HEALTH CONCERNS AND PRESCRIBED FIRE SMOKE

Introduction

Prescribed fire personnel are exposed to a number of toxins in the smoke they breathe. Sources of toxins include the burning vegetation and any trash, garbage, or structures that may be present in the burn unit. This discussion deals solely with toxins derived from burning vegetation. It does not cover specific toxins which may cause allergic or sensitivity reactions, such as smoke from poison ivy.

In 1994, the USDA Forest Service Pacific Northwest Research Station and the University of Washington Department of Environmental Health completed a study of smoke exposure on prescribed burns in the Northwestern US. Although the study found smoke exposure levels were higher on prescribed burns than on wildfires, the data showed that in most circumstances, fire crews are *not* subject to dangerous levels of toxins. A few instances did occur, however, when exposure threshold values were exceeded.

In April 1997, a conference was held to review the results of recent health studies and develop a risk management plan for protecting fire crews. The results were published by Missoula Technology Development Center in Health Hazards of Smoke, Technical Report 9751-2836-MTDC. (See Information Sources below for information on requesting a copy from MTDC.) Recommendations included changes in training and tactics to minimize exposure, and monitoring to safeguard personnel and increase awareness of potential health effects.
We need to be aware of the potential hazards, educate crew members, and take action to reduce exposure whenever possible.

Toxins in Prescribed Fire Smoke

The principle products of combustion on wildland fires are water vapor and carbon dioxide. Most toxins are products of incomplete or inefficient combustion. In general, the less efficient the combustion, the more toxins are produced. Remember that most smoke, and most of its toxins, is produced in the smoldering phase of the fire, after the flaming front has passed.

The five toxins of most concern in prescribed fire smoke are:

- carbon monoxide
- respirable particulates
- formaldehyde
- acrolein
- benzene

Carbon Monoxide

In the Forest Service study, CO was the toxin most frequently documented at concentrations above recommended levels during burns. Because CO is an odorless, colorless gas, crew members may be unaware of overexposure. CO affects the body by reducing the oxygen carrying capacity of the blood. Initial exposure symptoms include headache, nausea, dizziness, and weakness, followed in severe cases by loss of time awareness, motor skills, and mental acuity. The effects of this toxin are cumulative, so you should be mindful of

continued exposure over several days. As a general rule, carboxyhemoglobin levels decline 50% every four hours once exposure ceases. It can therefore take 18-24 hours to purge CO from the body.
The risk of overexposure to CO is significantly greater in smokers, who already have a significant background level of carboxyhemoglobin in their blood. CO also presents a greater potential hazard to pregnant women. Fetal blood levels of CO may be 10-15% higher than maternal levels.

Particulate matter
Particulates are the major pollutants from prescribed fire of concern to regulators. The US EPA recently revised the National Ambient Air Quality Standard to include PM2.5, fine particles which are 2.5 microns in diameter or less. Studies have shown a correlation between number of hospitalizations for respiratory problems and pollution events of high concentrations of fine particulates.

Over 90% of particulates produced in prescribed fire smoke are respirable. The remaining 10% drop out of the air, or are filtered by the nose or mouth. Particulates serve as vectors of carcinogens (such as polynuclear aromatic hydrocarbons) and other toxic compounds. Overexposure causes irritation of mucous membranes, and a decrease in lung capacity and function over time. At least one study, however, has shown recovery of normal lung capacity and function in nonsmokers after several months without exposure.

Formaldehyde
The odor of this toxin is detectable at very low concentrations (about 1.0 ppm). Low-level exposure causes irritation of eyes, stuffy nose and sore throat. Higher levels cause irritation to spread to the lower respiratory tract. Long-term exposure of formaldehyde may cause nasal cancer.

Acrolein
Acrolein is another type of aldehyde which has a piercing, choking odor, even at very low concentrations. Low-level exposure causes severe irritation of eyes and upper respiratory tract, producing stinging and tearing of eyes, nausea, and vomiting. Higher concentrations have been measured in white smoke, as opposed to emissions from glowing combustion.

Benzene
Although benzene is a natural product of wood combustion, the chief source for this potent carcinogen on prescribed burns is fuel for drip torches, pumps, etc. Ignition crews and engine operators are especially susceptible. Symptoms of exposure include headache, nausea, dizziness, and difficulty breathing. Prolonged exposure can result in anemia, liver and kidney damage, and cancer.

Combined Effects
Because particulates, formaldehyde, and acrolein all act as respiratory irritants, their combined effect must be considered when judging exposure. Tolerance levels may also be lower when working at high elevations or air temperatures.

Exposure Limits

The National Institute of Occupational Safety and Health (NIOSH) and the American Conference of Governmental Industrial Hygienists (ACGIH) develop recommendations for threshold limit values (TLV) for airborne concentrations of substances in the workplace. They make recommendations for:

- average exposure over an eight-hour day (Time Weighted Average),
- a higher concentration tolerable for short periods, about 15 minutes (Short Term Exposure Limit), and
- a maximum concentration that should never be exceeded (Ceiling).

The Occupational Safety and Health Administration reviews recommendations made by NIOSH, ACGIH and advocacy groups, and then regulates exposure limits to hazardous materials in the workplace.

Exposure Monitoring

Studies have shown that carbon monoxide exposure levels are significantly correlated to levels of particulates, formaldehyde, and acrolein, especially at lower concentrations. This is important because carbon monoxide is easy and inexpensive to monitor. There are two readily available means of monitoring CO.

Diffusion tube dosimeters are pen-like, and worn clipped to the collar during work. They provide cumulative data that can be used to calculate the average workday exposure (TWA), but do not provide any indication that the STEL has been exceeded. They are lightweight and inexpensive (about $4.50 each, not reusable). Diffusion tube dosimeter readings correlate reasonably well with laboratory analyses of air samples.

Dataloggers are highly accurate and provide more information than dosimeters, but are heavy and have a high initial cost ($800 each). They can provide continuous display of CO concentrations, and give an audible warning if the wearer exceeds exposure limits. Most dataloggers can download information into a computer.

Minimizing Risk

The burn boss should take steps to minimize crew members' exposure to smoke. These measures should be considered in the planning stages of the burn, and discussed during the pre-burn briefing. The following is a list of possible actions available to the burn leader to minimize risk.

- Provide awareness training for crew members.
- Remove trash from the unit.
- Minimize emission production during the burn. Conditions which typically produce greater emissions and/or exposure include: high or very low fuel moistures, high ground-level wind speeds, inversions or low mixing height, and low transport windspeeds. In the recent Forest Service study, fuel loading did not significantly effect exposure.

- Rotate crew members in high-exposure assignments, such as holding downwind. If smoke concentrations are very high, this may have the unwanted effect of overexposing more people. Think carefully before stationing crew in heavy smoke zones.
- Monitor exposure using CO dosimeters, especially for crew members at higher risk.
- Consider respirator use (see below).
- Don't smoke cigarettes. As previously mentioned, the toxic effects of compounds produced in prescribed fire smoke are intensified in cigarette smokers. One study in Australia showed crew members were more at risk from the carbon monoxide produced by their cigarettes than from the smoke of the burning vegetation.

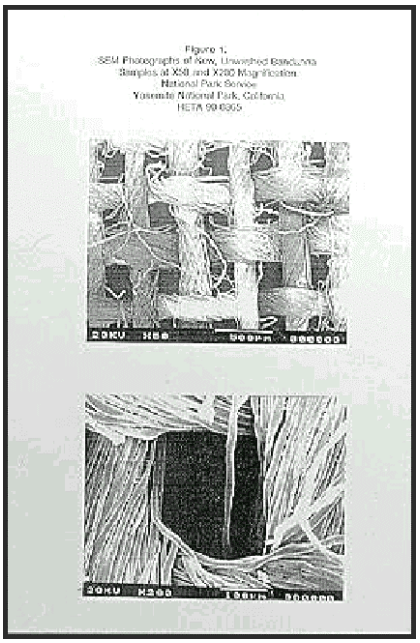
Remember to **listen to your body**. If you experience symptoms of overexposure, inform your line boss or supervisor on the burn. He or she will assist you in getting out of your position on the fireline, and in getting you first aid if necessary.

Respirators

The National Institute for Occupational Safety and Health (NIOSH) has *not* approved a respirator for wildland firefighting. However, several types of respirators have been studied for applicability on fires. One of the recommendations of the April 1997 Conference was to develop a respiratory protection program for use on prescribed burns, where toxin levels were found to be higher. The Missoula Technology Development Center was charged with this task.
The common types of respirators used on prescribed fires are disposable, half-mask and full-face. Each of the has its advantages and disadvantages. Facial hair may prevent a proper seal in these respirators.

Respirators may be fitted with filters for particulates and/or cartridges that will absorb specific organic vapors. High efficiency particulate air (HEPA) filters are designed to filter over 99% of respirable particulates. The drawback of HEPA filters and all cartridges is that they increase breathing resistance through the respirator, increasing stress on the user. The powered air purifying respirator (PAPR) overcomes this problem by incorporating a battery-powered blower to deliver decontaminated air to a full-face mask. However, PAPRs are expensive and bulky. Most recent research has focused on air-purifying respirators with gas cartridges that would remove 95% of respirable particulates, organic vapors and acid gases.

No respirator (except SCBA) protects the wearer against carbon monoxide! It is important not to develop a false sense of security while wearing a respirator. Even though you may be able to tolerate standing in smoke for long periods of time, you are still being exposed to carbon monoxide. Without the self-limiting irritation of the particulates, CO overexposure can occur more easily.



A bandana is not a respirator! In the scanning- electron micrograph of a bandanna at left, the pore size of the cotton fabric is approximately 250 microns. The size of particulates of concern for health impacts is 2.5 microns! Clearly, a bandanna does nothing to protect your respiratory system from particulates. (Also, never place a wet bandanna over your mouth to breathe through. This may result in a steam burn in your mouth and respiratory system.)

If an employer recommends respirators to its employees, it must enact an 11-step training and maintenance program, mandated by OSHA. This is one component of the respiratory protection program under development by MTDC.

Information and Equipment Sources

Health Hazards of Smoke: Recommendations of the April 1997 Consensus Conference summarizes the latest findings on this topic. There is a companion video for this publication. Both are available from Missoula Technology and Development Center; Building #1, Ft. Missoula; Missoula MT 59801; phone 406-329-3989.

Smoke Exposure at Prescribed Burns; Final Report is available from Pacific Northwest Research Station, Forestry Sciences Laboratory; 4043 Roosevelt Way, NE; Seattle, WA 98105; phone 206-553-7815.

Health Hazards of Smoke was an excellent newsletter with good articles on risk, monitoring, exposure limits and respirators. It is no longer in publication, but back issues may be available MTDC.

Carbon monoxide diffusion tube dosimeters and dataloggers are manufactured by National Draeger, Inc. Contact them at 412-787-8383 for local sources.

Dosimeters and respirators are available in some lab supply catalogs (e.g., Lab Safety Supply: 800-356-0783).