Smoke Safety for Prescribed Fire Practitioners

Smoke emissions generated during prescribed fires can impact the health and safety of practitioners and the community. Recurrent or ongoing exposure to these airborne contaminants may compromise your respiratory function and pose both short- and long-term health risks. **By learning about potential hazards, evaluating smoke exposure, and taking the appropriate precautions to mitigate exposure, you as a prescribed fire practitioner can better protect your health while implementing prescribed fires**.

What is Smoke?

Smoke is a result of incomplete combustion and is an inevitable result of fire consuming fuels. Smoke is made up of a mixture of chemical compounds, gases, and particles. **Particulate matter (PM)** is a primary pollutant of public health concern and is grouped into two size classes: **PM_{10}** (inhalable particles <10 microns) and **$PM_{2.5}$** (fine particles < 2.5 microns). While smoke particles range in size, most particulate matter from wildfires is within the $PM_{2.5}$ size range.[1]

Prescribed fire practitioners stepping out of the smoke. PC: David Benterou

The chemical makeup of smoke can vary by fire behavior. During the flaming phase of a fire, combustion is more complete, with less smoke production. When a fire transitions to the smoldering phase (e.g., when burning damp fuels, during securing operations), combustion is less complete, with more of the fuel converted to smoke. Inefficient combustion results in the emission of significantly more unhealthy compounds, including carbon monoxide (CO), volatile organic compounds (VOC), and fine particulate matter.[2,3] All other things being equal, burns that achieve more flaming combustion and minimize smoldering will likely produce less smoke and unhealthy compounds. Additionally, hotter combustion associated with flaming combustion can loft smoke to achieve better dispersion and less exposure at the ground level.

What is the difference between prescribed and wildfire smoke?

Prescribed fire smoke can be less toxic than wildfire smoke because only vegetation is burned. Smoke from wildfires that burn into the wildland-urban interface often includes toxins from burning structures and vehicles.[4,5] **Because prescribed fires are planned in advance, practitioners have more control over the amount of smoke produced and the duration of smoke exposure.** Generally, wildfires generate greater amounts of smoke, $PM_{2.5}$, CO, and air pollutants per acre burned than prescribed fires.[6,7] Additionally, wildfires are associated with longer-term, chronic smoke exposure, while prescribed fire operations typically involve shorter periods of smoke exposure.

Despite shorter exposure times, prescribed fire practitioners can be exposed to higher concentrations of smoke while on the fire line. This is largely due to practitioners being assigned to "holding" positions on prescribed burns for long periods of time.

How Does Smoke Exposure Affect Practitioners?

The level and duration of smoke exposure, a person's age and sensitivity, and other factors determine how much someone experiences adverse health effects from smoke. **Exposure to smoke, especially smoke from smoldering combustion, can lead to acute physical symptoms and cognitive impairment in the short-term**,[8] including:

- **Headaches, nausea, and fatigue** during shorter periods of exposure to heavy smoke and associated CO.
- **Coughing, a runny nose, or stinging eyes** due to PM and gaseous irritants in smoke, especially fresh smoke near smoldering sources.[8,9]
- **Confusion and impaired judgement** due to prolonged periods of exposure to heavy smoke and associated CO.[8,10]
- **Exacerbations of respiratory conditions in the short-term**, such as asthma and increased respiratory effects, including congestion, increased lung infections, and shortness of breath.[11,12]
- **Decline in lung function** over the duration of a burn due to prolonged PM exposure.[13]
- **Increased risk of heart attacks and cardiovascular issues.** Acute and prolonged exposure to smoke and associated CO increase risk of heart issues, especially for susceptible populations, including people with pre-existing respiratory and cardiovascular diseases, middle-aged and older adults, children, pregnant women, and fetuses.[11,14]

Longer-term smoke exposures can create cumulative stress on the cardiovascular and respiratory system, particularly for prescribed fire practitioners who burn frequently over consecutive days.[9,11] Practitioners may experience small but persistent declines in lung capacity over the course of a burn season due to chronic smoke exposure.[9] The repeated inhalation of $PM_{2.5}$ can also lead to an increased susceptibility to respiratory infections.[15,16] Cardiovascular impacts, including increased risk of hypertension, has been found in wildland firefighters.[17]

Over the span of your career as a prescribed fire practitioner, the cumulative effects of smoke exposures can shift from temporary physiological changes to permanent health risks. Long-term inhalation of PM and carcinogens found in smoke is linked to chronic diseases such as heart disease, hypertension, and some cancers.[18] Public health studies of wildland firefighter-based smoke exposure project an increased relative risk of mortality from lung cancer (8-43%) and/or cardiovascular disease (16-30%).[18]

How Can Practitioners Reduce Smoke Exposure?

You can reduce smoke exposure by taking steps to eliminate smoke-related hazards before, during, and after burns.

Before the Burn

- **Think about ways to remove or reduce sources of smoke exposure.** When designing and planning burns, burn unit boundaries can be adjusted to minimize smoke exposure. For example, carrying burn units to the top of a slope reduces the need for holding crews to stand on mid-slope lines where smoke exposure is often highest.

- **Address smoke-related hazards during safety briefings.** If you are in a leadership role (e.g., burn boss), normalize talking about and mitigating smoke impacts.
    - Provide N95 respirators to participants who wish to use them.

During the Burn

- **Use respiratory protection to reduce smoke exposure.** Use properly fitted N95 respirators to reduce exposure to $PM_{2.5}$. Bandanas and surgical masks are not sufficient for protecting against harmful smoke particles. Note that N95 respirators do not protect against hazardous gases.
- **Monitor your physical symptoms and the symptoms of your team** to identify when exposure is becoming hazardous. If you experience stinging eyes, headache, or develop a scratchy throat, reassess your positioning and move to cleaner air.[8]
- **Rotate crews between high-exposure tasks** (e.g., holding) **and lower-exposure tasks** (like patrolling or firing) to limit exposure.[8,15] Holding crews should be encouraged to move to cleaner air whenever possible.
    - For burn participants that are more susceptible to smoke impacts, limit their participation to roles where smoke impacts are less likely (e.g., the upwind side of the unit).
- **Minimize contact between food and contaminated clothes** to reduce textile-to-food ingestion.[20]
- **Minimize smoldering combustion** to reduce production of unhealthy smoke components.
- **When safe to do so, plan to minimize securing/cold-trailing activities** (e.g., putting out stumps and logs), allowing areas to burn out naturally. Minimize “dry” securing during the smoldering phase of burns. Use water to suppress dust and ash.
- **Try consolidating (“bone-piling”) logs so they can burn out naturally** rather than physically extinguishing every smoke source.[8]
- **If resources and project objectives allow, maximize heat and lofting** to reduce the smoke that remains near the surface where people can be exposed.

After the Burn

- **Host your after-action review (AAR) in a smoke-free area**.
- **After the burn, PPE can continue to release toxic compounds into the air**.[21,22] Take off smoke-laden clothing before getting into your vehicle or going indoors.
- **Bag and store contaminated gear as soon as possible in a well-ventilated area** away from your living quarters or sleeping area. Clean all contaminated gear and equipment as close to the fire line as possible.
- **If possible, use a different washing machine for your fire clothes** than for your everyday clothing. Organizations that burn frequently may consider having a designated washer and drier for employees’ PPE.

If you plan on wearing a mask on a prescribed burn, wear a "particulate respirator" that has been approved by the National Institute of Occupational Safety and Health (NIOSH). These respirators will say "NIOSH" and either "N95" or "P100" on them. Choose a respirator that has two straps that go around your head; ensure that the respirator fits securely over your nose and chin.[23] Those with facial hair will not be able to achieve a completely secure seal.

Though respirators can reduce smoke exposure, they can also make it more difficult to breathe, increasing the risk of heat-related illness. Be sure to take breaks often and drink water. Also be aware of your proximity to heat and embers when wearing a respirator, as most of them are made of synthetic materials.

Prescribed fire practitioners wearing N95 respirators when pile burning.
PC: David Benterou

Though prioritizing your health is a career-long commitment, there are opportunities to reduce smoke exposure and create safeguards to protect your well-being at every burn. Adopt a comprehensive approach to safety and protect the health of yourself and other practitioners.

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