Spring 1996

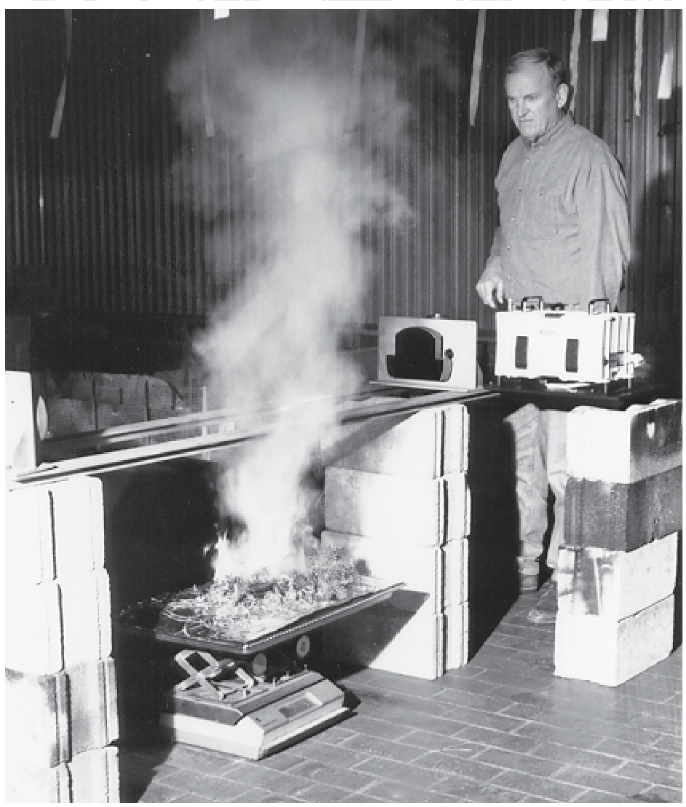
Health Hazards of Smoke

USDA Forest Service Missoula Technology & Development Center

The National Wildfire Coordinating Group coordinates wildland firefighting efforts among Federal and State agencies. The Coordinating Group assigned the Missoula Technology and Development Center to serve as the focal point for ongoing and future studies on the effects of wildland fire smoke on firefighters. This status report, the twelfth in the series, provides a review of project activities.

Project Review

Throughout the history of wildland fire suppression, firefighters have been exposed to smoke. The smoke has been viewed as a health, esthetic, economic, or political problem for communities and agencies. Until recently, little concern was expressed for the health of those most exposed to the problem, wildland firefighters. In his history of fire in America (1982), Pyne alludes to an emerging interest in carbon monoxide as a problem for firefighters. In the 1960's, researchers began probing the effects of working for days and weeks in the forest fire environment, but this research was episodic and the results were inconclusive (Thoele, 1995). A 1985 Fire Equipment Working Team survey found that dealing with smoke and carbon monoxide was not a high priority for fire managers. That position changed dramatically with the 1987 and 1988 fire seasons, when thousands of firefighters lined up at medical tents with respiratory complaints. To address the problem the National Wildfire Coordinating Group (NWCG), related agencies, employee groups, and specialists in occupational medicine, industrial hygiene, and risk management met early in 1989 to outline a study plan for determining the immediate and long-term exposure to forest fire smoke (Ward, Rothman, and Strickland, 1989).



Ron Susott of the fire chemistry project monitors a test using a new spectrometer. The smoke from a small-scale fire passes through an infrared beam that is reflected back to the FTIR for analysis (see report on page 3).

The comprehensive plan proposed studies in the areas of: emissions characterization, employee exposure, health effects, risk assessment, and risk management. The 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 funding priorities. The Center publishes a semiannual report to communicate recent research and future directions of the Health Hazards of Smoke project to firefighters, fire managers, researchers, regulatory agencies, organizations, and manufacturers.

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Ongoing emissions studies continue to expand our knowledge of the toxic constituents of smoke. Employee exposure studies have documented firefighter exposure to the most toxic constituents, including carbon monoxide, respirable particulate, formaldehyde, acrolein, and benzene. Health studies have measured the effects of daily and seasonal exposure on pulmonary function, but no longitudinal studies have been undertaken to explore the potential for long-term health effects, such as cancer, heart disease, or chronic obstructive pulmonary disease. The first phase of a comprehensive risk assessment procedure is now in progress (see page 5). The results of the risk assessment will identify appropriate risk management strategies and procedures that may include training, tactics, equipment, crew rotation, monitoring, medical surveillance, and respiratory protection.

When completed, the risk management program will be disseminated to workers in the field. An accompanying video will summarize findings of the project and essential elements of the risk management program. Afterward, management of the health hazards of smoke will become part of the health and safety program. But that will not signal an end of the problem. Agencies will have to remain informed of new research on emissions and health effects, of developments in respiratory protection, and of changes in air quality standards and regulations. As research expands our knowledge of toxics and health effects, the permissible exposure limits and regulations may be changed, requiring adaptation of the risk management program.

Pyne, S. *Fire in America*, Princeton University Press, Princeton, NJ, 1982.

Thoele, M. *Fire Line*, Fulcrum Publishing, Golden, CO, 1995.

Ward, D.; Rothman, N.; Strickland, P. (Editors), The Effects of Forest Fire Smoke on Firefighters: a Comprehensive Study Plan, U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Missoula, MT, 1989.

Exposure Summary

Exposure studies conducted by the Forest Service Pacific Northwest Research Station have documented the exposure of firefighters to a number of hazards in smoke. Fewer than 5% of the exposures reported in the study of prescribed fire exceeded the permissible exposure limits (PEL's) listed by the Occupational Health and Safety Administration (OSHA), the federal agency that sets limits and monitors compliance with the regulations. Wildland fire exposures exceeded PEL's less often than prescribed fire exposures (Table 1).

Table 1–Average exposures and exposure limits for hazards in smoke.

Hazard	WL fire	Rx fire	OSHA	NIOSH**	ACGIH**
CO (ppm)	4.1*	4.1	50	35	25
RPM (mg/m^3)	0.69	0.63	5.0	_	3.0
Form (ppm)	0.023	0.047	0.75	0.016	0.3 C*
Acrol (ppm)	0.003	0.009	0.1	0.1	0.1
Benz (ppm)	0.016	0.016	1.0	0.1	0.3

Where: **WL Fire** = wildland fire and Rx fire = prescribed fire; CO = carbon monoxide; RPM = respirable particulate matter; Form = formaldehyde; Acrol = acrolein; and Benz = benzene.

*All limits are time-weighted averages (TWA) unless noted; C = ceiling.
****NIOSH** - the National Institute for Occupational Safety and Health recommended exposure limits (REL); and
ACGIH - the American Conference of Governmental Industrial Hygienists threshold limit values (TLV); both are recommendations.

Wildland and prescribed fire exposure averages are from:

Reinhardt, T., Hanneman, A., and **Ottmar, R.** *Smoke Exposure at Prescribed Burns*, USDA Forest Service, PNW Research Station, Seattle, 1994.

Reinhardt, T., Black, J., and **Ottmar, R.** *Smoke Exposure at Wildfires in the Western United States*, USDA Forest Service, PNW Research Station, Seattle, 1995.

Smoke Studies

The Fire Chemistry Project at the Intermountain Fire Sciences Laboratory has installed new instrumentation to characterize the chemical composition of smoke. The instrument is an open-path Fourier transform infrared spectrometer (FTIR) that allows real-time analysis without the need to collect samples. The instrument has already been used to measure emissions from many fuel types including: ponderosa pine, sagebrush, grasses, poplar, maple leaves, and a variety of organic soils. The higher sensitivity and rapid response of the new instrument make it possible to survey a wide variety of fuels and to correlate fire behavior with emissions. For example, the white smoke generated by rapid heating of fresh fuel contains many oxygenated compounds not detected in the emissions from glowing combustion, and a higher ratio of formaldehyde (**Figure 1**). White smoke also contained a sugar that had not been detected in smoke before. Larger fuel elements were found to smolder in a way that produces a larger ratio of white smoke to glowing combustion.

The new system also has high resistance to chemical interference that plagues measurements of many chemicals, including acrolein. Acrolein has not yet been detected in the emissions from any of the samples, suggesting that firefighter exposure to acrolein may be lower than previous estimates based on field studies. Extensive investigation of how fuels and fire behavior affect emissions could produce guidelines to help firefighters reduce their exposure to the health hazards of smoke. (A description of the FTIR can be found in Health Hazards of Smoke, No. 8, Spring 1994: results from a prototype of this instrument, borrowed from the National Center for Atmospheric Research, were featured in Health Hazards of Smoke, No. 11, Fall 1995. For information on the Fire Chemistry Project contact Darold Ward, Ph.D., at the Intermountain Fire Sciences Laboratory in Missoula, MT.).

(**Note:** *Acrolein has been detected in all employee exposure studies. It has been found to be a significant contributor to the noncancer hazard index. See Risk Assessment on page 5.*)

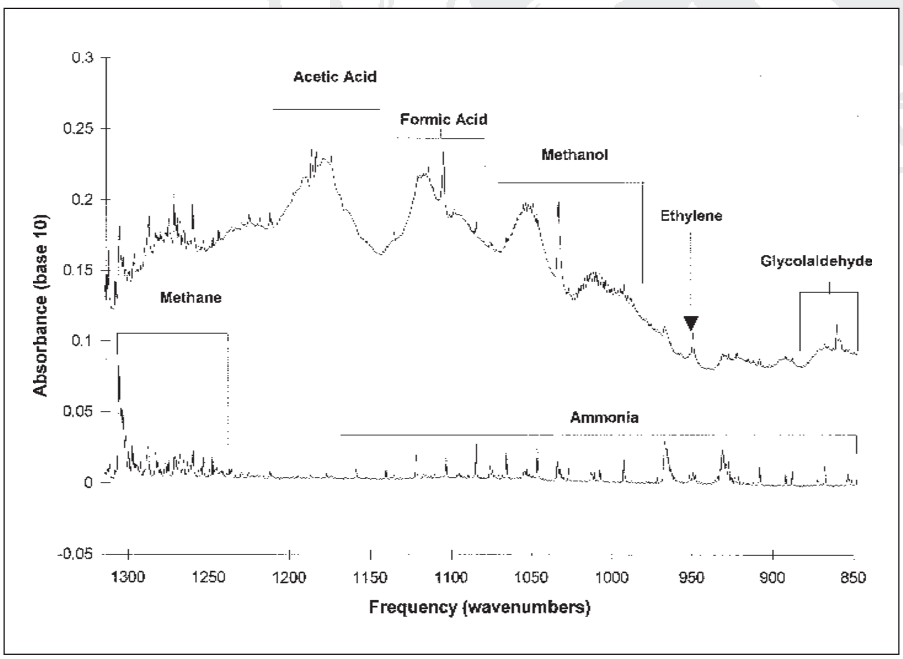


Figure 1—A portion of the spectrum of white smoke (top) shows many oxygenated compounds, while the same spectral region for glowing emissions (bottom) shows only ammonia and methane.

Research

Evaluation of Full-Face Air-Purifying Respirators for Wildland Firefighting Use
Beason, D., Johnson, J., Foote, K., and Weaver, W. Lawrence Livermore National Laboratory and California Department of Forestry and Fire Protection, Summary Report, 1996.

Wildland fire suppression personnel employed by the California Department of Forestry do not currently have equipment to protect themselves from the short-term (acute) effects of smoke from wildland fires. In addition, no regulations exist that specify appropriate respiratory protection. The current air-purifying respirator technology and carbon monoxide monitoring have not been adapted to fit wildland fire suppression requirements. This 3-year limited study evaluated the ability of wildland firefighters to perform their normal job function while wearing full-face air-purifying respirators.

In the first 2 years of this study a prototype "smart" air-purifying respirator that incorporated a real-time carbon monoxide monitor into a commercial full-face respirator was designed, developed, and field tested. Data on carbon monoxide exposure while fighting wildland fires was collected. During the third year of this study eight different commercially available full-face air-purifying respirators equipped with a variety of cartridges were evaluated. An apparatus to help the firefighter carry the respirator and carbon monoxide personal monitor was designed and fabricated. A smoke exposure test method was developed and a laboratory study on the penetration of smoke through respirator cartridges was conducted.

The authors concluded that the full-face air-purifying respirator was well received by firefighters;

firefighters felt that respirator use should not be mandatory. The HEPA (high-efficiency particulate air) with OV/AG (organic vapor/acid gas) was the cartridge of choice. Work rate was reduced with the respirator; however, work output might drop or cease without protection. Current respirator technology does not meet all the needs of the wildland firefighter.

A respiratory protection program will be required before respirators can be issued. The program should address where and how devices should be worn and include a medical examination. Carbon monoxide monitoring will still be necessary since air-purifying respirators do not remove CO. The authors also recommended that the California Department of Forestry consider a physical fitness training program to ensure the maintenance of physical fitness.

Respiratory Health Hazards and Lung Function in Wildland Firefighters
Harrison, R., Materna, B., and Rothman, N. Occupational Medicine: State of the Art Reviews, Philadelphia: Hanley and Belfus, Inc., 1995.

This review of research on airborne contaminant levels and possible respiratory effects associated with wildland firefighting includes the authors' recommendations for an occupational health program for respiratory hazards. According to the authors, when wildland firefighters spend long periods working in visible smoke, they may be at risk of exceeding regulatory and/or recommended full-shift occupational exposure limits for carbon monoxide, particulate, and aldehydes such as formaldehyde and acrolein. The authors' recommendations include: exposure monitoring, exposure reduction (including respiratory protection), medical surveillance, training, and research. The exposure monitoring would monitor carbon monoxide, a correlate of other hazards, as a way to provide protection from other contaminants. Exposure reduction includes crew repositioning, rotation, and shift limits. Respiratory protection, if used, will still require monitoring of carbon monoxide. Under medical surveillance the authors recommend baseline assessment with a questionnaire and pulmonary function measures, along with clinical followup of exposures and symptoms, and periodic pulmonary function surveillance. Training in health hazards and hazard reduction, monitoring equipment, and respirators is also recommended. Finally, the authors recommend epidemiological studies to evaluate the effects of chronic exposures.

Abstracts

Incidence of Respiratory Symptoms and Chronic Disease in a Non Smoking Population as a Function of Long-Term Cumulative Exposure to Ambient Air Pollutants
Abbey, D.E. Loma Linda University, 1994.

Data on occurrence and severity of chronic bronchitis and asthma, on occurrence of cancer, heart disease, and mortality, and on numerous lifestyle and air pollution exposure covariates were collected from a cohort of 6340 nonsmoking California Seventh-Day Adventists. Monthly pollutant exposures were estimated from ambient concentrations of seven air pollutants—ozone, NO_2, SO_2, TSP (total suspended particulate), PM_{10} (particulate matter < 10 µm), $PM_{2.5}$ (particulate matter < 2.5 µm), and SO_4—experienced by subjects from 1966 to 1987. Statistical analyses estimated relationships between these health endpoints and long-term average ambient air pollutant concentrations, adjusting for covariates. Total suspended particulate, the pollutant most related to health endpoints, was significantly related to the occurrence of and increases in the severity of chronic bronchitis and asthma and to the occurrence of cancer in females. Exposure to PM_{10} was associated with the occurrence of chronic bronchitis and the severity of asthma, and $PM_{2.5}$ was significantly but less strongly associated with several respiratory endpoints. Ozone and SO_4 were significantly associated with occurrence and severity of asthma. There were no significant associations between any health endpoint and SO_2 or NO2. Multipollutant analyses were performed to investigate whether any of the significant relationships between pollutants and health endpoints were due to surrogate relationships with other pollutants.

Canadian Environmental Protection Act Priority Substances List Assessment Report: Polycyclic Aromatic Hydrocarbons
Government of Canada, Ottawa, 1994.

Polycyclic aromatic hydrocarbons (PAH's) are emitted into the Canadian environment from both natural and anthropogenic sources. Forest fires, which release approximately 2000 tons of PAH's per year, are the single most important source of PAH's in Canada. However, since forest fires are generally widely separated in time and space across the country, they do not result in continuous exposures in any specific areas. Anthropogenic sources are numerous and result in emissions of PAH's into all environmental compartments. Based on these considerations, it has been concluded that PAH's are entering the environment in a concentration or under conditions that may have harmful effects on the environment. These PAH's are not considered to constitute a danger to the environment on which human life depends. The PAH's benzo(a)pyrene, benzo(b)fluoranthene, and indeno(1,2,2cd)pyrene may constitute a danger in Canada to human life or health.

Dead Space in the Breathing Apparatus: Interaction with Ventilation
Warkender, D. and Lundgren, C. Ergonomics, 38: 1745-58, 1995.

Dead space in breathing apparatus may cause increased ventilation and/or CO_2 retention. Interactions between ventilation and dead space were tested in three devices: a full-face mask with oro-nasal (mouth and nose) cup, a full-face mask without the cup, and a mouthpiece. Ventilation and gas exchange were measured in five subjects. Since the dead space can vary with ventilation levels, it is not sufficient to test breathing apparatus only at rest as required by NIOSH. Dead space increased during exercise, and ventilation was 10 to 12% higher during exercise in the mask without the oro-nasal cup. Comparisons of the mean inspired PCO_2 to the maximum values considered acceptable by various organizations showed that the mouthpiece was always acceptable, the oro-nasal mask was marginally acceptable, and the mask without the cup was not acceptable in some conditions.

Risk Assessment

"We fear things in proportion to our ignorance of them."
Livy (Roman historian, 64 B.C. to 17 A.D.)

Assessment of the Health Risks of Chronic Smoke Exposure for Wildland Firefighters
Booze, T. and Reinhardt, T. Preliminary Report of Screening Health Risk Assessment, Radian Corporation, 1996.

This report presents the results of a screening health risk assessment for wildland firefighters exposed to smoke from wildfires and prescribed burns. A screening assessment makes use of limited resources to identify areas where significant health risk may be present, and allows areas where risk is not significant to be identified. This is done in part by making assumptions about exposure in the absence of suitably specific data. These assumptions are designed to be protective of health by making conservative estimates, resulting in risk estimates that are higher than thought to actually occur. This assessment is limited to handcrew firefighters exposed to smoke from natural fuels at either wildfires or prescribed burns.

This screening risk assessment focused on chemicals of potential concern (COPC) that had been identified in previous studies. Respirable particulate matter (RPM), an important COPC in smoke, was omitted from this assessment because acceptable toxicity values were not readily available (Future risk assessment efforts will include RPM). Toxicity values were obtained primarily from Environmental Protection Agency data bases, which are intended to protect all members of the population.

Exposure assessment was based on Type I and Type II crews, exposed to average and reasonable maximal exposures (RME), a near worst-case scenario based on the 95% confidence interval of available exposure data. For example, the average wildfire exposure of a Type I crew member (smokejumpers, hotshots, rappel, and helitack) was estimated at 8 years, 64 days per year, and 9.4 hours per day, while the RME exposure was estimated at 25 years, 97 days per year, and 9.4 hours per day. Average estimates for Type II crew members (Ranger District crews) were 7 years, 10 days per year, and 9.4 hours per day, while the RME was 25 years, 46 days per year, and 9.4 hours per day. Smoke exposure estimates for the RME conditions were based on the 95% confidence interval of exposures. Exposure estimates were based on crews in the Pacific Northwest; exposure patterns may differ in other regions. Risks were estimated for cancer and for noncancerous health effects.

The cancer risk is an upper-bound estimate of the probability of developing a cancer over a lifetime of exposure to the conditions specified in the risk assessment. Under the worst-case RME condition, which specifies 25 years with 97 days per year of high exposures, the wildfire cancer risk estimate for a Type I crew member was 3 cancers per 10 000 exposed population (or 300 per million, Table 1). The risk for the average (mean) Type I exposure was 24 excess cancers per million. Risks for the Type II crew members were 1.4 per 10 000 (or 140 per million) for the RME and 3.2 per million for the mean exposure conditions. Actual risks are not likely to be greater and may, due to assumptions, extrapolations, and uncertainty, be significantly lower.

Table 1—Summary of cancer risk.*

Crew type	Wildfires	Prescribed burns
Type I RME**	300	60
Type I Mean	24	2.6
Type II RME	140	78
Type II Mean	3.2	1.3

** Risk per million persons exposed.*
***RME = reasonable maximal exposure.*

The assessment indicated that benzene and formaldehyde were the most significant contributors to the cancer risk. Other chemicals evaluated in this assessment, including polycyclic aromatic hydrocarbons, did not appear to be significant contributors to the risk. The risk estimates do not imply that 3 out of 10 000 Type I firefighters exposed under the RME assumptions used in this report will develop cancer. Instead they are values used to determine what should and should not be considered a significant risk. The cancer risks values reported are within values that have been considered acceptable for an occupational exposure. Cancer risks for prescribed burns fell well below those estimated for wildfire exposures.

Noncancer hazard indices were calculated to determine the potential for adverse effects. Values above 1 indicated a potential for an adverse effect. Type I crew exposures yielded hazard indices of 226 for the RME and 99.4 for the average conditions. Type II crew exposures yielded indices of 107 for the RME and 15.5 for the mean exposure conditions. Values for more frequent wildfire exposures generally exceeded those for prescribed burns.

Table 2—Summary of noncancer hazard indices.

Crew type	Wildfires	Prescribed burns
Type I RME*	226	118
Type I Mean	99.4	17.5
Type II RME	107	152
Type II Mean	15.5	10.5

**RME = reasonable maximal exposure.*

The assessment indicated that acrolein was responsible for a large part of the noncancer hazard index. The inhalation reference dose is based on animal studies of the most sensitive adverse effect, the effect occurring at the lowest dose. In the case of acrolein, the nasal passage response to irritation is the most sensitive adverse effect. The acrolein concentration used in this assessment (0.01 to 0.04 mg/m^3), based on employee exposure studies, is well below the occupational exposure limits recommended by NIOSH and ACGIH and enforced by OSHA (0.23 mg/m^3). All other COPC's evaluated for noncancer effects had hazard indices less than 1. Respirable particulate matter was not evaluated in this assessment.

In summary, this screening-level risk assessment indicates that further risk assessment efforts should be focused on specific COPC's, and shows that adverse health effects are unlikely for the others, based on the available data and assumptions used. The contribution of respirable particulate matter remains to be evaluated. The risk levels for benzene and formaldehyde will be further evaluated, but based on this assessment they are within the ranges considered acceptable by regulatory agencies. Risk assessments will be improved with better data and a sensitivity analysis that determines how much of an effect is exerted on the total risk by each component. Risk management of long-term exposure to avoid chronic health effects will be based on subsequent analyses and the outcome for respirable particulate matter. Exposure management remains a good strategy where acute health effects are probable from short-term exposures that exceed occupational exposure limits.

(**Note:** *The reasonable maximal exposure (RME) estimates define a worst-case scenario based on the 95% confidence interval of available exposure data, describing the highest exposure that could reasonably be expected to occur. The RME for Type I crew members assumes 25 years of exposure to prolonged high exposures. The estimate assumes 25 consecutive fire seasons similar in duration to the 1988 or 1994 seasons, with 97 days of exposure to pollution concentrations ranging from 50 to 100% higher than the average exposures measured in employee exposure studies. While some firefighters may work as many days, few spend 97 days on fires, and it is doubtful that significant numbers of firefighters would be exposed for 97 days at the levels used in the RME assumptions. With an RME cancer risk of 3 in 10 000, and a population of about 2000 Type I firefighters potentially exposed, one could reasonably expect 0.6 firefighters might develop cancer over a 70-year life span. The RME defines the worst that could occur under extreme conditions. The average and RME values provide a range of risk estimates that, if not representing the true risk, will err on the side of health protectiveness*).

Cancer Risks

Oncologists estimate that genetics is the source of 60 to 90% of cancers, with bad habits, food, and pollution making up the remainder. Cancer risks less than 1 in 1 million pose a negligible addition to the background cancer risk in the United States of approximately 1 in 3. Some common cancer risks include:

- *One x-ray is 7 in 1 million*
- *Lifetime radon exposure (@ 4 picocuries per liter) is 20 in 1000*
- *Smoking two packs of cigarettes per day is 100 in 1000.*

Some foods also increase cancer risk, with 6 pounds of peanut butter, 80 quarts of milk, or 90 pounds of steak each carrying a 1 in 1 million risk.

Risk Management

Respiratory Problems

An examination of Northern Region (R-1) Forest Service reported injuries for 1994 and 1995 led Mark Vore, forest dispatcher on the Idaho Panhandle National Forests and Paul Fieldhouse, medical unit coordinator for the Aerial Fire Depot in Missoula, to conduct a further analysis of respiratory problems associated with firefighting. The 1994-1995 data included:

Total injuries	Fire injuries	Upper respiratory (UR)	UR % of fire
804	575	172	30%

Data from medical aid stations for eight fires in 1994 indicated:

Total visits	Total UR*	UR %
8816	4239	48%

* UR = cough, cold, and sore throat.

Of these visits, 80.7% of upper respiratory problems were due to colds (38.8% of total), 6% for coughs (3% of total), and 13% for sore throat (6.3% of total). By way of contrast, lacerations, abrasions, contusions, sprains, breaks, dislocations, stings, and bites accounted for 811 visits or 9.2% of total visits. In recognition of the problem Vore, Fieldhouse, Mike Sternberg, supervisory forestry technician for the Idaho Panhandle National Forests, and a county health nurse drew up recommendations.

Promote General Health of Firefighters:

- Provide for good rest, in warm, dry areas if possible
- Provide proper equipment for the conditions
- Consider nutritional supplements
- Maintain adequate hydration
- Monitor for signs of fatigue or illness
- Allow R and R (rest and relaxation) for sick firefighters
- Recognize that coughing expels inhaled particulate, but also has the potential to spread infection.

Figure 2
72%

7 1/8 x 5
10 x 7

Print to Outside Edge of Border
DO NOT Print Border

When possible, firefighters should select tactics that minimize exposure to smoke, such as working on the flank of the fire.

Limit the spread of contagious illness:

- Limit communal contacts (shared canteens, shared tents)
- Segregate infected personnel
- Demobilize crews if a large proportion of the crew is sick
- Consider county health assistance at fire camps.

Promote personal hygiene practices, such as covering the mouth and nose when coughing or sneezing; washing hands after toilet and before meals.

Vore and coworkers provide these suggestions as the start of a plan to reduce the incidence of upper respiratory problems among firefighters.

(**Note:** *Additional considerations include tactics to avoid exposure to smoke, such as siting fire camps in areas free of smoke, more frequent crew rotations, increased R and R during periods of increased exposure, and maintenance of a healthy immune system by managing stress, maintaining fitness and avoiding fatigue, and improved nutrition (see immune friendly foods in HHS No. 6, Spring 1993), and of course, minimizing exposure to smoke, including smoke from cigarettes*).

Risk Management Program

When the research studies and the risk assessment have been completed, a comprehensive risk management program will be prepared for implementation by fire managers and firefighters. The program may include:

Monitor Exposure

- Use data loggers to monitor carbon monoxide; pull back or reposition crews as the time-weighted average approaches 25 ppm.
- Maintain records and document significant exposures.
- Forward data summary to NWCG for use in medical surveillance and the prospective health study.

Manage Exposure

- Site camps in smoke-free areas; use personal tents to improve sleep and reduce exposure to particulate and to limit exposure to infected coworkers.
- Alter work/rest and R and R schedules during periods of exposure; provide time off after days of exposure to allow time for respiratory clearance
- Develop and use tactics to avoid exposure to smoke (reposition, flank, etc.).
- Maintain a healthy immune system by maintaining fitness and avoiding exhaustion, providing good nutrition and supplements if needed, and by managing stress effectively (communication, concern, cooperation).
- Teach and demonstrate health habits to limit exposure to infection (don't share water bottles - except in emergencies).
- Monitor smoke management procedures for effectiveness.
- Provide appropriate training in smoke management for fire managers and firefighters.
- Consider a no-smoking policy for all wildland firefighters.

Respirators

- Consider the use of air-purifying respirators for selected workers (for example, full-face respirators for those who work in high exposure areas on prescribed burns; lightweight, low-maintenance (disposable) devices for hot shots; half-mask respirator for those working around engines or fuels).
- Provide mandatory medical testing, mask fit testing, training, and surveillance for those using respiratory protection.
- Assign responsibility for cleaning, maintenance, and storage of respirators, and for monitoring the effectiveness of the program.

Surveillance

- Establish baseline data with pulmonary function testing and a comprehensive questionnaire covering medical history, smoking and other exposures, symptoms, or respiratory problems.
- Conduct periodic followup for continuing employees.
- Retest after significant exposures.
- Forward data summary to NWCG for use in medical surveillance and the prospective health study.
- Conduct annual review of illness/injury and worker's compensation files.

Data Base/Research

- Collect and tabulate monitoring, surveillance and exposure data for annual summaries and for use in the prospective health study, the chronic pulmonary function study, and other health-related research.

Annual Review

- Designate responsibility to develop, disseminate, and coordinate elements of the risk management program. The NWCG Safety and Health Working Team (SHWT) will be responsible for the review of annual summaries of monitoring, surveillance, and exposure data, publication of annual summaries, and adjusting the program as necessary. The SHWT could help design, contract, and monitor the prospective health study, the chronic pulmonary function study, and other health-related research deemed necessary to ensure employee health.

Risk management program elements will be finalized during the Health Hazards of Smoke Symposium being planned for 1997 (see note on pg. 10), included in the final report, and disseminated to the field. If you have ideas or suggestions for this developing program, send them to Brian Sharkey at MTDC.

Warning Signs

In addition to the information available from smoke monitoring devices, risk assessment and research studies point to several possible warning signs that could help firefighters minimize exposure to smoke. The risk assessment (see page 5) identified acrolein as the greatest contributor to the noncancer health risk. Acrolein is a potent respiratory irritant that also causes eye irritation and lacrimation (formation of tears). High levels of exposure can cause bronchial inflammation, bronchitis, and pulmonary edema. And chronic exposure has been reported to cause metaplastic and hyperplastic changes in the trachea and nasal cavities of animals. Acrolein concentrations have been correlated to other contaminants in smoke, including carbon monoxide, respirable particulate, and formaldehyde. Due to its irritating qualities, acrolein serves as an early warning of exposure to smoke. While sensitivity to acrolein varies among individuals, eye irritation is certain as levels approach permissible exposure limits.

Studies at the Intermountain Fire Sciences Laboratory suggest the possibility that smoke color may be associated with toxicity. The white smoke generated by rapid heating of fresh fuels contains higher formaldehyde concentrations than the emissions from glowing combustion. Large fuel elements produce a larger ratio of white smoke. Of course, the smoke from smoldering combustion contains higher concentrations of carbon monoxide. Further work in this area could provide warning properties of toxic emissions that could be used to minimize exposure to the health hazards of smoke. Until then, avoid working around white smoke. If you do work around smoke, redeploy when the smoke causes eye and respiratory tract irritation.

Respirator Standards

The Occupational Safety and Health Administration and NIOSH are updating the standards that regulate the use and certification of respirators in the workplace. Under the new regulations (42 CFR part 84) NIOSH will certify three classes of filters (N, R, and P) with three levels of efficiency (95, 99, and 99.97%) in each class. The efficiency indicates the degree to which the filter removes small (0.3 µm) particulate. The N series particulate respirators are for use against particulates that are free of oil or other severely degrading aerosols and have no time limitations. The R series respirators may be used against degrading aerosols for no longer than one shift. The P series filters can be used against any particulate aerosol and have no limitations. All N, R, and P particulate filters must be discarded when they become soiled , damaged, or when breathing becomes difficult. Filters tested under the old standards may be used for three more years.

Assigned protection factors (APF's) are numbers given to classes of respirators (such as half face or full face) that indicate the anticipated maximum protection the respirator can provide. A respirator with an APF of 10 could be expected to protect a worker exposed to air concentrations up to 10 times the permissible exposure level (PEL) for a particular toxic chemical, such as formaldehyde. If the contaminant level is up to 50 times the PEL, a full-face respirator is required. If the level of exposure exceeds 50 times the PEL, a self-contained breathing apparatus (SCBA) must be used.

(**Note:** *Lightweight, comfortable, maintenance-free respirators conforming to the new NIOSH requirements are now available. For example, Racal has dust/mist filters in the 95, 99, and 100% (99.97% HEPA filter*) range, including one filter that removes nuisance-level organic vapors (those below the OSHA PEL). Since particulate and other contaminants seldom exceed PEL, an efficiency of 95% would seem adequate in most circumstances. If you decide to use respiratory protection for prescribed or wildfire use, be certain that the device you select is made of fire-retardant materials.

A half-face or maintenance-free respirator with an RPF of 10 should be adequate for most conditions. Some firefighters involved in prescribed burning have indicated a preference for a full-face respirator to protect their eyes from exposure to smoke. Since air-purifying respirators do not remove carbon monoxide, it remains a potential hazard even when other contaminant exposures are controlled. Finally, remember that OSHA requires a written 11-step respirator program if you decide to use respiratory protection.)

Monitoring Guide

An introductory guide to monitoring firefighters' exposure to smoke is available from the Forest Service's Pacific Northwest Research Station in Seattle, WA. The guide discusses the use of electronic dosimeters that measure carbon monoxide exposure and record the exposure data for evaluation on a computer. The basic steps to start a smoke monitoring program are presented, along with the use of carbon monoxide measurements to predict exposure to respiratory irritants. Copies of the guide, titled

"Guide to Monitoring Smoke Exposure of Wildland Firefighters," may be obtained by calling (206) 553-7815.

EPA Particulate Recommendations

The Environmental Protection Agency is considering changes in the particulate matter (PM) standards that govern the nation's air quality. Recommendations for change include:

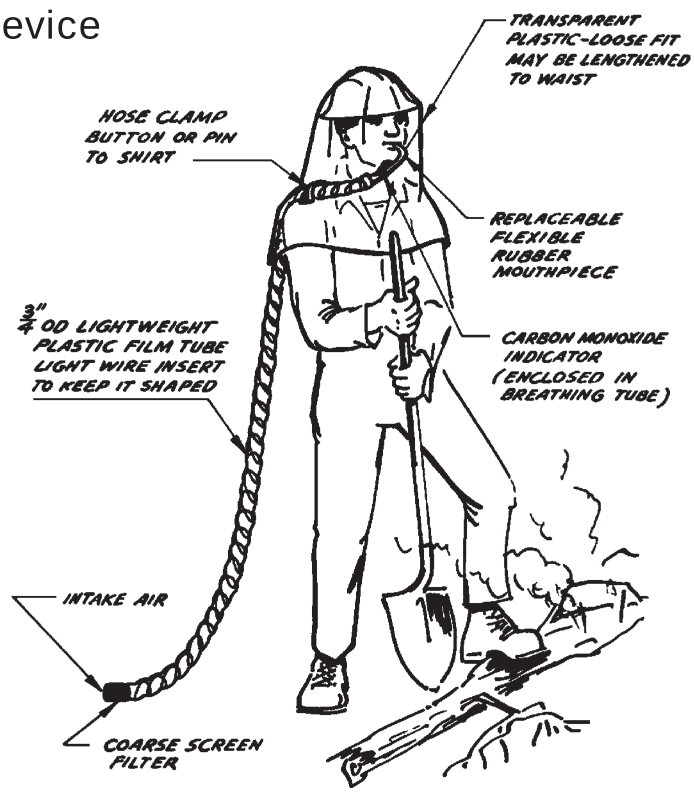
- Introduction of new 24-hour and annual standards for $PM_{2.5}$, fine particulate with an aerodynamic diameter less than 2.5 µm;
- Retention of the annual PM_{10} standard to provide protection from coarse particles.

The 24-hour PM2.5 standard is recommended to be in the range of 25 to 85 µg/m^3. The current 24-hour PM10 standard is 150 µg/m^3.

The proposed changes are based on studies that indicate increased health risks with exposure to fine particulate. One study looked at the association between air pollution and mortality in six cities. The authors found that air pollution was positively associated with death from lung cancer and cardiopulmonary disease, and mortality was most strongly associated with fine particulates (Dockery and others, New England Journal of Medicine, 329: 1753-1759, 1993).

(**Note:** *Larger particles are trapped in the airways and removed by the ciliary escalator and expectoration. The smoke from forest fires contains a high proportion of fine particulates that can be inhaled into the alveolar region of the lung, where they are absorbed or removed more slowly.*)

Smoke Protection Device



Employee suggestion (circa 1960) for a respiratory protection device.

Coming Up

Technical Committee

Representatives of the Health Hazards of Smoke Technical Committee will meet in conjunction with the NWCG Safety and Health Working Team at the team's spring meeting in May.

HHS Symposium

The Missoula Technology and Development Center, the NWCG Safety and Health Working Team, and the Health Hazards of Smoke Technical Committee are considering holding a symposium on the Health Hazards of Smoke in 1997. One purpose would be to review progress in five major areas; hazardous emissions, employee exposure, health effects, risk assessment, and risk management. It is intended that the symposium be broad in scope, and that it bring together the range of professionals with an interest in the effects of forest fire smoke on wildland firefighters, including fire managers, firefighters, researchers, regulators, manufacturers, and others. The symposium's major goal would be to translate prior research and risk assessment findings into a comprehensive risk management program, capable of being implemented within the existing fire management structure. The format would include invited presentations, slide and poster presentations, open forums, and working groups. For more information, contact Brian Sharkey, Ph.D., c/o USDA Forest Service MTDC, Building 1, Fort Missoula, Missoula, MT 59801 (406-329-3989; Fax - 406-329-3719; DG - B.Sharkey:R01A).

Glossary/Index

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References are for volume number and page (1: 5,7 refers to vol. 1, pages 5 and 7).

NWCG: The National Wildfire Coordinating Group coordinates firefighting efforts among federal and state agencies. **1:** 1, 2; **2:** 1, 2, 8; **3:** 1, 2; **4**: 1, 2, 9; **5:** 1, 2, 10; **12**: 8.

OSHA: The Occupational Safety and Health Administration, the Labor Department agency responsible for enforcing workplace safety standards. **1:** 2; **2**: 3, 6; **4:** 4; **5:** 2, 4, 8; **8**: 6; **12**: 2, 9.

PAH's: Polynuclear aromatic hydrocarbons, a class of compounds that includes known or suspected carcinogens. **4**: 4; **12**: 4, 6.

PEL: Permissible Exposure Limits (OSHA), REL: Recommended Exposure Limits (NIOSH), and TLV: Threshold Limit Values (ACGIH) set the upper limits for exposure to workplace hazards. **6**: 2,3; **12**: 2.

Pulmonary Function Tests: Measures of lung function used to determine the effect of exposure to contaminants. **1**: 2, 3, 4; **2**: 4, 6; **3**: 3, 5; **4**: 4, 5; **5**: 7, 9; **7**: 7, **9**: 3, 4, 5, 6; **11**: 2, 3, 4.

Respirable particulate: Small pieces of airborne soot that can find their way to the alveolar region of the lung. **1**: 2, 3, 4, 5; **2**: 1, 4, 6; **3**: 1, 3, 5, 6, 7, 10**,** **4:** 2, 4, 6, 7; **5:** 2, 4, 5, 6, 7**;** **7:** 3, 7 **10:** 4, 5; **11**: 5, 6; **12:** 2, 5, 6, 10.

Respiratory system: The airways and lungs responsible for the intake of air and the exchange of oxygen and carbon dioxide. **2**: 1.

Risk Assessment: Analytical process used to organize data to evaluate possible impacts of exposure on human health. **7:** 2; **8**: 3; **10**: 2, 3; **11:** 6; **12**: 5, 6.

Risk Management: Ways to monitor and minimize the risks of exposure to forest fire smoke. **1**: 4, 5, 6; **2**: 6, 7; **3**: 6, 7, 8, 9; **4:** 6, 7; **5**: 2, 8, 9; **11**: 7,8; **12**: 4, 7, 8.

STEL: Short-term exposure limit. **2**: 3; **4**: 7; **5**: 4, 5; **6**: 2, 3.

TWA: Time-weighted average. **2:** 3; **4**: 7; **5**: 4, 5; **6**: 2, 3, 4; **12:** 2.