

Health Hazards of Smoke

Recommendations of the
Consensus Conference
April 1997



United States Department of Agriculture
Forest Service

Technology & Development Program
Missoula, Montana

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5100 Fire
9751-2836-MTDC

November 1997

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About the Cover—Firefighters from the Pike Hotshot Crew wear smoke sampling packs to gather breathing zone data for the Pacific Northwest Research Station study of smoke exposure.

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Summary

For decades, firefighters and fire managers have been concerned about the health effects of smoke from wildland and prescribed fires. Early research proved to be inconclusive. A 1985 survey of the fire community indicated that studying the health effects of smoke was not a high priority for fire managers. That position changed dramatically with the 1987 fires of northern California and the 1988 Yellowstone fires, when thousands of firefighters experienced respiratory problems. To address these concerns, the National Wildfire Coordinating Group (NWCG), related agencies, employee groups, and specialists in occupational medicine, industrial hygiene, toxicology, and risk management met in San Diego in 1989. They developed a study plan for determining the immediate and long-term effects of exposure to forest fire smoke.

The comprehensive plan proposed studies in the areas of emissions characterization, employee exposure, health effects, risk assessment, and risk management. NWCG assigned the Missoula Technology and Development Center (MTDC) to serve as the focal point for ongoing and future studies on the



effects of wildland fire smoke on firefighters.

The Center convened a technical panel to help guide the project, to review and evaluate existing research, and to identify research and development priorities. The Center published a semiannual report to communicate findings and developments of the Health Hazards of Smoke project to firefighters, fire managers, researchers, regulatory agencies, organizations, and manufacturers.

In April 1997 a conference reviewed progress in each area of the study plan, and reached consensus on the elements of a risk management plan that could be implemented within the existing fire management structure. This document includes the papers presented at that conference and the recommendations for implementing the risk management plan.

In brief, participants concluded that toxic emissions were present in smoke, that the incidence of exposure in excess of Occupational Safety and Health Administration permissible exposure limits was relatively low (fewer than 5% of prescribed fire cases, even less for wildfire), and that documented health effects were moderate and often

reversible. Recommendations for risk management include changes in training and tactics to further minimize exposures, and monitoring to increase awareness of smoke and to help limit exposure. Health maintenance recommendations are intended to prevent the spread of illness and ensure healthy immune function. Medical surveillance is needed to track exposures and further research is necessary to fill gaps in our understanding of emissions, exposure, and health effects.

Risk Management Plan: Conference Recommendations



In April 1997, the NWCG Safety and Health Working Team and MTDC sponsored a conference to review progress in each area of the study plan, and to reach consensus on the elements of a risk management plan. This document outlines the comprehensive risk management

plan produced at that conference. While some elements of the risk management plan (health maintenance, training, and tactics) should be implemented immediately, others (monitoring) will require a phase-in period. The need for respiratory protection

will require further study and development, pending the success of other elements of the program. Finally, certain research projects will receive immediate attention while the attention others receive will depend on program priorities and the availability of adequate funding.

Program Management

The basic authority for safety and health standards is mandated by the Department of Labor, Occupational Safety and Health Administration (OSHA). That authority is contained in documents including:

Occupational Safety and Health Act of 1970

Executive Order 12196, February 26, 1980

29 CFR 1910 Occupational Safety and Health Standards

29 CFR 1960 Basic Program Elements for Federal Employee Occupational Safety and Health Programs

According to Executive Order 12196, the head of each agency shall:

Furnish to employees places and conditions of employment that are free from recognized hazards that are causing or are likely to cause death or serious physical harm.

Studies of wildland firefighters indicate the potential for exposure to toxic by-products of combustion. While it is impossible to ensure complete safety in the wildland environment, management has the responsibility to ensure the health and safety of wildland firefighters.

Recommendations

- Develop an interagency Risk Management Plan for fire management activities.
- Develop occupational guidelines for use in field operations to

manage employee exposure to the health hazards of smoke.

- Sponsor additional research to improve the understanding of the risks and effects of smoke on employee health based on the hazards and the risk assessment, and to determine the effectiveness of the risk management plan.

Training and Tactics

Exposure studies show that firefighters are sometimes exposed to levels of smoke that exceed OSHA permissible exposure limits. Improvements in training and tactics should further minimize opportunities for exposure.

Recommendations

Training

- Modules on the health hazards of smoke should be developed and included in courses for agency administrators and fire program managers.
- Include a segment on the health hazards of smoke in all appropriate fire training courses at the local, regional, and national levels.
- Develop a course to orient program administrators with responsibilities for implementing respiratory protection or smoke monitoring programs.
- Create a photo series that visually displays a range of smoke conditions and

corresponding levels of carbon monoxide.

- Develop a wallet-sized reference card to aid visual recognition of different levels of smoke and carbon monoxide.

- Recommend that fire behavior analysts and safety officers include smoke considerations in their messages and briefings where appropriate.

- Prepare an orientation video suitable for all agency personnel, with emphasis on the effects of smoke on wildland firefighters and what firefighters and fire managers can do to avoid exposure.

Tactics: Wildfire

- Include smoke hazards on the ICS-215A worksheet at planning and briefing sessions.
- Use flank attack as opposed to head attack, where appropriate, in heavy smoke situations.
- Minimize mop-up when possible.
- Adjust operational periods on mop-up to avoid periods of inversion.
- Use time and patience instead of water to put the fire out: use burn piles, allow areas to burn themselves out. Rely on burn-up instead of mop-up.
- In heavy smoke conditions, give up acres to gain control.
- Fire behavior forecasts should discuss smoke and inversion potentials.

- Locate camps and incident command posts in areas that are not prone to inversions.
- Reduce dust by watering roads at the incident, on drier roads leading to the incident, and in the base camp area.
- Use minimum impact suppression techniques (MIST).

Tactics: Prescribed Fire

- Use equipment rather than people, when possible, in holding areas (sprinklers, foam, etc.).
- Design burn plans with “maximum allowable perimeter” to permit minor slopovers.
- Minimize mop-up whenever possible (consider regulatory conflicts regarding hazard tree removal, endangered species, and so forth in risk assessments for fire safety and health).
- Minimize snag falling, consistent with safety concerns, to avoid putting heavy fuels on the ground that will require mop-up.
- Change ignition times and firing patterns to minimize smoke impacts on lighters.
- Address smoke impacts in the job hazard analysis (JHA).
- Rotate personnel out of heavy smoke areas.
- Adjust prescriptions where possible to reduce smoke by providing more complete combustion.

Use visual reference materials and monitoring equipment to reinforce

smoke training and tactics, and to document their impact on employee exposure.

Monitoring

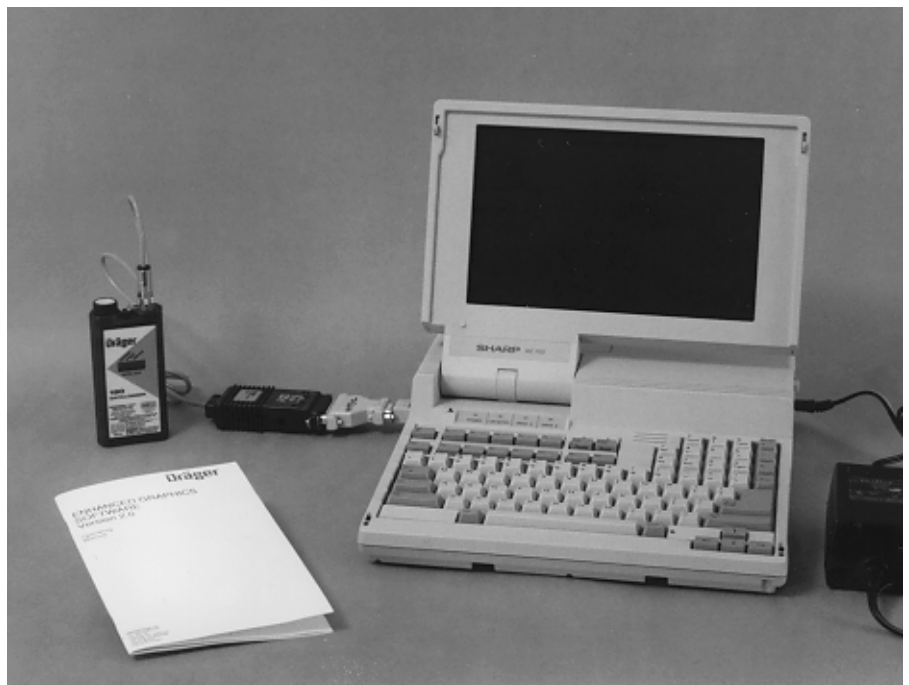
The working group proposed the following actions (in order of importance):

Electronic Dosimeter for CO Exposure Monitoring

A CO exposure monitoring program using electronic datalogging dosimeters is recommended. These relatively simple and inexpensive battery-powered instruments measure CO levels and display and store the data. Stored exposure data may be transferred to a computer at daily or weekly intervals. Each unit, about the size of a pack of

cigarettes, is worn near the firefighter’s breathing zone during the workshift. The unit weighs less than 8 ounces and costs less than \$800. Using the USDA Forest Service as an example, the initial scale of the program is suggested to be on the order of 10 instruments per region, covering different types of crews, using one dosimeter per crew. Data collection would be primarily conducted by fire management or safety/health staff of each participating agency, after initial training. Data collection should employ a standard protocol that includes quality assurance steps so that data would be comparable within and among agencies and from year-to-year.

The program should begin with lab tests of models from potential vendors to establish their accuracy and precision of CO measurement in smoke matrix, then proceed to a field-test to



Carbon monoxide datalogger (left) linked to PC for data storage and analysis.

determine ease of use, ruggedness, effects of dust, water, and temperature and the effectiveness of radio-frequency shielding. Agencies could then negotiate lowest-cost bulk orders for approved models. With a year or two of logistical experience and phased implementation, the program could provide most crews with CO monitoring protection.

Monitoring should endeavor to limit employee exposure below a ceiling of 200 ppm CO and a maximum time-weighted average (TWA) of 25 ppm CO. This limit protects employees from respiratory particulate, formaldehyde, and acrolein as well as carbon monoxide by maintaining exposure levels below OSHA permissible exposure limits (PEL's).

Benefits of this action are:

- Lowest-cost and least-intrusive way to monitor smoke exposure (carbon monoxide is correlated with other hazards in smoke).
- Meets OSHA requirements for routine monitoring of the hazards found in smoke.
- Greatly increases hazard awareness; provides crews and managers with feedback about the hazards of smoke.
- Should provide rapid reduction of overexposure to smoke because of the instruments' alarm features.
- Collects data to define high-exposure and low-exposure situations for each region, tactic, and condition.
- Obtains broad baseline of CO exposure data from which to measure progress at controlling exposures.

- Allows respiratory irritant exposures to be estimated based on correlations of these irritants (formaldehyde, acrolein, and respirable particulate) to CO levels in smoke.

Particulate Matter Characterization

Fully characterize the chemical composition of particulate matter in smoke (both respirable and total particulate) by laboratory evaluation. The composition of particulate (amounts of organic and inorganic chemicals) would be evaluated by detailed chemical analysis. Smoke from unusual fuels from different regions would be cost-effectively compared in this way. Field verification of laboratory results would be necessary, but the lab evaluation will limit the cost of the field exposure assessment to those chemicals (if any) that pose a potential hazard to firefighters.

Benefits of this action are:

- Answers questions about toxic chemicals associated with particulate exposures and the unusual properties of smoke from certain vegetation fires (such as poison oak).
- Guides any further particulate matter exposure characterization in the field.
- May assist in establishing an occupational exposure criteria for smoke particles.
- May establish the link between health effects and exposures, especially by defining additional respiratory irritants in smoke.

- When combined with CO measurement, will better define the relationship between respiratory irritants and CO for field verification. Ultimately, correlations between irritants and CO may be used routinely to estimate exposure to a number of chemicals based on CO monitoring.

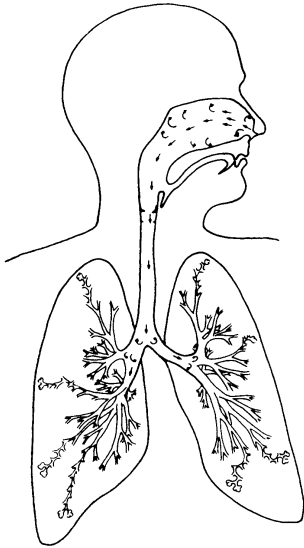
Reactive Gas Characterization

Comparative study of reactive gases in smoke should be accomplished using different measurement methods. The use of the Fourier transform infrared spectrophotometer (FTIR) allows instantaneous measurements of such gases, yet results are not always in accordance with traditional sorbent-based methods. Side-by-side measurements of reactive gases (such as aldehydes) in smoke using different methods in a lab situation will define whether existing methods introduce biases or artifacts when measuring gases in smoke, and will identify poorly characterized gases for further exposure assessment in the field.

Benefits of this action are:

- Answers questions about toxic gases in smoke and unusual properties of smoke from certain vegetation fires (such as poison oak).
- Guides any further smoke exposure characterization in the field
- May explain the link between health effects and exposures, especially defining additional respiratory irritants in smoke.

- Will better define correlation between respiratory irritants and CO for field verification and ultimately, routine use of correlations to estimate multiple chemical exposure from CO measurement.



Health Maintenance

Analysis of data from medical aid stations at incidents indicates that 30 to 50% of reported visits were due to upper respiratory problems, defined as coughs, colds and sore throats (Vore, 1996). Upper respiratory problems may be due to exposure to smoke, or to exhaustion, stress, or poor nutrition, all of which suppress the immune system and increase the likelihood of upper respiratory infections. Steps should be taken to maintain the health of firefighters' immune systems and to avoid the spread of infection. These steps include but are not limited to the following recommendations.

Recommendations

Health Promotion

- Emphasize the importance of good health and fitness in all training.
- Monitor personnel for signs of fatigue and illness.
- Ensure that firefighters are properly equipped for anticipated conditions (cold nights, rain).
- Provide for good rest and sleeping conditions.
- Encourage a high fluid intake before, during, and after work for all personnel.
- Provide for adequate nutrition and supplements (e.g., antioxidants) if needed.
- Allow sick firefighters adequate time for recovery.

Health Maintenance

- Promote personal hygiene by providing washing facilities near food lines and toilets.
- Limit close contact among firefighters by providing personal sleeping tents.
- Discourage sharing of canteens except in emergencies.
- Encourage personnel to cover their mouth and nose when they cough or sneeze to avoid the spread of infection.
- When symptoms are "above the neck" (stuffy nose, sneezing, scratchy throat), it is safe to continue work. If symptoms include fever,

aching muscles, nausea, or diarrhea, hard work should be reduced or curtailed.

- Segregate infected personnel when possible.
- Demobilize crews that have a large number of sick personnel.
- Consider the need for medical assistance when conditions at the incident are severe (e.g., numerous or severe respiratory problems, inversions in fire camps).

Health Video

All fire suppression personnel need to be informed about their role in health maintenance. The video should emphasize:

- Healthy Behaviors, such as washing before eating, not sharing canteens, and minimizing smoke exposure (including cigarettes).
- Physical Fitness is essential for firefighters to perform their arduous work and to adjust to environmental stressors such as heat and altitude. Fitness boosts the body's ability to fight illness and recover from injury. Physical exhaustion suppresses immune function and leads to upper respiratory infections.
- Rest and Sleep are essential for good performance and health. Locate camps in smoke-free areas, supply fire personnel with individual tents and quiet sleeping areas, and adhere to work/rest ratios.
- Nutrition, including energy, nutrients and water, is critical to performance and the function of the immune

system. Provide firefighters adequate energy by serving a variety of foods, including fresh fruits and vegetables; encourage attention to hydration (before, during, and after work); provide supplements, if necessary, to ensure health and performance.

- Stress Management techniques (e.g., relaxation, meditation) should be taught to personnel to help them cope with physical and emotional stresses that are known to suppress immune system function. All personnel should be aware of the different ways stress can affect health and safety and what they can do to minimize the problem.

Respiratory Protection

Respiratory protection should be considered only when other controls, such as training, tactics, and monitoring, fail to protect worker health and safety. It is hoped that monitoring will demonstrate that changes in training, tactics, and other elements of this program will further minimize the already low level of exposure (less than 5% of prescribed fire cases and a lower percentage of wildfire cases exceed OSHA permissible exposure limits). In the meantime, we propose developing a respiratory protection program and a limited pilot project using respirators for selected prescribed burning conditions. These measures would develop the capability to implement a large-scale respirator program, and

serve the immediate needs of those working on prescribed fires.

Recommendations

Air-Purifying Respirators

Design and conduct a pilot test of respirator use for *prescribed fire*. Develop and field test a respiratory protection program that meets OSHA requirements (29 CFR 1910.134) (including medical evaluation, monitoring, medical surveillance, fit testing, training, maintenance, records, etc.).

- MTDC will complete a model respiratory protection program and distribute the program to field study sites on computer disks.
- Recommend a NIOSH-certified respirator with 95N multigas cartridges (95 indicates that the filter removes 95% of respirable particulate; N means the respirator is not resistant to oil; multigas indicates removal of organic vapors and acid gases; the cartridge does not remove carbon monoxide).
- Develop and test the training package required to support the respiratory protection program (medical and fit testing, training, maintenance, etc.).
- Establish performance criteria and tests (heat, flame resistance) for air-purifying respirators intended for use on prescribed and wildland fires.

Monitor Regulations and Products

MTDC will continue to monitor new regulations (NIOSH, OSHA)

and products (respirators, monitors), and disseminate information as necessary.

New Product Development

If needed, develop, test, and seek NIOSH approval for a respirator designed specifically for the wildland firefighter (e.g., mouthpiece respirator).

Note: Removing carbon monoxide from the breathing air currently requires converting CO to CO₂ in an exothermic reaction. The process adds additional breathing resistance, increases respiratory work with the respiratory stimulus of carbon dioxide, and increases heat stress with the breathing of hot air. No device that is currently available effectively protects the worker from all the hazards in smoke.

Respirators should not be used unless a respiratory protection program is in effect.



Medical Surveillance and Research

A program of medical surveillance is needed to track firefighters' health. In addition, health-related research should be considered to determine the long-term effects of exposure to smoke. Emissions and exposure research should be completed to allow a full assessment of risk.

Recommendations

Medical Surveillance

Establish Baseline—Use a comprehensive, confidential questionnaire that covers medical history, smoking and other exposures (occupational, wood burning), symptoms, or respiratory problems (e.g., asthma, allergies) for all employees involved in wildland fire suppression.

Periodic Followup—Employ a schedule that includes periodic pulmonary function testing for continuing seasonal and career employees.

Research: Health Related

Respiratory Health—Conduct a 5- to 10-year respiratory health effects study to assess the effects of smoke exposure on lung function.

Retrospective Cohort Mortality Study—Consider a retrospective study to assess long-term cancer, heart, and chronic pulmonary disease risks among a cohort of firefighters with many years of experience.

Research: Emissions and Exposures

Crystalline Silica—Crystalline silica, detected in employee

exposure studies, is a health hazard that could cause irreversible lung damage. Particulate samples collected at wildfires during 1994 and 1995 provide an opportunity to assess exposure levels and risks. This information is essential to complete a comprehensive risk assessment of pulmonary health risks (Pacific Northwest Research Station).

Lung Function and Exposure—Data on employee exposure and lung function has been collected but not analyzed. Statistical analysis of the data would allow an evaluation of the relationship

between smoke exposure and lung function in wildland firefighters (Pacific Northwest Research Station).

Fire Camps—Studies have shown that smoke exposure in fire camps can be high, especially during periods of inversions when smoke is trapped in valleys. Inexpensive monitoring equipment will allow assessment of the exposure to particulate matter and carbon monoxide at fire camps to determine the risk and the need for specific risk management strategies (Pacific Northwest Research Station).

Carbon Monoxide Ratios—There are many toxic compounds and irritants contained in the smoke from burning biomass. Assessment of the ratio of toxic compounds to easily measured carbon monoxide in a variety of vegetation types and from different geographic areas will add confidence and accuracy to estimates of potential exposure (Intermountain Fire Sciences Laboratory).

Ozone Formation—Ozone could be an additional source of respiratory irritation for firefighters. Assessment of ozone exposure would provide additional information for risk assessment and the development of strategies to mitigate exposures (Intermountain Fire Sciences Laboratory).



Subject participating in lung function test.

Risk Communication

In conjunction with the preceding recommendations, a concerted risk communication effort is needed. Risks should be communicated widely, in terms understandable by the average employee. Specific recommendations for dissemination of the outcomes of

the Health Hazards of Smoke project include:

- Wide dissemination of the risk management plan and disclosure of the risks of smoke exposure to prospective firefighters.
- A video that reviews the Health Hazards of Smoke project and outlines elements of the risk management plan (video in progress at MTDC).
- Presentations dealing with the Health Hazards of Smoke project and risk management plan at regional and national meetings.
- Periodic updates to review the effectiveness of the risk management plan, new regulations, research, and products (e.g., annual Health Hazards of Smoke report).

