Mitigation Strategies for Wildfire Smoke and Other Respiratory Hazards in Wildland Firefighting

Drew Lichty

Introduction – Who Am I?

- UBC Occupational and Environmental Hygiene Class of 2023
- BCWS Co-Op Student (Summer 2022)
- Canada Wildfire Occupational Hygienist (May 2023)
- Collaborates closely with the BCWS Research & Innovation Business Area

Introduction – Research & Innovation

- A 5–7-person team established in 2018 to strengthen and modernize the BC Wildfire Service's approach to fighting fire.
- Health, wellness, and safety of BCWS staff has been a core theme since the program's inception.

Health, wellness, and safety of BCWS staff

Wildland fire science

Social / human behavioural research

Equipment and technology

Agenda

The wildland fire environment

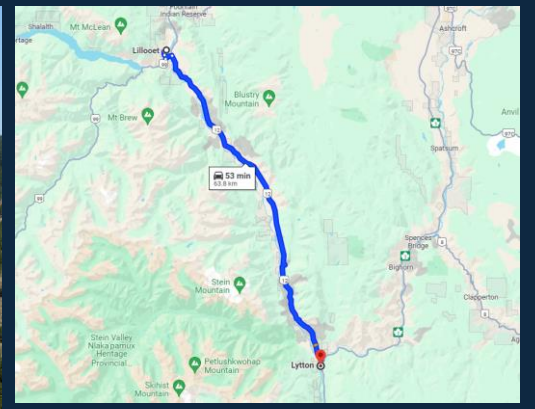
What are the exposures of concern & how are wildland firefighters exposed?

What does the research say regarding exposure levels?

What are we doing to control exposure?

The Fire Camp

- Remote
- Limited facilities
- Staff rest, eat, sleep, and work here
- Ambient wildfire smoke exposure



The Fireline

- Extremely Remote
- No Facilities
- Ambient wildfire smoke
- Point source wildfire smoke
- Ash, dust, and engine exhaust

Section 2: What are wildland firefighters exposed to?

What characteristics of the fireline impact how, and when they are exposed?

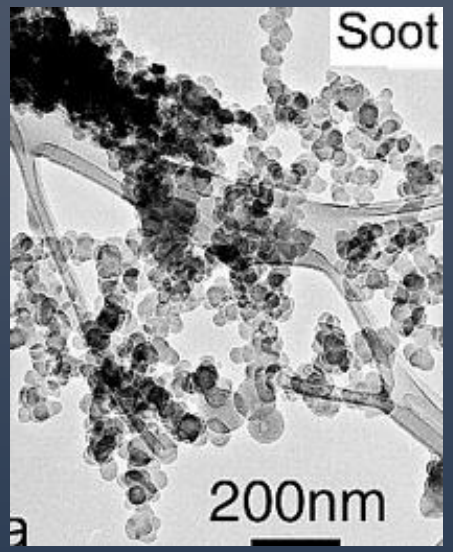

PM
SOx
PAHs
Wildfire Smoke
VOCs
NOx
CO

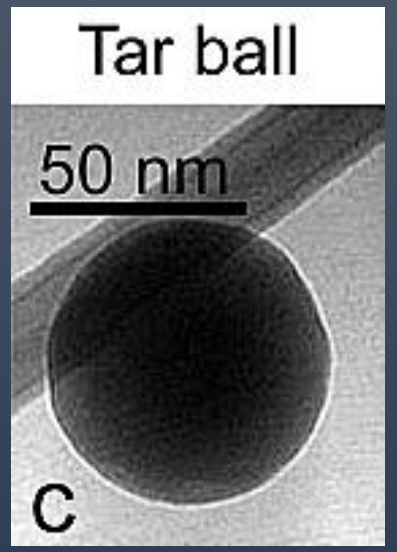

Silica
Ash, Dust, and Soot
Dermal PAH
PM

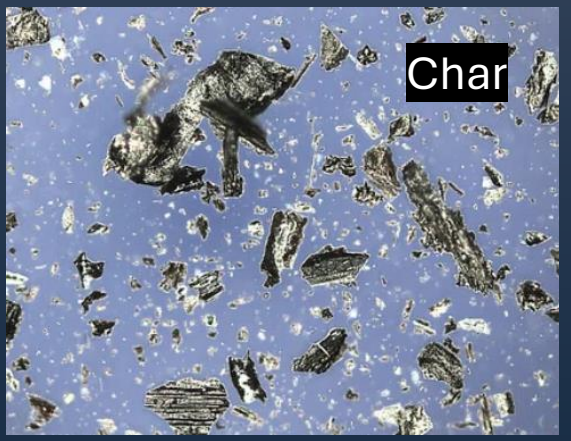

PM
350
41
4
16
4
4
PAHs
Engine Exhaust
VOCs
NOx
CO

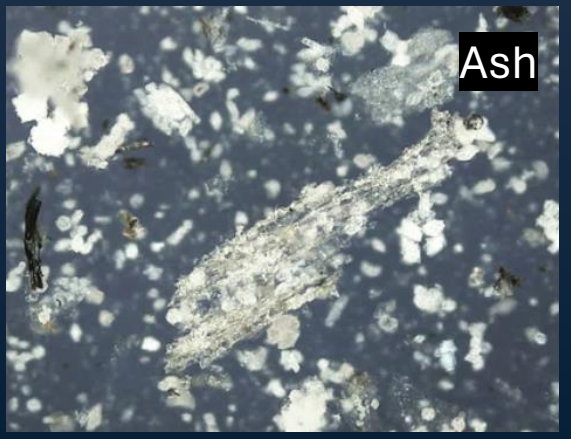
Wildfire Smoke Particulate Matter

- Mostly in the sub-micron range (<0.3 um) consisting of:
  - **Soot/Black Carbon**
  - **Tar Balls**
  - **Char**
  - **Ash**
- Wildfire smoke PM induces local and systemic inflammation, oxidative stress, and cytotoxicity and **may be more toxic than other sources of ambient PM2.5** (1,2).



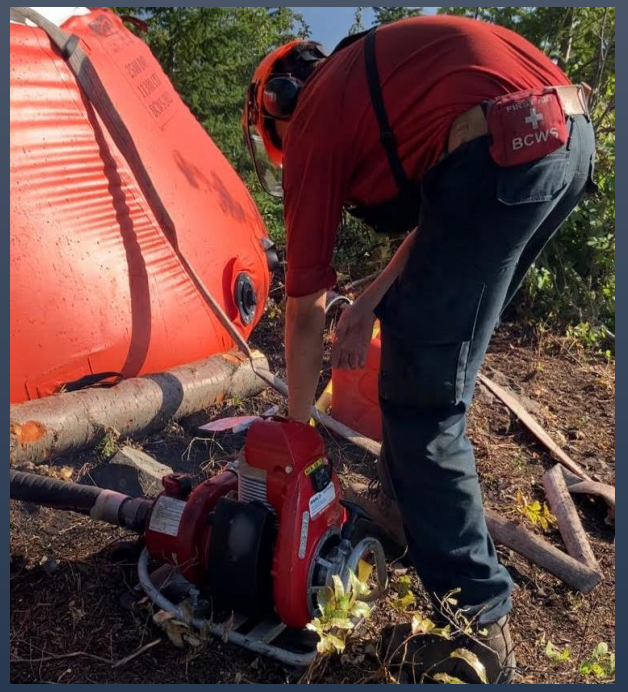






Carbon Monoxide

- An **invisible & odourless** gas in wildfire smoke and engine exhaust.
- **Chronic, low-moderate exposure (5-10 ppm)**
  - Fatigue, Reduced exercise tolerance, headache, nausea
- **Short term high exposure (300-500 ppm+)**
  - Confusion, Dizziness, Collapse, Death

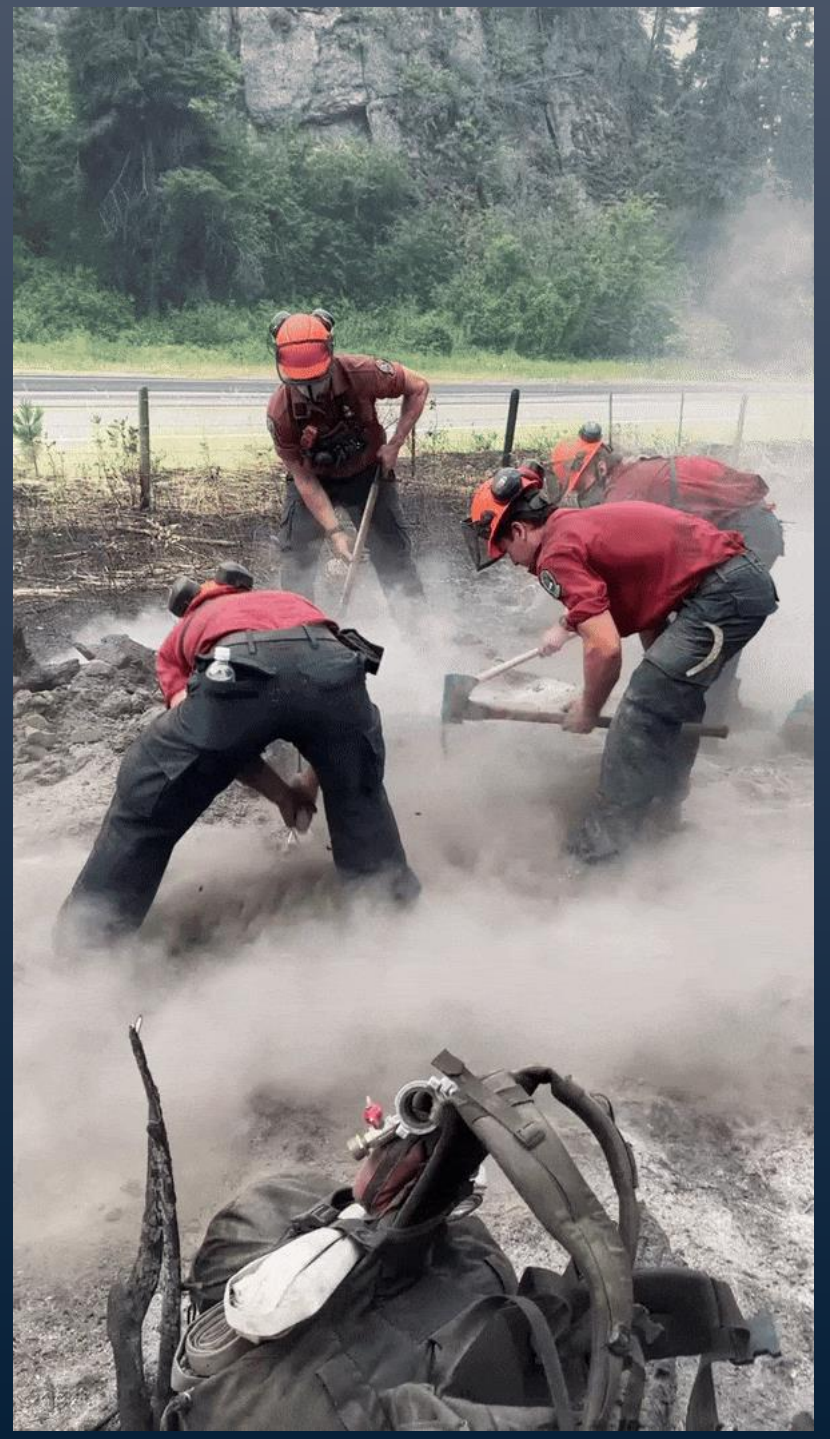


Polycyclic Aromatic Hydrocarbons (PAHs)

- A class of compounds released during combustion, existing as **particles and gases.**
- A mixture of confirmed, suspected, and unknown **carcinogens**.
- Can be absorbed via inhalation, ingestion, or **dermal absorption**.
- Occupational exposure to PAHs is associated with increased risk of lung, skin, and bladder cancers.

Crystalline Silica

- Wildland firefighters are exposed to **crystalline silica** during activities that disturb soil.
- Chronic exposure to silica can lead to **silicosis** and **lung cancer**.



Volatile Organic Compounds

- **Formaldehyde**
  - Eyes, nose, and throat irritant
  - Upper respiratory tract carcinogen
- **Acrolein**
  - Eyes, nose, and throat irritant
  - Pulmonary edema, emphysema
- **Benzene**
  - Headache and dizziness
  - Leukemia

Other Considerations for Assessing Exposure

Shift Length Adjustments

- Wildland firefighting shifts are often 12 – 16 hours.
- Not all of these hours are at the fireline.
- Important exposures may occur off the fireline.
  - Atmospheric inversions can cause **extended periods of 24/7 exposure.**

Source: WorkSafeBC OHS Section 5.50(1)

Factor	Length of work period (in hours)
0.7	More than 8, but not more than 10
0.5	More than 10, but not more than 12
0.25	More than 12, but not more than 16
0.1	More than 16

Breathing Rate Adjustments

- Typically, OELs assume 10 m^3 of air in 8 hours (~21 litres/min).
- WFFs breathing rates range from **24 – 60 litres/min.**
- Additionally **high altitudes** increase breathing rates and internal dose of some contaminants.

Photo Credits: Alaska Division of Forestry & Fire Protection

Dermal Contamination

- WFFs are **dermally exposed to PAHs** from smoke, ash, and soot from regular work practices.
- Re-exposure to PAHs from contaminated PPE and surfaces has been shown in structural firefighting and is likely occurring in WFF.
- Shift length and camp facilities **may not adequately support effective decontamination procedures.**

Photo Credits: US DOI, University of Nebraska Omaha

Culture

- WFF culture lags behind structural firefighting.
- Many WFFs take **pride** in soot covered skin and blackened Nomex.
- A culture of stretching laundry far as possible and in extreme situations - forgoing showers altogether.
- Widespread notion that **wildfire smoke exposure is not dangerous as it is "natural".**
- **Personal & Crew pride in completing objectives** may cloud judgement and push limits beyond reasonable exposure.

Section 3: What does the research say about exposure levels?

A note on exposure limits

- Exposure limits are the maximum allowed airborne concentration in a workplace for a given substance.
- Exposure limits are not a fine line between “healthy” and “unhealthy”.
- Judging workplace monitoring data against an exposure limit allows us to make risk assessment judgements.
- Some workplace exposures are “Designated Substances”, for which we follow the principal of reducing exposures ***as low as reasonably achievable.***

Respirable Particulate Matter

Top 5% of Exposures (ug/m^3)	"Working" Exposure Limit (ug/m^3)	Hazard Ratio
1,820	700	**2.6**

Goal is to get this to 0.5!

- Wildfire smoke is largely respirable/fine particulate matter.
- There is no "Wildfire smoke" or "PM2.5" Occupational Exposure Limit.
- Some wildfire organizations use a working OEL for respirable particulate of 700 ug/m^3.

Carbon Monoxide

Top 5% of Exposures (ppm)	12hr Exposure Limit (ppm)	Hazard Ratio
11	6.25	**1.76**

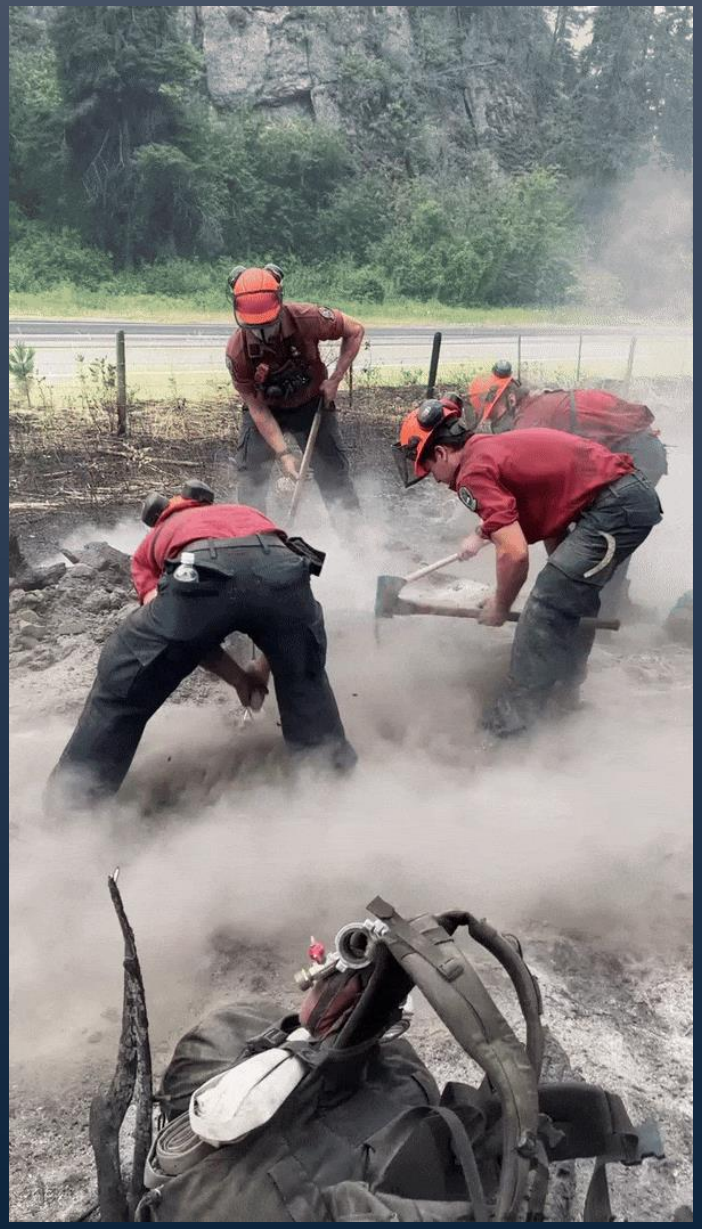
- WFFs are generally exposed to low levels of CO when averaged over the course of a shift.
- CO is largely driven by **engine exhaust**, especially when smoke levels on the fireline are low.
- **High exposure firelines are common** and can considerably exceed exposure limits.

Crystalline Silica

Top 5% of Exposures (ug/m^3)	12hr Exposure Limit (ug/m^3)	Hazard Ratio
119	6.25	**19.0**

Source: Reinhardt & Broyles 2019 (3)

- Silica exposure can be highly variable and task-dependent
- Those engaged in dry mopping, digging guard, and wet mopping are at highest risk.
- Can also be exposed by driving on dusty FSRs, and dusty fire camp.



Volatile Organic Compounds

Hazard	Top 5% of Exposures (ppb)	12hr Exposure Limit (ppb)	Hazard Ratio
Formaldehyde	83	25	**3.3**
Benzene	37	125	0.3

- While there are many hazardous volatile organic compounds present in wildfire smoke, not all have been evaluated.
- Of those evaluated, formaldehyde is the only VOC that is consistently present on the fireline in concentrations above exposure limits.

Section 4: What is BCWS doing to assess and control exposures?

UNBC
Smoke Exposure and Respiratory Health Study (2019)

- Involved **34 BCWS wildland firefighters** during the 2017 fire season.
- Assessed **lung function** change from pre- to post-season for all three crews.
- Small but consistent **declines in lung function were observed** in all three crews across the fire season.
- This is in line with broader academic research – it is unknown to what extent these declines persist between seasons.

Carbon monoxide exposure assessment (2022)

- This project assessed CO exposure on the fireline.
- **Tasks associated with engine use** such as sawyers and pump operators were at elevated risk of overexposure to carbon monoxide.
- Engine exhaust was the main driver of exposure as the firelines assessed had relatively low smoke exposure.
- When CO was used to estimate smoke exposure found that staff were exposed to levels that would amount to “Unhealthy” on the Air Quality Index.
- Smoke exposure is **highly variable and dependent on fireline conditions**.
- Some deployments can have extremely low exposure while others can have extremely high exposure. It can be difficult to anticipate ahead of time.

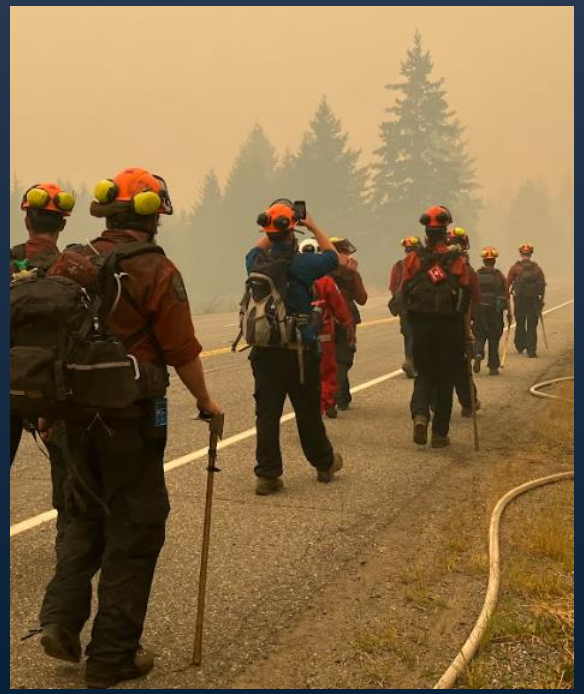
Polycyclic Aromatic Hydrocarbon Research

- BCWS partnered with researchers from the University of Alberta to conduct a suite of research that evaluated **exposure to a PAHs** - specific class of carcinogenic compounds found in wildfire smoke, ash, and soot.
- PAH absorption can be easily measured in urine, allowing us to identify the effect of various **mitigation strategies**.
- This research evaluated the use of **respirators** and **enhanced skin hygiene** protocols on reducing exposure.

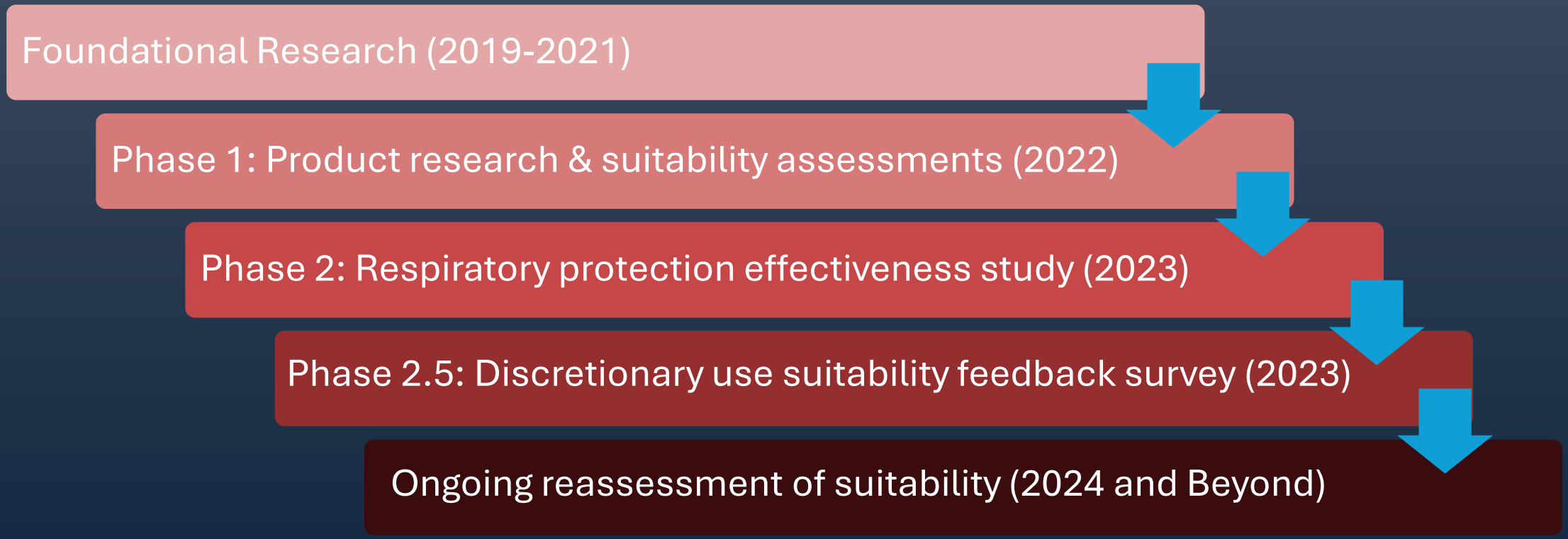
Polycyclic Aromatic Hydrocarbon Research

The results of this research have identified that:

1. Wildland firefighters are **exposed to PAHs** in the air they breathe and through skin absorption of soot.
2. In some cases, the level of PAHs in the body **exceed exposure limits**.
3. Discretionary use of a **respirator reduced PAH absorption**.
4. **Enhanced skin hygiene** *may* reduce PAH absorption.



Identifying and Implementing Respiratory Protection: A Phased Approach



Phase 2: Respiratory Protection Suitability Research

- In 2023 three models of respiratory protection were trialed to assess protection against PAHs.
- The study followed **85 participants across six BCWS unit crews for 3 consecutive days each.**
- Air, skin, and urine were samples for PAH exposure and absorption.
- The analysis of results by the University of Alberta is still underway.

Sundstrom SR100 with replaceable particulate & gas cartridges

Fair Air Mask with washable filter inserts

RZ M2.5 mask with replaceable filter inserts

Phase 2.5: Discretionary Use Suitability Feedback Survey (2023)

- Upon the end of the three-day period, we **offered participants the opportunity to keep their respiratory protection** for the rest of the season if they agreed to **provide feedback** under scenarios of realistic discretionary use.

Phase 2.5: Discretionary Use Suitability Feedback Survey (2023)

- Typical respirator use on the fireline looked like:
  - Wearing for **15-30 minutes** at a time, 2-3 times per day, for a total of 1-2 hours per day.
  - Most often wearing their RPE during **wet and dry mopping.**
  - Positive impact during short-term and light-work.
  - Negative impact on communication via both in-person and radio.
  - Some **interference with other PPE** including glasses, face screen, helmet, or PELTORs.
  - 60% of respondents reported **facial hair** that would interfere with the mask seal.
- **100% of respondents agreed that respiratory protection should be implemented within BCWS.**

Respirator Options for 2024

- **N95 Respirator with Exhalation Valve**
  - Lightweight and easy to pack and disposable.
- **3M Quick Latch**
  - Option for protection against particulates and gases.
  - Quick latch mechanism facilitates communication and hydration.
- **3M Secure Click**
  - Option for protection against particulates and gases.
  - Enhanced breathability, speech diaphragm, easier filter attachment, and one-click seal check.

Respirator Limitations

- No protection against carbon monoxide.
- An extremely physical and hot work environment.
- Frequent in-person and radio communications.
- Lack of ability to maintain clean shaven face.
- No flame-resistant respirator options.
- Minimal space for additional packed gear.
- Cartridge change-out schedules are unknown.

Other Mitigation Strategies

Dermal Exposure	Inhalation Exposure	All Exposure Routes
Provide paid time to decontaminate skin and PPE at base.	Incorporate smoke exposure risk assessments into operational decisions.	Educate staff on the hazards of exposure and how to reduce.
Provide options for skin decon in the field.	Rotate workers out of high exposure tasks and fireline areas.	
Provide adequate infrastructure to shower and launder PPE without delay.	Incorporate air quality forecasting into fire camp locations.	
Provide multiple sets of Nomex.	Monitor fire camp air quality and implement controls when air quality is impacted.	Empower staff to make decisions to lower their exposure at the cost of productivity.
Reduce mop-up where possible.	Ensure indoor air quality at fire camps is adequately filtered when air quality is impacted	
Reduce cold-trailing where possible.	During atmospheric inversions, adjust shift timing around forecasted inversion break.	

Visual Smoke Density Guide

- A tool to aid staff in making decisions regarding their exposure to smoke, by establishing visuals of typical smoky conditions.
- Visuals are paired with monitoring data and binned into risk categories with recommended actions regarding task rotation and respirator use.
- *"If it looks like this, you are exposed to this, and the recommended actions are this."*

Mitigation Strategies
Incorporate smoke exposure risk assessments into operational decisions.
Rotate workers out of high exposure tasks and fireline areas.
Empower staff to make decisions to lower their exposure at the cost of productivity.

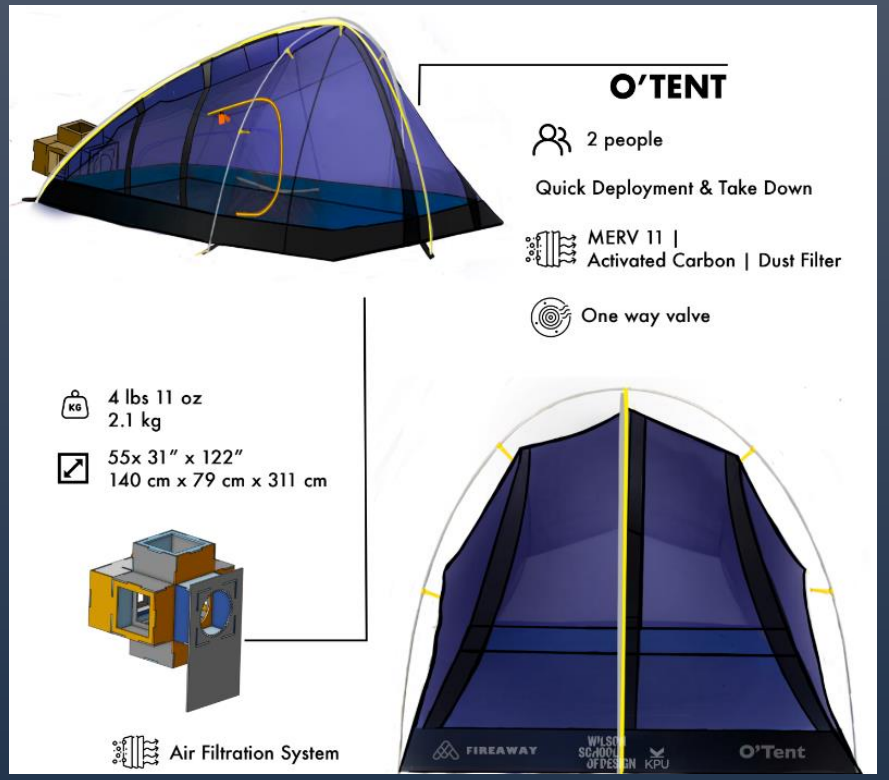
Fire Camp Air Quality

- We have procured a suite of air quality monitoring devices to be posted at smoke-impacted fire camps to:
  - Assess “off-shift” exposure among staff returning from the fireline
  - Assess “on-shift” exposure among fire camp staff.
- Ultimately, the goal is to provide real time air monitoring data for all fire camps, establishing “trigger points” which implement a tiered control system.

Mitigation Strategies
Incorporate air quality forecasting into fire camp locations.
Monitor fire camp air quality and implement controls when air quality is impacted.
Ensure indoor air quality at fire camps is adequately filtered when air quality is impacted
Empower staff to make decisions to lower their exposure at the cost of productivity.

Fire Camp Air Quality

- We are piloting two prototype **“Clean-Air Shelters”** created by students in the Kwantlen Polytechnic University Wilson School of Design
- The goal of these shelters are to provide rest from wildfire smoke at staging areas and fire camps.
- BCWS is testing these shelters at smoke-impacted fire camps this summer to assess performance and practicality.
- Similar “clean-air shelters” could be a potential **engineering control deployed in fire camps at certain trigger points** identified by real time monitoring.



Mitigation Strategies
Incorporate air quality forecasting into fire camp locations.
Monitor fire camp air quality and implement controls when air quality is impacted.
Ensure indoor air quality at fire camps is adequately filtered when air quality is impacted
Empower staff to make decisions to lower their exposure at the cost of productivity.

UBCO Cardiorespiratory health study

- This study seeks to determine the **cardiorespiratory impacts** of wildfire smoke, ash, and dust in BCWS firefighters across multiple seasons (2024 – 2025).
- Pre-, mid-, and post-season **biological monitoring** including blood, urine, and sputum samples, lung and vascular function tests, VO2 max, ultrasounds, and vitals.
- We will conduct **exposure assessments** throughout the season targeting **respirable PM and Silica.**

Mitigation Strategies
Incorporate smoke exposure risk assessments into operational decisions.
Rotate workers out of high exposure tasks and fireline areas.
Educate staff on the hazards of exposure and how to reduce.
Empower staff to make decisions to lower their exposure at the cost of productivity.

Washington, Oregon, and California Wildfire Smoke Regulations

- New Permanent Rules which apply to ALL employers in these states other than enclosed buildings and vehicles (with adequate air filtration) and wildland firefighting.
- Based on the EPA Air Quality Index.
- Employers must monitor current PM2.5 for worksites, and implement training, controls, and respirators as AQI progressively worsens.

Washington State Department of Labor & Industries

OSHA | Oregon OSHA
Department of Consumer and Business Services

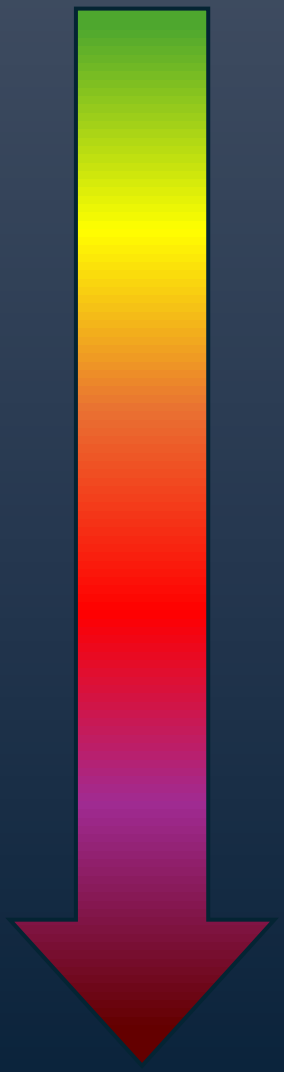
STATE OF CALIFORNIA
CAL OSHA
DEPARTMENT OF INDUSTRIAL RELATIONS

AQI Basics for Ozone and Particle Pollution

Daily AQI Color	Levels of Concern	Values of Index	Description of Air Quality
Green	Good	0 to 50	Air quality is satisfactory, and air pollution poses little or no risk.
Yellow	Moderate	51 to 100	Air quality is acceptable. However, there may be a risk for some people, particularly those who are unusually sensitive to air pollution.
Orange	Unhealthy for Sensitive Groups	101 to 150	Members of sensitive groups may experience health effects. The general public is less likely to be affected.
Red	Unhealthy	151 to 200	Some members of the general public may experience health effects; members of sensitive groups may experience more serious health effects.
Purple	Very Unhealthy	201 to 300	Health alert: The risk of health effects is increased for everyone.
Maroon	Hazardous	301 and higher	Health warning of emergency conditions: everyone is more likely to be affected.

Average fireline exposure to PM2.5 is more than 1.5x this! (470 ug/m^3)

Washington Smoke Regulations



Fine Particulate Matter (PM2.5) Concentration

0 – 20

20 – 35

35 - 250

250 - 500

500 - 555

555 +

1. **Prepare a Wildfire Smoke Response Plan**
2. **Provide training and education to employees.**
3. **Monitor PM2.5 forecasts**

4. **Notify employees of PM2.5 conditions.**
5. **Consider exposure controls.**
6. **Consider providing voluntary respirators**

7. **Implement exposure controls.**
8. **Must make N95s available for voluntary use.**

9. **Ensure workers experienced requiring medical attention are moved to clean air.**
10. **Directly distribute N95s to employees for voluntary use.**

11. **Implement a complete required respiratory protection program that includes fit testing, medical evaluations, and clean-shaven mandates.**

12. **Require respirators with protection factors of 25 or more (such as powered air purifying respirators)**

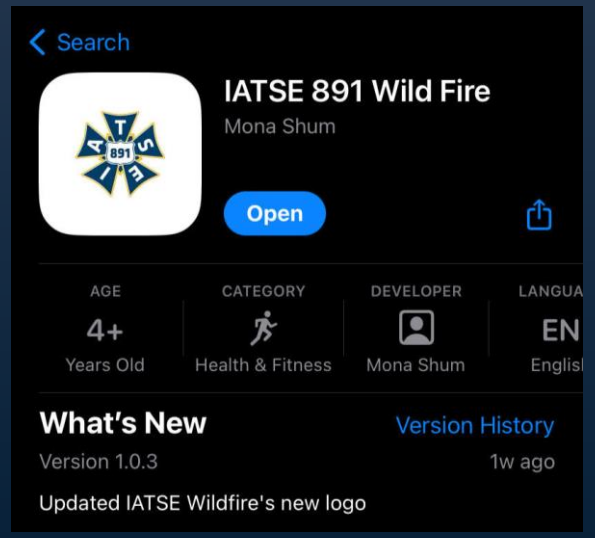
What does this mean for you?

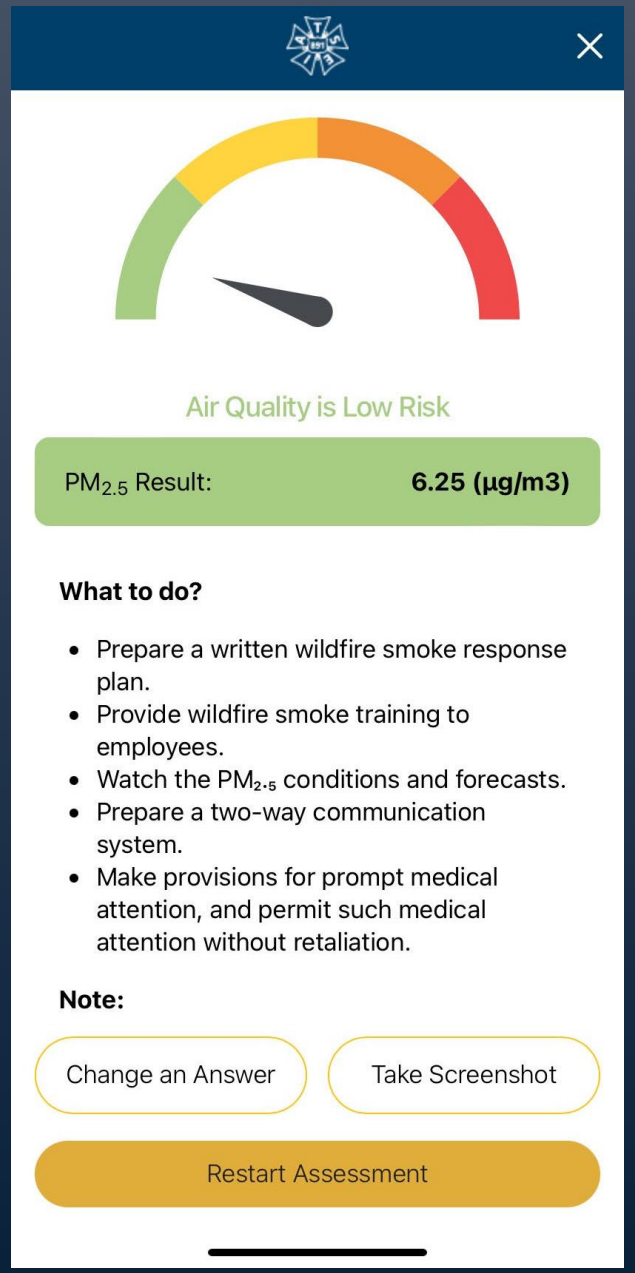
- Neighboring jurisdictions in the western US have adopted permanent, mandatory wildfire smoke regulations for all employers as a response to the worsening air quality impacts from wildfire smoke.
- It is possible that similar regulations may be implemented in British Columbia in the future.
- Employers can be proactive by implementing control strategies guided by these regulations.

Satellite imagery of province-wide smoke impacts taken July 2023. Source NASA.

Wildfire Smoke App

- Created by *IATSE 891* and *Aura Health and Safety.*
- Created for the film industry, but applicable anywhere.
- Based on Washington Wildfire Smoke Regulations.
- Incorporates local AQI readings based on your phones geo-location or you can input your own monitoring results.
- Available on iOS App Store and Google Play.





Sources for wildfire smoke exposure

- Wildfire smoke: Frequently asked questions | WorkSafeBC
- Washington Wildfire Smoke Regulation
- Wildfire Smoke Response Plan Template
- CAN/CSA-Z94.4-18 Selection, use, and care of respirators
- IATSE 891 Wild Fire App on the App Store
- IATSE 891 Wild Fire App on Google Play
- BCCDC Wildfire Smoke Info Page
- Improving Ventilation and Indoor Air Quality During Wildfire Smoke Events

Questions?

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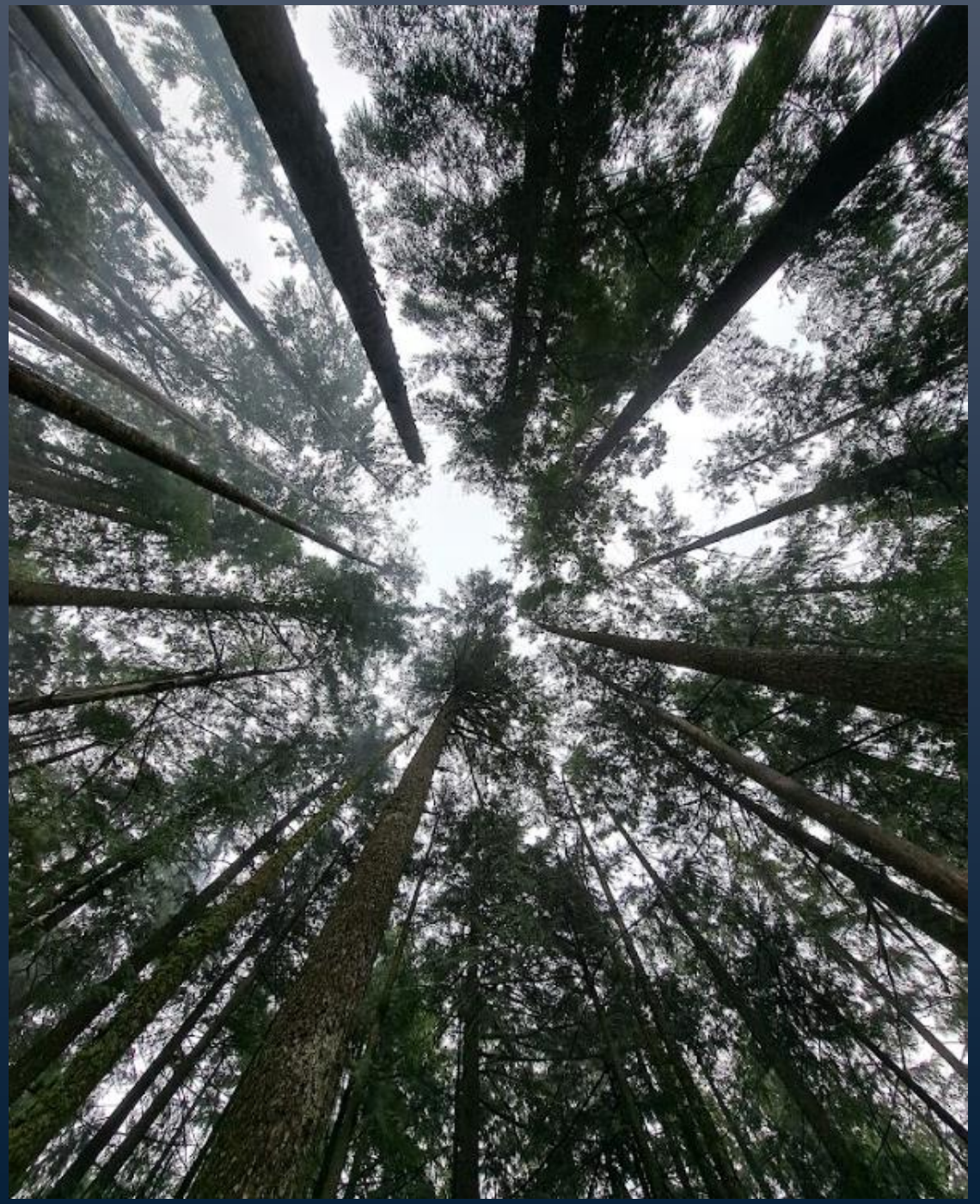

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