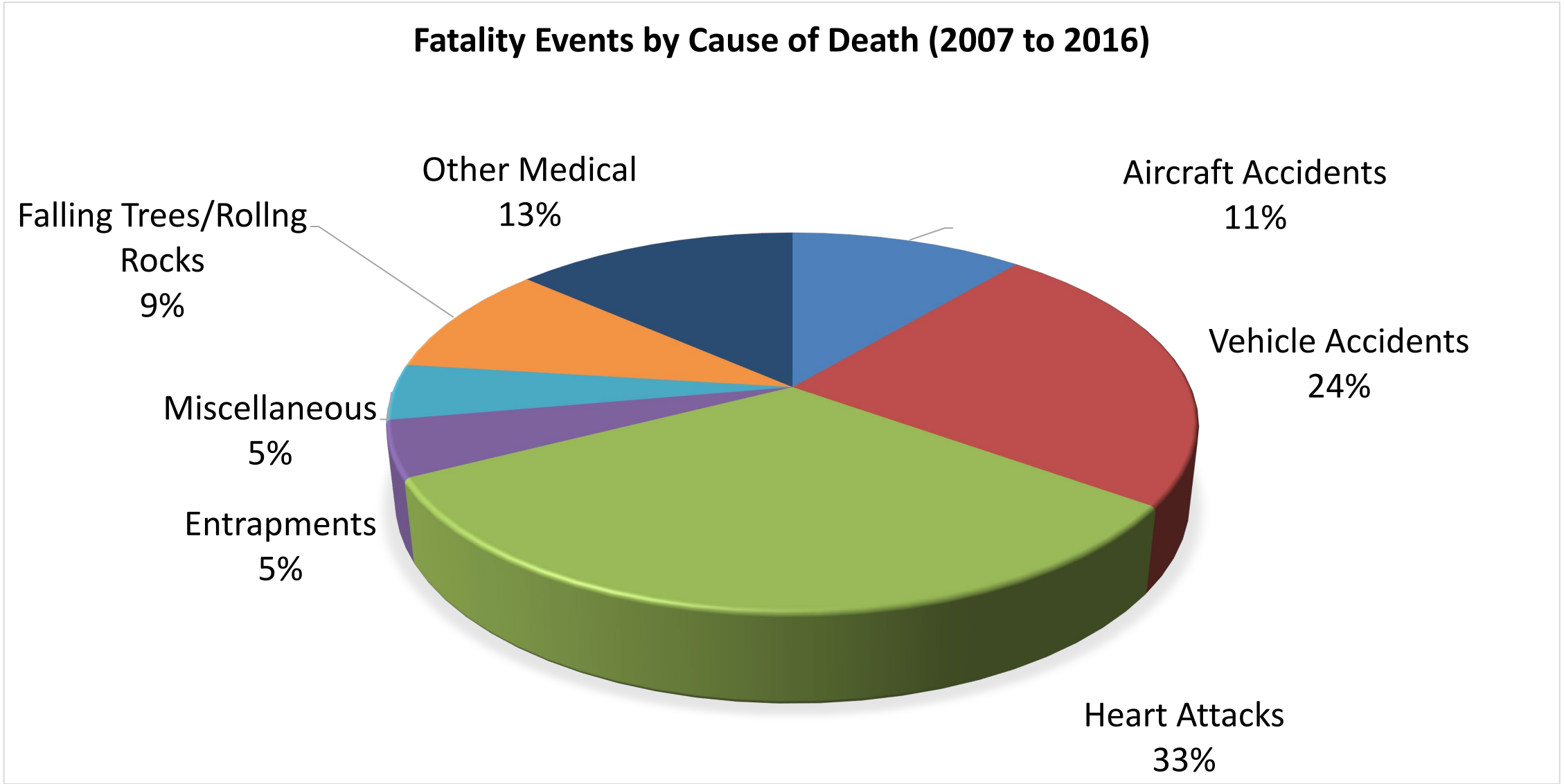
Health Effects From Research

- **Cross-shift and fire season**
  - Respiratory outcomes
  - Inflammation and Oxidative Stress
- **Long-term Health Effects**
  - Years of firefighting associated with hypertension and arrhythmias
  - Estimated risk of lung cancer and cardiovascular disease

Pre/Post Season Health Assessments

- Liu et al. 1992
  - Airway response ↑
  - Lung Function
    - Mean FVC, FEV1, FEV25-75 ↓
- Gaughan et al. 2008
  - Mean FEV1 ↓
  - Upper and lower respiratory symptom score ↑
  - Neutrophilic and eosinophilic inflammation ↑

National Wildfire Coordinating Group
10-yr Fatality Report



International Agency for Research on Cancer

World Health Organization

IARC MONOGRAPHS VOL 132: OCCUPATIONAL EXPOSURE AS A FIREFIGHTER

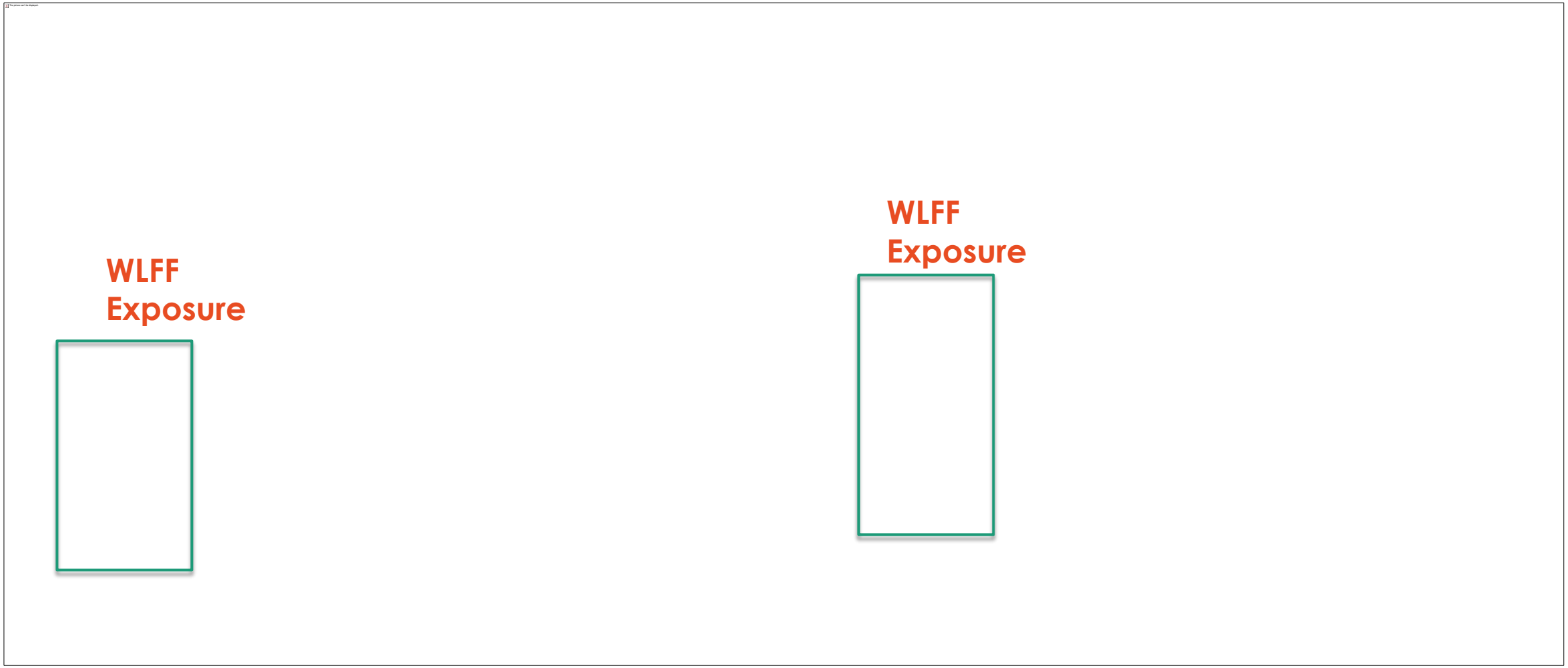
Long-Term Health Risk

Navarro et al. 2019

Estimate lifetime risk of lung cancer (LC) and cardiovascular disease (CVD) from exposure to particulate matter from smoke.

- Exposure-response relationships
- Field Measurements
  - PM_4
  - Heart Rate

Exposure – Response – Pope III et al. 2011



Methods

Estimation of Mortality Risk (Pope et al., 2011)

$$RR = 1 + \alpha(dose)^{\beta}$$

$$Daily\ dose\ PM_4(mg) = Exposure\ Concentration\left(\frac{mg}{m^3}\right) \times Breathing\ Rate\left(\frac{L}{min}\right) \times Daily\ Shift\ Duration\left(\frac{hrs}{shift}\right) \times F$$

F – Frequency of exposure =($\frac{shift\ days\ per\ year}{365\ days\ per\ year} \times \frac{years\ of\ firefighting\ career}{45\ years}$)

WLFF Risk Assessment – Methods

$$Dose = Conc. x\ BR\ x\ Shift\ x\ F$$

Exposure Scenario	Shift Exposure (mg/m^3)	Breathing Rate (LPM)	Shift Duration (hours)	Fire Days (Days/ Year)	Career Duration	PM_4 Daily Dose (mg)
Short Season	0.5	24	13.6	49	5	0.15
					10	0.30
					15	0.45
					20	0.60
					25	0.74
Long Season				98	5	0.30
					10	0.60
					15	0.89
					20	1.19
					25	1.49

WLFF Risk Assessment - Results

Exposure Scenario	Career Duration	Excess Risk (%)	
		LC	CVD
Short Season 49 fire days/ year	5	8	16
	10	13	19
	15	18	22
	20	22	23
	25	26	25
Long Season 98 fire days/ year	5	13	19
	10	22	23
	15	29	26
	20	36	28
	25	43	30

Systematic Review

Identification of studies via databases

Keywords

Firefighter, fire fighter, fire personnel, occupational exposure

AND

Wildfire, wild fire, wildland fire, forest fire, woodland fire, brush fire, bush fire, bushfire, grass fire, prescribed fire, prescribed burn, vegetation fire, vegetative fire, wood smoke, woodland smoke, biomass smoke

AND

Cancer, neoplasm, tumor, malignant, carcinogen, cardio, heart, respiratory, lung, health, disease, illness, inflammatory, inflammation, mutagenicity, urine, blood, biomarker, biomonitor, biological monitor, derma, toxic, exposure, adverse effect, stress, hypertension, mortality, morbidity, risk, hazard, aerobic, metabolic

Records Identified (N = 1836) → **Duplicate Records Removed (N=921)**

Title and Abstract Screened → **Full Reports Reviewed (N= 109)**

Studies included in review (N=49)

Data Extracted

Study Location	Sampling Type and Timeframe	Sample Size
Occupational Setting (WF/Rx)	Mean Concentration	Range, Min, Max

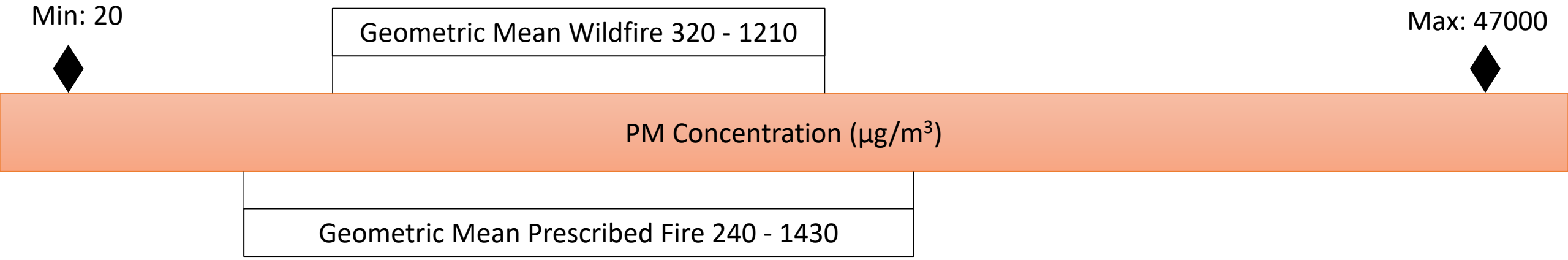
Chemical Class	Chemical Measured	IARC Classification
Particulate Matter (PM)	PM_{10}	1
	PM, respirable	1
	PM, total	1
Polycyclic Aromatic Hydrocarbons (PAHs)	Anthracene	2B
	Benz[a]anthracene	2B
	Benzofluoranthenes	2B
	Benzo[b]fluoranthene	2B
	Benzo[j]fluoranthene	2B
	Benzo[k]fluoranthene	2B
	Benzo[a]pyrene	1
	Chrysene	2B
	Cyclopenta[c, d]pyrene	2A
	Dibenzo[a,h]anthracene	2A
	Indeno-1,2,3-[cd]pyrene	2B
	Naphthalene	2B
Metals	Arsenic	1
	Beryllium	1
	Cadmium	1
	Chromium	1
	Lead	2A-inorganic
	Nickel	1
Volatile Organic Compounds (VOCs)	Acetaldehyde	2B
	Acrolein	2A
	Benzene	1
	Ethylbenzene	2B
	Formaldehyde	1
	Styrene	2B
Other	Asbestos (all forms)	1
	Carbon black (total)	2B
	Radioactivity	1
	Silica (Quartz and Cristobalite)	1

Particulate Matter (PM)

26 papers reported $PM_{2.5}$, $PM_{respirable}$, PM_{10}

Area samples > Personal Samples

3 Individual Samples > OSHA PEL



Volatile Organic Compounds

Mean Ranges Reported (ppm)

- Benzene: <LOD – 10.21
- Formaldehyde: 0.006 – 0.21
- Acrolein: 0.001 – 0.015
- Acetaldehyde: 0.02 – 0.05
- Styrene: 0.23 – 1.8

Polycyclic Aromatic Hydrocarbon (PAHs)

Air
(N=12)
Geometric Mean
(ng/m^3)

Naphthalene (personal)

Wildfire: 91 - 3189
Prescribed Fire: 669 - 6170

Benzo(a)pyrene

Personal: 5 - 15
Prescribed Fire: 3 - 185

Urine
(N=8)
1-hydroxypyrene
Ng/g creatinine

Pre-shift

57 - 313

Post-shift

101 - 576

Skin
(N=2)
Naphthalene

Measured on:
Hand
Throat
Chest

Post-Pre Difference

Cherry et al. 2021 ($ng\ wipe^{-1}$)
Hands: 0.98
Throat: 1.28

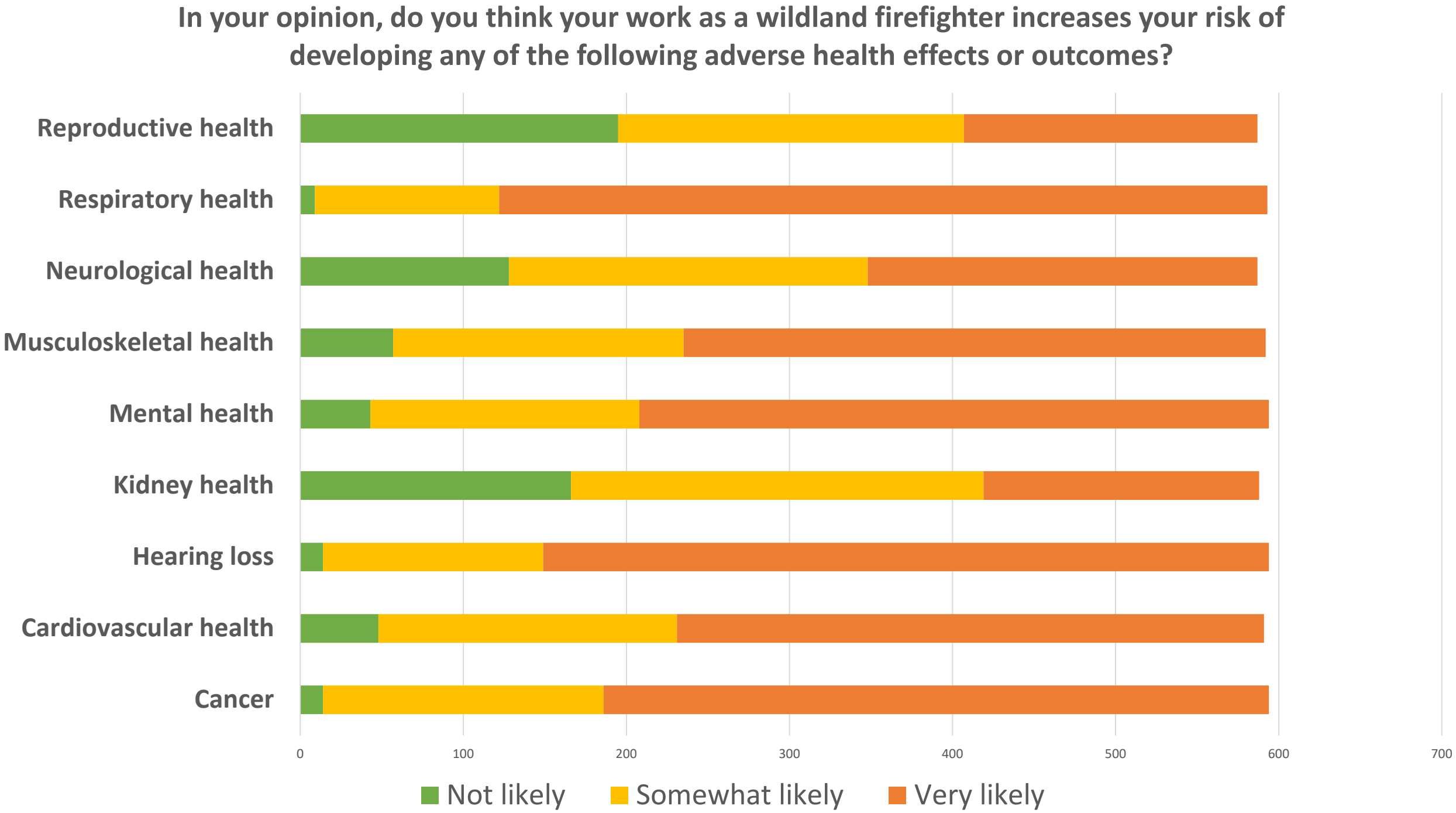
Cherry et al. 2022 (1-NAP ng/ml)
Total: 1.37

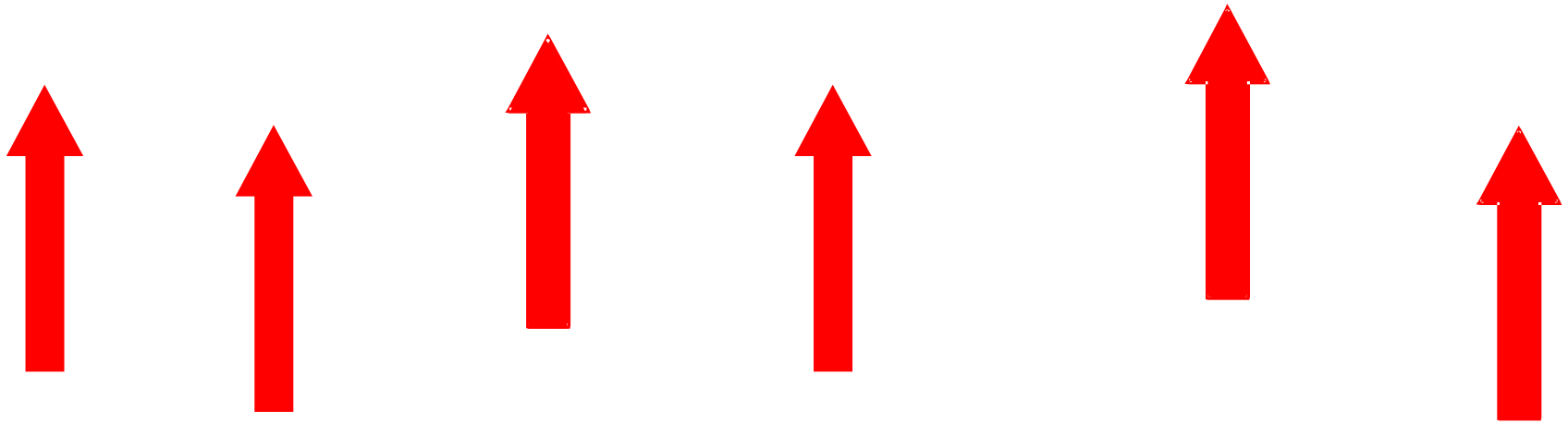
Other Carcinogen Exposures

- 1% arsenic, 8 % chromium and 52% of nickel above NHANES in urine
- Reinhardt & Broyles 2019 reported ~ 30% of silica samples
- Asbestos (naturally occurring and contamination) has been measured.
- Radionuclides measured in Chornobyl and Belarus exclusion zone, Lisbon, and outside Los Alamos Lab, NM
- Four papers reported black carbon exposures. None above OELs

Summary of Results

- 49 studies identified 31 carcinogens
- Shift exposures are highly variable
- Particulate matter is the most studied
- Skin hygiene can reduce absorption of carcinogens


In your opinion, do you think your work as a wildland firefighter increases your risk of developing any of the following adverse health effects or outcomes?
Reproductive health
Respiratory health
Neurological health
Musculoskeletal health
Mental health
Kidney health
Hearing loss
Cardiovascular health
Cancer
0
100
200
300
400
500
600
700
Not likely
Somewhat likely
Very likely



Mitigation Recommendations

- Minimize mop-up
- Limit shift length
- Rotate crews out of heavy smoke areas and high exposure tasks
- Develop fire-specific OELs
- Locate ICPs and other camps out of smoky areas
- Skin Hygiene

H.R.3684 - Infrastructure Investment and Jobs Act

The Secretary of the Interior and the Secretary of Agriculture shall—

(A) develop and adhere to recommendations for mitigation strategies for wildland firefighters to minimize exposure due to line-of-duty environmental hazards.

(B) establish programs for permanent, temporary, seasonal, and year-round wildland firefighters to recognize and address mental health needs, including post-traumatic stress disorder care.

National Defense Authorization Act FY23

Sec. 5305 Fairness for Federal Firefighters

- Presumptive illness coverage
  - Cancer
  - 24hr post incident cardiac/stroke

- Comprehensive long-term health study
  - Exposed to fires, smoke, and toxic fumes
  - Race, ethnicity, age, gender, and time in service
  - Recommendations for legislative action to prevent health effects from toxic exposure
  - Annual report

Table 1. Conditions Presumed to be Employment-Related for Federal Firefighters

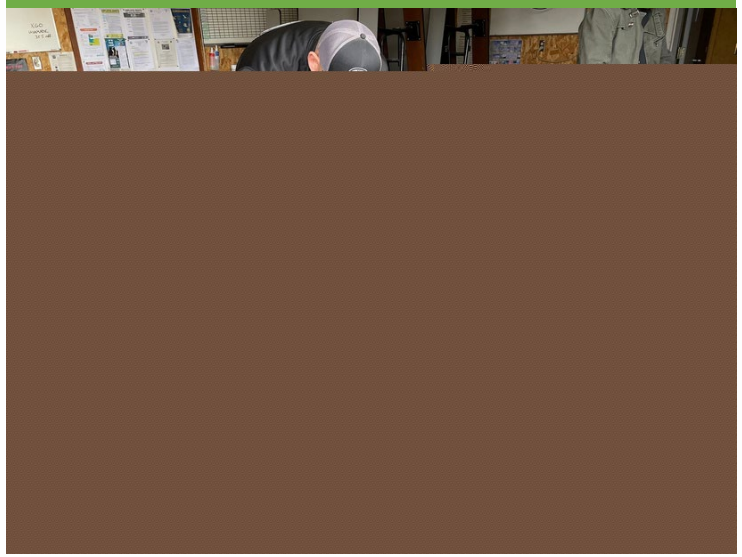
Cancers		
Bladder cancer	Brain cancer	Colorectal cancer
Esophageal cancer	Kidney cancer	Leukemias
Lung cancer	Mesothelioma	Multiple myeloma
Non-Hodgkin lymphoma	Prostate cancer	Skin cancer (melanoma)
Testicular cancer	Thyroid cancer	
Other Conditions		
Chronic obstructive pulmonary disease	Sudden cardiac event or stroke within 24 hours of engaging in firefighting activities	

Federal Wildland Firefighter Health & Wellbeing Program

Behavioral Health

Physical Health & Readiness

Environmental & Occupational Health



Research Partnerships

Medical and Public Health Advisory Team

Evaluation process for requesting access to DOI/USFS Firefighter participants

Assess projects for:

- Alignment with research priorities
- Reduce/prevent disruption of ops
- Reduce duplication and research fatigue

Projects will be evaluated and connected with possible participants

Open for applications twice per year (spring and fall)

Research Challenges and Gaps

- Dynamic environments
- Lack of knowledge on long-term risks
- Non-smoke exposures
- Occupational limits for smoke
- Mitigations and exposure reduction
- Cumulative exposure and stressors

Considerations

- What research and applied practices can we learn and benefit from?
- What motivates us to make changes in our behaviors?
- What small changes in our culture can lead to significant health benefits?

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Department of the Interior, Office of Wildland Fire

Questions?