Wildland Firefighter Exposure to Smoke and COVID-19: A New Risk on the Fire Line

Kathleen M. Navarro[1], Kathleen A Clark[2], Daniel J Hardt[3], Colleen E Reid[4], Peter W Lahm[5], Joseph W Domitrovich[6], Corey R Butler[7], John R Balmes[8,9]

Affiliations:

1. Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Division of Field Studies and Engineering, Cincinnati, OH
2. Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Respiratory Health Division, Morgantown, WV
3. Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Western States Division, Spokane, WA
4. Geography Department, University of Colorado, Boulder, CO
5. USDA Forest Service, Fire and Aviation Management, Washington, DC
6. USDA Forest Service, National Technology and Development Program, Missoula, MT
7. Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Western States Division, Denver, CO
8. Department of Medicine, University of California, San Francisco, CA
9. School of Public Health, University of California, Berkeley, CA

Corresponding Author:

Kathleen Navarro, PhD, MPH
Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Division of Field Studies and Engineering
1090 Tusculum Ave MS 13
Cincinnati, OH
513-841-4257
knavarro@cdc.gov

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Abstract:

Wildland firefighters respond to wildfires throughout the United States and perform arduous work in remote locations. Due to congregate work and living settings, wildfire incidents can be an ideal environment for the transmission of infectious diseases. In this review, we examine how exposure to wildfire smoke may contribute to an increased likelihood of SARS-CoV-2 infection and severity of COVID-19 illness. Exposure to particulate matter (PM), a component of wildfire smoke, has been associated with oxidative stress and inflammatory responses in humans and laboratory settings, which increases the likelihood for adverse respiratory symptomology and pathology. In multiple epidemiological studies, wildfire smoke exposure is associated with acute lower respiratory infections, such as bronchitis and pneumonia. Wildland firefighters may be at an increased risk for COVID-19 illness due to particle based transport of SARS cov-2 virus through PM transport of the SARS-CoV-2 virus and up-regulation of angiotensin-converting enzyme II, which SARS-CoV-2 virus depends on to gain entry into alveolar and vascular cells. Co-occurrence of SARS-CoV-2 infection and wildfire smoke inhalation may also increase risk for more severe COVID-19 outcomes such as cytokine release syndrome, hypotension, and acute respiratory distress syndrome. Current infection control measures include social distancing, masks, frequent cleaning and disinfecting, and daily screening for COVID-19 symptoms, which are very important to reduce infections and severe health outcomes. Exposure to smoke may provide an additional risk for SARS-CoV-2 infection and severity of outcomes during the current and possibly future fire seasons.

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Introduction

Over the past decade, an average of approximately 6.8 million acres have burned annually due to wildfires across the United States (1). During the peak of the 2015 and 2017 fire seasons, on average, over 27,000 fire personnel were deployed to wildfire incidents each day in the western US (2, 3). Wildland firefighters perform arduous work under difficult conditions in remote locations for shifts often longer than 24 hours, for up to 14–21 days. Hence, wildfire incidents can be an ideal environment for the transmission of infectious diseases, including SARS-CoV-2, due to close living and working conditions, limited access to hygiene supplies, and a workforce that responds to incidents all over the country on short notice. Furthermore, occupational factors that increase stress on the body such as arduous work, long work shifts, and environmental exposures (including smoke) may contribute to an increased susceptibility for SARS-CoV-2 infection.

Wildland fire smoke contains a variety of air pollutants including particulate matter (PM), which is a heterogeneous mixture of particles and liquid droplets consisting of organic compounds (including PAHs), metals, acids, soil, or dusts suspended in the atmosphere. PM is a commonly measured air pollutant and classified by the particle's aerodynamic diameter: coarse (aerodynamic diameter between 2.5-10 μm), fine (<2.5 μm), and ultrafine (<0.1 μm) (4,5). Previous studies that attempt to quantify wildland firefighter toxic smoke exposure have measured fine PM (≤ 2.5 μm), and respirable PM (≤4 μm) (4). Between 2009 and 2012, the United States Department of Agriculture Forest Service (USFS) reported that 22% of wildfire and 20% of prescribed burn (fires intentionally set for resource benefit) work shifts exceeded PM_4 daily occupational exposure limit (0.7 mg/m^3) that was specifically recommended for wildland firefighters (6).

In March 2020, the World Health Organization declared the coronavirus disease 2019 (COVID-19), caused by the novel SARS-CoV-2 virus (a beta coronavirus), a global pandemic (7). Although some individuals with SARS-CoV-2 infection are asymptomatic, many experience the cardinal symptoms of dry cough, fever, and/or shortness of breath (8). Moderate to severe cases of SARS-CoV-2 respiratory infection can precipitously progress to pneumonia with hypoxemia, acute lung injury leading to acute respiratory distress syndrome (ARDS) and respiratory failure. Severe COVID-19 can have multiple extrapulmonary manifestations including acute cardiac injury, acute kidney failure, stroke, and multiple organ failure (8). Moreover, progression of severe COVID-19 is age-related and up to 20% of cases in persons older than 65 develop ARDS (9). The mortality rate in patients with COVID-19 ARDS is often greater than 50% (10).

Past research suggests associations between ambient air pollution, mostly measured by PM concentrations, and case fatality in both the 2003 SARS outbreak and 2020 COVID-19 pandemic. Cui et al. (2003) conducted an ecological study and found a positive association between SARS case fatality and ambient air pollution levels (including PM_{10}) (11). A recently published Chinese study assessed the risk of SARS-CoV-2 infection to short-term air pollutant exposure levels and found significant associations for several pollutants, including $PM_{2.5}$ (12). A preliminary analysis by Wu et al. (2020) reported an 8% increase in the COVID-19 mortality rate for every 1 $\mu g/m^3$ increase in annual $PM_{2.5}$ exposure in the US (13).

In this article, we review how smoke in the wildland fire environment may influence the risk of SARS-CoV-2 infection and severity of COVID-19 illness. We also highlight current best practices for prevention of COVID-19 and possible mitigative strategies to reduce both smoke and SARS-CoV-2 exposure for individual wildland firefighters during wildfire operations.

PM Exposure and Risk of Lower Respiratory and SARS-CoV-2 Infections

Considerable evidence has been reported to support an association between exposure to air pollution and increased risk of lower respiratory infection. The epidemiological literature for exposure to $PM_{2.5}$ as a specific pollutant associated with this risk is less extensive and studies typically do not differentiate viral from bacterial infection (14). Several epidemiological studies do shed light on $PM_{2.5}$ exposure and COVID-19. One study in Beijing showed that ambient $PM_{2.5}$ concentrations were significantly associated with flu-like illness risk, in adults more than in children (15). A second study from China involving over 4.2 million hospital admissions for pneumonia in 184 cities showed that short-term elevations in $PM_{2.5}$ concentrations were associated with increased pneumonia admissions (16). Controlled exposure studies to NO_2, O_3 and/or $PM_{2.5}$ in both animals and humans show enhanced viral proliferation and severity of infection of several viruses, including influenza, rhinovirus, and respiratory syncytial virus (RSV) (5).

Lung deposition of PM is determined by a number of biological and physical properties, but particle size is a chief determinant for regional deposition along the respiratory tract (5). Although past exposure assessments of wildland firefighters have measured exposure to $PM_{2.5\text{-}4}$, data from wood and wildfire combustion studies have demonstrated that most PM from wildfire smoke is composed of submicron particles (about 300 nm), much smaller than 2.5 microns (17, 18). Upon inspiration, smaller particles are transported into more distal regions of the respiratory tract and become independent of gravitational forces. Respirable particles penetrate beyond the terminal bronchioles into the alveolar region. Ultrafine particles ($PM_{0.1}$) readily cross alveolar surface membranes where they are translocated into epithelial tissue, interstitium, pulmonary endothelium, or to secondary organs (19). Translocation of particles is usually rapid (one to two days) and dose-dependent, meaning that when there are more particles, more will be translocated across surface membranes (20). For wildland firefighters, during arduous work, dominant nose breathers will switch to nasal-oral breathing. This nasal-oral switch allows for less efficient filtering of inspired air, and a greater proportion of larger particles will be deposited into more distal airways and the alveolar region (21, 22).

The respiratory system utilizes a number of innate defense mechanisms to trap and remove PM. Upper airway filtering efficiently prevents most inhaled particles ≥ 10 μm from penetrating into the lower airway (23). Within the tracheobronchial region, the mucociliary escalator transports distally deposited particles superiorly, for elimination through the cough reflex. However, if this mechanism gets overwhelmed or damaged, particles will accumulate. Alveolar macrophages readily phagocytize particles in the deep lung and then migrate to terminal bronchioles for mucociliary clearance, migrate into the interstitium for lymphatic clearance, or simply remain particle-laden within the alveolar region (24, 25). Migliaccio et al. (2013) demonstrated that post-wood smoke exposure, pulmonary macrophages showed decreased ability to defend against infection in mice (26).

A unifying mechanism by which ambient PM deposited in the lower airways and alveoli is thought to increase risk of infection is through oxidative stress and production of free radicals, causing local damage to epithelial cells (27). PM generated through wildfires has the potential to promote local oxidative stress and inflammation (28-31). Following PM-induced epithelial injury, pattern receptors located on resident macrophages recognize and bind to endogenous DAMP (damage-associated molecular patterns) molecules. Once activated, these macrophages release pro-inflammatory cytokines, tumor necrosis factor alpha and interleukin-1 (TNF- α and

IL1), that cause endothelial selectins to recruit leucocytes (neutrophils and monocytes) to the injured area. Macrophages and leucocytes then phagocytize dead or damaged epithelial cells and further release profibrotic cytokines and growth factors for tissue repair (22, 30). Epithelial reactive oxygen species (ROS) can also induce inflammatory cytokines to be released through the activation of the nucleotide-binding oligomerization domain-like receptor related protein 3 inflammasome (NLRP3), activator protein 1 (AP-1), and mitogen-activated protein kinase (MAPK) signaling (22, 32). In addition, immunoglobulin E (IgE)-dependent adaptive immune response occurs when susceptible wildland firefighters inhale PM containing adsorbed allergens. Exacerbation of pre-existing asthma can be caused by both early-phase and late-phase responses to inhaled allergen and sensitization to a new allergen can lead to new-onset asthma (33).

Two hypotheses may explain the apparent association between increased cases of COVID-19 and elevated PM exposure. The first hypothesis suggests that the SARS-CoV-2 viral clusters are adsorbed to respirable PM to promote SARS-CoV-2 airborne transmission (34). This PM-facilitated airborne transmission has been identified in experimental studies for other viruses such as RSV, the *Morbillivirus* paromyxovirus, and the H5N1 virus (avian influenza) with corresponding increases of infection rates (31, 32, 34-36). Although past studies examined viruses that were more contagious, the infectiousness of SARS-CoV-2 and how transmission associated with respirable PM is not yet known. Wildfire smoke consists of PM composed of mostly organic material. Consequently, airborne droplets containing SARS-CoV-2 viral clusters naturally adsorb to this organic PM since SARS-CoV-2 is a lipid virus. Studies have hypothesized that organic PM may create a suitable environment for transporting the virus over greater distances than close contact exposures to the droplets created by coughing, talking, or sneezing, as airborne droplets quickly lose momentum through evaporation (37, 38). We hypothesize that this expanded range of respirable transmission potentially presents wildland firefighters with a greater risk for SARS-CoV-2 infection.

Another hypothesis regarding the association of COVID-19 severity and mortality with elevated PM exposure involves histological changes observed within pulmonary capillary endothelial and alveolar epithelial cells. Following PM exposure or smoke inhalation, epithelial cells upregulate angiotensin-converting enzyme II (ACE-2), a transmembrane protein receptor for the virus, to reduce cytokine-induced lung injury and inhibit ARDS (39). Rats exposed to wood smoke have demonstrated significant increases in ACE-2 expression within alveolar cells (40). Similar increases in expression of ACE-2 have been found in cigarette smokers compared to non-smokers (41). Recently published studies have determined that SARS-CoV-2 virus depends on the ACE-2 protein embedded on epithelial cell membranes to gain access into cells. This offers one explanation for why smokers have higher COVID-19 illness rates and more severe outcomes than non-smokers (16.9% versus 5.2%) (42, 43). Consequently, wildland firefighters who have had high exposure to wildfire smoke may have an additional risk for contracting SARS-CoV-2 as a result of increased expression of alveolar ACE-2 from exposure to wildland fire smoke.

Wildfire Smoke Exposure and Risk of Lower Respiratory Infection

Wildfire smoke exposure has been associated with lower respiratory infections such as acute bronchitis and pneumonia in many epidemiological studies (44-46). Several systematic reviews have found associations between wildfire smoke and emergency department visits and hospitalizations for acute bronchitis and pneumonia (4, 47-50). Yao et al. (2016) reported a significant association between $PM_{2.5}$ on extreme fire days with physician visits for individuals with lower respiratory tract infections in British Columbia over 10 fire seasons (51). In San Diego and Colorado, Hutchinson et al. (2018) and Alman et al. (2016) reported significantly elevated risks of ED visits and hospital admissions for individuals diagnosed with respiratory infections during wildfires (52, 53).

Wildfire smoke exposure may also be associated with risk for respiratory infection during the winter months after an intense, prolonged wildfire season. Landguth et al. (2020) examined seasonal influenza infection rates between 2010 and 2018 and reported a 22% increase in seasonal influenza incidence associated with elevated daily average $PM_{2.5}$ concentrations during the previous summer wildfire season (54). Though not studied specifically in wildland firefighters, the published epidemiological literature provides considerable evidence for an association between exposure to wildfire smoke and respiratory infections.

Wildfire Smoke Exposure and Risk of Severe COVID-19 Outcomes

As noted above, exposure to PM from wildfire smoke can affect lung health through oxidative stress which subsequently leads to cell toxicity and an inflammatory response (29). Kim et al. (2018) examined lung toxicity in mice and mutagenicity in *Salmonella* from exposure to PM in both the flaming and smoldering phases of combustion from multiple biomass fuel types (30). After adjusting for mass of fuel burned, the researchers reported that PM from smoldering eucalyptus had the highest lung toxicity, as measured by increases in neutrophil count measured in bronchoalveolar lavage fluid per mass of fuel burned, and mutagenicity, measured by a *Salmonella* plate incorporation assay, for eucalyptus and pine and pine needles, respectively. Gaughan et al. (2008) found an association between post-fire respiratory symptom scores with inflammatory biomarkers (eosinophilic cationic protein and myeloperoxidase) measured in sputum and nasal lavage fluid of wildland firefighters (55). This provides evidence that wildland firefighters may be at increased risk for severe respiratory outcomes through activation of inflammatory pathways.

Other recent studies measured inflammatory markers in wildland firefighters conducting prescribed fires, intentionally ignited low-intensity fires for resource benefit, and during a large wildfire event (28, 56). Adetona et al. 2017 found that wildland firefighters who ignited prescribed fires using torches filled with diesel and gasoline had elevated inflammatory markers for serum amyloid, interleukin (IL)-8, and C-reactive protein (CRP), compared to firefighters tasked with holding (ensuring the fire did not escape) (28). The additional exposure to combustion of diesel and gasoline could have led to an increase in inflammatory markers. Lastly, Main et al. (2020) reported a significant increase in the inflammatory biomarkers, IL-6 and IL-8, after a 12-hour work shift compared to before the shift among wildland firefighters during a large wildfire event in Australia in 2009 (56).

COVID-19 disease severity is also associated with cytokine release syndrome (resulting in "cytokine storm") induced by SARS-CoV-2 virus (9, 57). Chen et al. (2020) reported that severe cases of COVID-19 had more frequently elevated levels of CRP and cytokines (IL-6, IL-10 and TNF- α) than less severe cases (58). Ruan et al. (2020) examined predictors of fatality in 150 cases of COVID-19, and found that mortality may be due to viral-caused hyperinflammation as measured by elevated IL-6 and CRP in non-survivors compared to survivors ($p<0.0001$) (59). An excessive inflammatory response to SARS-CoV-2 infection may be related to risk of hypotension and ARDS (9). Hypotension may also result from increased expression of ACE-2 in vascular cells resulting from increased cytokine release. ACE-2 lowers blood pressure by converting angiotensin II (a vasoconstrictor) into angiotensin(1-7) (60). Because the airway inflammation that wildland firefighters experience from exposure to smoke involves the same inflammation pathways that have been reported in severe COVID-19 cases, firefighters could have more severe COVID-19 outcomes.

Overall, wildland firefighters are at a greater risk for developing adverse respiratory health effects from wildfire smoke exposure due to a number of unique factors inherent to the wildfire environment. First, combustion of wildland biomass can produce PM containing adsorbed antigens that can elicit acute airway inflammatory responses or exacerbate chronic inflammation in sensitized individuals with asthma (33, 48). Wildfire PM also has a higher proportion of ultrafine particles that are readily translocated across the alveolar-capillary membrane and cause alveolar, pulmonary interstitial, and secondary systemic cell damage. Furthermore, the long workday and job demands of wildland firefighters can profoundly increase PM exposure (6). Both innate and adaptive immune responses are also modified by the sex of an individual (61) In a small pilot study, Rebuli et al. (2019) exposed both male and female adult participants to wood smoke and nasally inoculated live attenuated influenza virus following smoke exposure (62). After 2 days, males had increases in inflammation-related gene expression, whereas female inflammatory gene-expression was down-regulated. These sex-related differences in gene expression suggest that firefighters, the vast majority of whom are males, would be at higher risk of increased inflammatory reaction.

Wildland Firefighter Exposure to Smoke

When performing common job tasks on wildfires and prescribed fires, wildland firefighters can be exposed to elevated concentrations of air pollutants found in smoke. Table 1 provides a description of common job tasks performed by wildland firefighters and how they can be exposed to smoke while performing those tasks. Reinhardt and Broyles (2019) reported that job task, type of wildfire crew, and wind position were important factors for predicting exposure to PM_4 (6). Exposure to PM_4 was significantly lower for firefighters completing non-arduous ancillary tasks such as operational breaks or waiting for assignments compared to mop-up (extinguishing a fire). Gaughan et al. (2014) reported that wildland firefighters constructing the fire line had higher PM exposures compared to those performing mop-up at a large wildfire incident (63). This study also found that during fire line construction, an arduous task, wildland firefighters operating a chainsaw and clearing brush for the chainsaw operator had higher PM exposures compared to fire line construction or supervisory firefighters as measured by real-time particulate matter samplers. In a 2015-2017 USFS follow-up study, wildland firefighters had significantly higher exposures of PM_4 when completing direct fire suppression (including fireline construction) compared to those firefighters who performed other job tasks. This study also found that "firing" and "holding" tasks resulted in elevated mean concentrations of PM_4. (*Navarro KM, Butler C, O'Dell K, et al. Exposure to Particulate Matter and Estimation of Volatile Organic Compound Across Wildland Firefighter Job Tasks. In Preparation 2020)*.

When compared to laboratory and field studies that found increased respiratory inflammatory responses, wildland firefighters experience similar or higher exposures to PM on wildfires. Rebuli et al. (2019) exposed study participants to 0.5 mg/m^3 of wood smoke for 2 hours (62). Adetona et al. (2017) reported the $PM_{2.5}$ time-weighted average concentrations at 0.24 mg/m^3 (range: 0.01-0.61 mg/m^3) for firefighters that performed firing (28). Exposure assessment studies reported mean exposure $PM_{2.5\text{-}4}$ from 0.32 to 0.51 mg/m^3 across work shifts and maximum exposures that ranged from 0.68 to 2.56 mg/m^3 for wildland firefighters at wildfires (6, 63). Wildland firefighters working on the fire line typically have long work shifts and multi-week fire assignments that can result in higher cumulative exposures which may increase risk of adverse health outcomes.

In addition, wildland firefighters, incident management personnel, and camp support crew can be exposed to smoke at incident command posts (ICPs) that support thousands of individuals while off the fire line, which can contribute to a higher cumulative work exposure (64, 65). Although wildland firefighters perform arduous tasks and are in great physical condition, fire personnel supporting fire operations at ICPs can be older, not as physically active, and have underlying health conditions. In 2006 and 2007, incident management personnel were surveyed to examine health status, activity levels, and cardiovascular risk factors. The surveys found that incident management personnel had an average of 2.6 coronary artery disease risk factors and indicated a need for improved physical activity, nutrition, and a reduction in stress (66). The National Wildfire Coordinating Group recommended that personnel at ICPs follow exposure limits to PM from the US Environmental Protection Agency (35.5-80.4 $\mu g/m^3$ over 24 hours), because they may be demographically similar to the general population and can have underlying health conditions or behaviors that put them at increased risks for adverse health outcomes from exposure to smoke including cigarette smoking, cardiovascular disease, high blood pressure, and obesity (67). Unfortunately, the health status of firefighters is not well known, and it is unknown how underlying health conditions or behaviors may put them at increased risks for adverse health outcomes.

Prevention and Mitigation Strategies for Wildland Firefighters

The best way for wildland fire personnel to prevent COVID-19 illness is to avoid being exposed to SARS-CoV-2. As of August 2020, current guidance and recommendations to prevent or minimize the transmission of SARS-CoV-2 include social and physical distancing of wildland fire personnel, wearing cloth face coverings or masks (especially when social distancing is not possible), frequent cleaning and disinfecting of surfaces and equipment, and daily screening for

COVID-19 symptoms and body temperature (68, 69). To promote social and physical distancing, it is recommended to have smaller “spike” or remote camps to insulate crews and modules from each other and other outside personnel (69). Working as a crew or module requires close contact (riding in crew vehicles, hiking, and working next to each other). If a crew can “insulate as a unit” or create a “module as one”, they can limit outside exposure to SARS-CoV-2 and may be able to safely complete operational tasks in closer proximity (68, 69). However, this will require all fire personnel to be vigilant when interacting with the public and anyone outside of their crew or module on and off work. Cloth face coverings or masks are recommended as a source control when interacting with individuals outside of the crew, module, or unit, and when not engaged in arduous work.

To remain ready to respond to wildfires and for the next work shift, wildland firefighters will need to refurbish tools and supplies daily. Frequent cleaning and disinfecting of high-touch surfaces, equipment (e.g., hand tools or radios), and vehicles is recommended to prevent exposure to SARS-CoV-2 and should be integrated into the daily work routine (69). Lastly, all fire response personnel should self-monitor and report any COVID-19 symptoms before going to work or accepting a wildfire assignment (68). Wildland firefighting management should maintain a healthy workforce of all personnel that respond and support wildfire response throughout the fire season by prioritizing proper rest, hydration, and nutrition for all fire personnel (70).

Mitigating exposures to smoke can be difficult for wildland firefighters as smoke is part of the wildfire environment on the fire line and in ICPs. Currently, there is no respirator available for wildland firefighter that meets the National Fire Protection Association Standard and will provide protection for all inhalation hazards and is able to be worn in the extremes of the wildfire environment (71). Job tasks known to have elevated smoke exposure include mop-up, holding, fire line construction, and firing (6, 28, 63, 72). Mitigation strategies will be dependent on fire behavior, available resources and personnel, and operational objectives. Current mitigations proposed for this fire season include: rotating fire personnel in areas of high unavoidable smoke exposure, using air resource advisors to monitor and address smoke issues, and locating ICPs and remotes camps in areas with least smoke exposure practicable (73). Camps, where firefighters rest when off-shift, should not be sited in areas with a high likelihood of strong nighttime inversions, which can trap smoke and lead to higher exposures to smoke (64, 65).

To reduce cumulative exposures to smoke across a fire assignment, wildfire incident management personnel should rotate and re-assign crews and resources after completing job tasks associated with higher smoke exposures to job tasks that have lower expected smoke exposures. Reductions in exposure across multiple assignments may reduce cumulative exposure across a career. Past exposure assessments completed by the USFS demonstrate that wildland firefighters are good estimators of their own exposures, as self-reporting of categorical smoke exposure (low to high) is associated with measured concentrations of PM_4. (*Navarro KM, Butler C, O'Dell K, et al. Exposure to Particulate Matter and Estimation of Volatile Organic Compound Across Wildland Firefighter Job Tasks. In Preparation 2020)* Self-reported qualitative smoke exposure could be used by wildfire incident management personnel to track cumulative exposure throughout individual fire assignments or across the fire season. Additional mitigation strategies should be considered for crews, modules, or individuals reporting high cumulative smoke exposure.

The wildfire environment includes many risks and hazards such as burnovers/entrapments, heat-related illnesses and injuries, vehicle-related injuries (including aircraft), slips, trips, and falls, falling trees and others (74). These risks may be independent or interdependent and are often managed through the "Operational Risk Management" framework, which is a continuous assessment process of identifying hazards and implementing controls to make decisions and reduce unintended outcomes. Every risk is assessed by its probability (likelihood of mishap if risk is present) and severity (consequences if mishap occurs) (75). Wildland firefighting management has a mission to manage fire, while considering all risks to maintain a healthy workforce throughout the fire season. The risk of SARS-CoV-2 infections and COVID-19 illness during the 2020 fire season is an additional risk to consider when assessing all risks and hazards in the wildfire environment. It is important for all fire personnel to understand the risk of smoke and how to mitigate exposure. Although this is not a systematic literature review, we have demonstrated that exposure to smoke may be associated with SARS-CoV-2 infections and severity of illness outcomes. All fire personnel should try to mitigate smoke exposure, when tactics can be adjusted, while meeting operational objectives on the fire line and fire management goals.

Conclusion

Studies have demonstrated that exposure to wildfire smoke is independently associated with airway inflammation, cell toxicity, oxidative stress, and increased risk of respiratory infections. Occupational wildfire smoke exposure may modify firefighter susceptibility to SARS-CoV-2 infection or their risk for developing severe COVID-19 illness. Preventing the transmission of SARS-CoV-2 infection may be difficult in the extreme work environments of wildland firefighting personnel. All wildland fire personnel should stay up-to-date on the basic understanding of COVID-19, how the disease is thought to spread, disease symptoms, and what measures can be taken to prevent or minimize transmission. Prevention measures for wildland firefighters should include social and physical distancing as a unit, cloth face coverings or masks when operating outside their unit, frequent cleaning and disinfecting, and screening of fire personnel daily for symptoms of COVID-19.

Disclaimer

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Table 1. Definitions for Common Job Tasks Performed by Wildland Firefighters

Job Task	Definition
Direct Suppression	Use tactics (such as constructing fireline) next to the fire's edge to stop forward progression of the main fire. Firefighters are likely to be exposed to smoke when working close to this active fire edge.
Fireline Construction	Clear vegetation (often first with chainsaws) and dig or scrape down to bare mineral soil to create a fuel break and stop forward progression of the fire.
Firing	Ignition of burnable materials (fuels) drip torches filled with a diesel/unleaded gasoline mixture, fusees, flare launchers, or other incendiary devices. How the burn is ignited (through firing patterns) may produce different amounts of PM in the smoke.
Holding	Monitor and patrol a section of the fireline (on wildfires and prescribed fires) and ensure that fire does not cross the fireline. Firefighters performing holding can be instructed to stand along a fireline and watch for the fire escaping control lines which can involve being in areas of high smoke and low visibility.
Indirect Suppression	Use tactics (such as constructing fireline) away from the fire's edge to stop forward progression of the main fire. Often these indirect suppression firelines will be used to implement a firing operations.
Mop-up	Extinguish any burning or smoldering material by digging out the burning material or applying water to prevent rekindling and improve the chances the fireline will hold the fire.
Patrolling	Inspect and monitor a fire perimeter
Staging	Crews or resources waiting for operational assignments
Structure Protection	Use tactics to protect a structure from active wildfire in the immediate area or prepare the structure for the threat of wildfire

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