# HETA 98-0173-2782
# Colorado Department of Public Health and Environment
# Colorado

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# PREFACE

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# ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Jane McCammon of HETAB, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS) with extensive assistance from Lyle McKenzie of the Colorado Department of Public Health and Environment. Tim Reinhardt of Radian International provided draft materials and technical assistance that were invaluable in project development. Desktop publishing of this report was performed by Joyce Woody. Review and preparation for printing were performed by Penny Arthur.

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# Health Hazard Evaluation Report 98-0173-2782
# Colorado Department of Public Health and Environment
# Colorado
# March 2000

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## SUMMARY

On March 30, 1998, the Colorado Department of Public Health and Environment (CDPHE) requested assistance in a project to be conducted in cooperation with the US Department of Agriculture Forest Service (USFS) and the Department of Interior Bureau of Land Management (BLM) personnel. The goal of the CDPHE project was to field-test implementation of a wildland firefighter smoke exposure management and monitoring program outlined in earlier National Wildfire Coordinating Group (NWCG)-sponsored research. CDPHE also hoped to provide further exposure data related to fuels in areas of the United States other than the Pacific Northwest where much of the previous data had been collected. CDPHE requested assistance from NIOSH to train firefighters in the use of CO dosimeters during wildland fires, and to assist in data collection when the USFS and BLM conducted firefighting activities during the 1998 fire season.

NIOSH and CDPHE equipped four crews of wildland firefighters (USFS and BLM) with carbon monoxide (CO) monitors, related equipment for calibration and data transfer, and training for two people from each crew in the use of the monitors. The firefighters monitored CO exposures from 0 to 176 hours (depending upon the crew) during the fire season. During 8 of the 41 monitoring periods, CO exposure concentrations exceeded the NIOSH recommended ceiling exposure limit of 200 parts per million (ppm). During 10 of the 41 sessions, measured CO concentrations exceeded the ACGIH excursion limit of 125 ppm. Time-weighted average exposures were all within current occupational exposure limits. During 2 of the 41 periods (each 480 minutes in length), CO exposure concentrations of 21 and 22 ppm were measured. These exposures approach the American Conference of Governmental Industrial Hygienists (ACGIH) time-weighted TLV of 25 ppm.

The data collected in this evaluation indicate that wildland firefighters may be exposed to CO concentrations in excess of recommended ceiling/excursion limits during as much as 25% of their firefighting efforts. This project showed that managers and safety officers can establish exposure monitoring and control programs to aid in the reduction of firefighter exposures to smoke components, given the proper financial and administrative support. Several issues will need to be further evaluated and addressed before such programs can be optimally effective. These issues include: availability of equipment and training; consistent documentation of monitoring conditions among firefighters; a written smoke exposure management plan containing a response strategy when CO monitors alarm, health surveillance programs, and training and tactics to minimize exposures.

Keywords: SIC Code 0851 (Forestry Services) Wildland firefighter, carbon monoxide, CO, State health department, Colorado Department of Public Health and Environment, CDPHE, National Wildfire Coordinating Group, NWCG, United States Forestry Service, USFS, Department of Interior, DOI Bureau of Land Management, BLM

# Highlights of the NIOSH Health Hazard Evaluation

## Wildland Firefighter-Managed Carbon Monoxide (CO) Exposure Monitoring

**NIOSH investigators joined with the Colorado Department of Public Health and Environment (CDPHE) to find out if a proposed exposure management program for wildland firefighters would work. Our goal was to outline strengths and limitations of putting the plan into action. In addition, our hope was to collect usable data about CO exposures of Colorado-based wildland firefighters.**

## What NIOSH Did

- We worked with CDPHE to carry out the firefighter exposure management program proposed by the NWCG (National Wildfire Coordinating Group). The proposed program had firefighters measure their exposure to CO and manage their exposure to smoke.
- We (NIOSH and CDPHE) developed a plan of action to equip and train firefighters to implement the program.
- Before the fire season, we trained four crews of Federal wildland firefighters in the use of CO exposure monitors that were provided to the crews through an Interagency Agreement.
- We visited the firefighters periodically to provide technical support and help them with any problems.

## What NIOSH Found

- Wildland firefighters were exposed to CO concentrations above recommended ceiling/excursion limits during 10 of 41 data recording sessions.
- Time-weighted average (TWA) CO exposures were not above current occupational exposure limits.
- Strengths of the proposed exposure management plan included: efficient exposure data collection; increased involvement of firefighters in exposure control; and the ability to measure exposures early in the firefighting efforts.
- Limitations of the proposed plan included inadequate/insufficient computer resources, radio frequency interference with the CO monitors, inadequate note-taking by firefighters, and the absence of a defined planned response to CO monitor alarms.

## What Federal Wildland Fire Management and Safety Personnel Can Do

- Commit resources to the use of CO monitors as a tool to manage smoke exposure.
- Develop a written smoke exposure management plan with a strategy for response to CO monitor alarms, related health surveillance, training, and tactics to reduce exposure.

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National Institute for Occupational Safety and Health
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# INTRODUCTION

On March 30, 1998, the National Institute for Occupational Safety and Health (NIOSH) received a request for technical assistance from the Colorado Department of Public Health and Environment (CDPHE), Denver, Colorado. CDPHE requested assistance in an interagency project to be conducted in cooperation with US Department of Agriculture Forest Service (USFS) and Department of Interior, Bureau of Land Management (BLM) personnel. CDPHE had entered into an interagency agreement with USFS to conduct the project. Subsequent to this agreement, support for the program under which CDPHE was to conduct the work was discontinued.

The goal of the CDPHE project was to field test implementation of a cost-effective way to conduct wildland firefighter smoke exposure management and monitoring objectives outlined in earlier USFS-sponsored research. This research demonstrated that carbon monoxide (CO) could be used as a surrogate measure of other smoke-related exposures, and would provide guidance as to when firefighters should use administrative controls or air-purifying respirators to reduce exposures during wildland fires. Because CDPHE was actively involved in a surveillance and intervention program for CO poisoning, the Department made plans to field test the viability of the proposed monitoring program outlined in that work (as discussed below). CDPHE also hoped to provide further exposure data related to fuels (trees and other vegetation) in areas of the United States other than the Pacific Northwest, where much of the previous data had been collected. CDPHE planned to equip firefighters with carbon monoxide (CO) monitors that displayed exposure concentrations, alarmed when high concentrations were detected, and stored data for transfer to a computer.

CDPHE had sufficient equipment to initiate the project but insufficient staff to carry out the work. The Department therefore requested assistance from NIOSH to train firefighters in the use of CO dosimeters during wildland fires, and to assist in data collection when the USFS conducted controlled burns in Colorado during the 1998 fire season.

# BACKGROUND

During wildland fires in northern California in 1987 and in Yellowstone National Park in 1989, thousands of firefighters experienced respiratory problems. To address concerns raised during those fires, a comprehensive study plan was initiated in 1989 by the National Wildfire Coordinating Group (NWCG), related agencies, employee groups, and specialists in occupational medicine, industrial hygiene, toxicology, and risk management. The plan was designed to determine the immediate and long-term effects of exposure to forest fire smoke.

In April 1997, a consensus conference reviewed progress in each area of the study plan. Conference participants recommended monitoring to increase awareness of the health effects of smoke and to limit exposure. Reinhardt and Ottmar presented guidelines for a firefighter smoke exposure monitoring program.[1] The guidelines described a simplified cost-effective approach to acquire baseline data and track future progress towards controlling smoke exposure among firefighters. Reinhardt demonstrated that exposure to acrolein, benzene, formaldehyde, and respirable particulate matter could be predicted from measurements of carbon monoxide (CO). The authors/presenters concluded that electronic CO dosimeters were the best tool to assess smoke exposure on a routine basis. Guidelines from this presentation, and other direct technical input from Reinhardt, were used in the design of the CDPHE/NIOSH protocol discussed here.

Measurement of wildland firefighter exposure has been hampered by the inability to quickly measure smoke early in the fire.[2] Data collection efforts have been poorly suited to the mobility and responsiveness needed to capture smoke exposure during initial attack. Most studies have repeatedly obtained measurements of smoke exposure during the latter stages of fire suppression, when smoke exposures are considered low. For example, few exposure measurements have been taken during initial fire attack operations, during backfires and burnout operations, or at the fire camp.

CO monitoring provides key information that firefighters and fire managers need to work safely because CO is an identified hazard and it always accompanies other hazardous components of smoke. Therefore, establishing a routine CO monitoring program that is well integrated into the wildland fire incident management system would ensure that the monitoring and safer work practices occur (even in dynamic situations) without imposing an unnecessary burden on firefighting activities.

For the work outlined in this report, CDPHE and NIOSH developed a protocol based on the suggestions of Reinhardt and Ottmar. Our goal was to determine the feasibility of implementing the protocol and to outline strengths and limitations in the field application of the plan. In addition, our hope was to collect usable data about the exposures incurred by wildland firefighters based in Colorado.

# METHODS

## Participants in the study

A memorandum of understanding to facilitate the collection and analysis of data was established between the US Department of Interior (USDI) BLM Grand Junction District, US Department of Agriculture (USDA) Forest Service White River National Forest, and CDPHE. BLM and USFS selected ten firefighters to participate in the training and data collection. These firefighters represented two crews from each agency, for a total representation of four crews. One of the four crews was a helitack crew; the remaining three units were ground-based firefighters.

Technical assistance and funding for the project was provided by NIOSH through two programs in the Division of Surveillance, Hazard Evaluation, and Field Studies. Equipment acquired by CDPHE was purchased through NIOSH Sentinel Event for Notification of Occupational Risk (SENSOR) funds. Technical assistance was provided by NIOSH Hazard Evaluation and Technical Assistance Program staff in the Denver Field Office.

## Training

CDPHE and NIOSH provided training for ten firefighters. During the one-day, five-hour hands-on training session, firefighters were provided with four self-contained kits that included a total of 11 CO dosimeters (2-3 per kit), related software and hardware for transferring stored data to a computer; calibration gas tanks (0, 50, and 100 parts per million [ppm] of CO) and flow-regulating valves, "breatholyzer" devices for collecting and analyzing expired breath CO concentrations, and simplified instruction sheets for calibration procedures. Each crew was asked to provide a notebook computer for the training and later data collection.

During training, the need for an additional set of simplified instruction sheets outlining steps to transfer the data from the datalogger to the computer became evident. Those instructions were subsequently developed and distributed.

The instructors introduced the firefighters to the project, explaining the objectives and goals. It was explained that this equipment should be used to measure exposures, as an alarm to warn firefighters of high CO concentrations, and as a guide for when they need to don respirators or move to an area of lower exposure. Firefighters were guided through operation of the dosimeters and transferring data. The importance of record-keeping was emphasized, and forms for recording field data were provided to each crew. Each crew was asked to record data that would facilitate correlation of collected data with fire type, weather conditions, duration of firefighting efforts, activities, etc.

All instruction sheets and data collection forms provided to the firefighters are included with this report as Attachment 1.

## Communication

The operational bases for these four crews were greater than 100 linear miles apart. In addition, they traveled to distant locations nationwide to fight fires. To facilitate communication between the crews and CDPHE/NIOSH, the CDPHE project officer was on call on a 24-hour basis via a cellular telephone throughout the project period. This allowed firefighters to check in regarding problems, questions, and refresher training they might need.

CDPHE visited the bases of the crews three weeks after the initial training. The hope was that this visit would serve to remind the crews to actually collect the data, and also would allow firefighters to ask questions about problems they had experienced in using the monitoring equipment.

Each crew was again visited by CDPHE and NIOSH two months after the training. The purpose of this visit was to gather interim data, provide additional assistance, encourage the crews to continue monitoring CO exposures, and check the status of the project. Dosimeters and stored data were collected approximately 90 days after the initial training.

## Sampling Instrumentation

All dosimeters provided to the firefighters were Biosystems Toxilog Model 54-1800-DL Personal Atmospheric Monitors equipped with CO sensors. Firefighters were instructed to calibrate the monitors before use with primary standard calibration gas of known concentration (0 and 100 parts of CO per million parts of air) and to conduct a quick check of calibration periodically using 50 ppm of CO. These monitors measure airborne CO in concentrations of 0 to 999 parts of CO per million parts of air, and are accurate to within $\pm$5 ppm, according to the manufacturer. The monitors were set to log data every minute and to alarm when CO concentrations exceeded 200 ppm at any time or if 8-hour time-weighted average exposures exceeded 50 ppm.

Equipment costs for this project are presented here for use by other agencies that may be interested in initiating a similar program: $7700 for 11 dosimeters; $540 for 4 data downloading cradles; $1320 for calibration gas (one each of 0, 50, and 100 ppm per crew); $1500 for 12 gas flow regulators; $60 for equipment bags ($15 each for each crew); $100 for parts to assemble 11 expired CO devices ($1100 if the device is purchased preassembled). Each crew had a computer available for storing accumulated data. This cost would have to be considered if a computer were not available. These costs will change over time with changes in technology.

# EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for the assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects even though their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the criterion. These combined effects are often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus potentially increase the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the workplace are: (1) NIOSH Recommended Exposure Limits (RELs),[3] (2) the American Conference of Governmental Industrial Hygienists' (ACGIH®) Threshold Limit Values (TLVs®),[4] and (3) the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs).[5] Employers are encouraged to follow the OSHA limits, the NIOSH RELs, the ACGIH TLVs, or whichever are the more protective criterion.

OSHA requires an employer to furnish employees a place of employment that is free from recognized hazards that are causing or are likely to cause death or serious physical harm [Occupational Safety and Health Act of 1970, Public Law 95–596, sec. 5.(a)(1)]. Thus, employers should understand that not all hazardous chemicals have specific OSHA exposure limits such as PELs and short-term exposure limits (STELs). An employer is still required by OSHA to protect their employees from hazards, even in the absence of a specific OSHA PEL.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8- to 10-hour workday. Some substances have recommended STEL or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from higher exposures over the short-term.

## Carbon Monoxide (CO)

CO is a colorless, odorless, tasteless gas produced by incomplete burning of carbon-containing materials; e.g., natural gas. The initial symptoms of CO poisoning may include headache, dizziness, drowsiness, and nausea. These initial symptoms may advance to vomiting, loss of consciousness, and collapse if prolonged or high exposures are encountered. Coma or death may occur if high exposures continue.[6,7,8,9,10,11]

The NIOSH REL for CO is 35 ppm for an 8-hour TWA exposure, with a ceiling limit of 200 ppm which should not been exceeded.[12,13] The NIOSH REL of 35 ppm is designed to protect workers from health effects associated with COHb levels in excess of 5%.[6] The ACGIH recommends an 8-hour TWA TLV of 25 ppm, with an excursion ceiling limit of 125 ppm (based upon the guidelines that under no circumstances should exposures for any listed chemical exceed 5 times the TLV-TWA).[4] The TWA TLV is intended to protect workers from health effects associated with COHb levels in excess of 3.5%. The OSHA PEL for CO is 50 ppm for an 8-hour TWA exposure.

# RESULTS

## CO Data Collection

Three of the four firefighting crews used the CO monitoring equipment provided for them. The extent of participation among the 3 crews, characterized by the number of hours and minutes of data collection, is presented below:

| Group # | Hours of Data Collection |
|---|---|
| 1 | 0 |
| 2 | 35 |
| 3 (Helitack) | 152 |
| 4 | 176 |

The data collection effort lasted for one summer firefighting season, with approximately 90 days between training and the last data gathered. The four crews were dispatched to 41 wildfires during the course of this project. These fires occurred in Colorado, Florida, and Idaho. The helitack crew spent approximately 20 days of the season at a helibase in Florida with minimal exposure to smoke.

The fire season was characterized as average to above average nationwide, but significantly below average in Colorado. Many of the prescribed burns conducted during this season did not involve the personnel or resources of the crews in this HHE. Thus, no data were gathered during this activity even though it was an initial goal based upon gaps in existing data.

It was difficult to correlate exposure data to specific tasks, operations, or fire types. Although forms for recording date, fire name, fire location, site data, and activities related to exposures were provided, use of the forms proved difficult. The crew that logged over 175 hours of data used the forms on four fires during which data were collected. The crew that logged over 152 hours of data took sketchy notes related to three of the days during which data were collected. The third crew took no notes related to working conditions during data collection.

Firefighters verbally reported that CO exposure data were collected primarily during firefighting activities (as compared to collecting data when they used gasoline-powered tools, for example). However, one crew's field notes indicated that the monitor was used when there was no fire on two of four occasions for which notes were taken. Most firefighters reported that they activated the CO monitors when they left base to fight the fire, and deactivated them upon returning to base.

One firefighter reported that his worst exposure was when he stood next to the fire truck operating the truck-mounted gasoline-powered water pump (peak exposure logged during this time was 450 ppm CO). He indicated that he used the CO monitor to determine the best place to stand while operating the pump, thus reducing his exposure through changing his work practices.

The helitack crew indicated that maximum CO readings were noted immediately upon exiting the aircraft. This may have represented exposure to CO from the engine exhaust.

Dates and times recorded by the CO monitors were often incorrect, having been set by incorrect computer dates during calibration or other computer/CO monitor interfacing operations. (This potential problem had been addressed in training.) Thus, it was difficult to correlate written notes with recorded CO data. Data were lost due to data storage errors (i.e., new files were stored over old files of the same name, thus erasing the old files).

One CO monitor was damaged and became non-functional during the course of this project, one data downloading cradle was damaged, and no equipment was lost.

All crews reported difficulty measuring expired CO concentrations (commonly referred to by the crews as "breatholyzer" CO measurements). Only one crew did that measurement, and only on one occasion. No data from that measurement were recorded.

A summary of CO exposure data collected by the firefighters is presented in Table 1. These data reflect sessions during which more than one hour of CO exposure information was recorded by the monitors. If the CO monitor recorded data for greater than 8 hours, the 8 hours of highest exposure were used to calculate the time-weighted average (TWA) exposure. (This was done to take the most conservative approach, and because so little information was available about tasks during the exposure monitoring.) Exceptions to this included three exposure monitoring periods that were 47.6, 12.7, and 10.8 hours in duration, during which CO measurements ranged from 0 to 4 ppm.

Fuel types noted by the crew that gathered the most data included grass, light fuels, cottonwoods, tamarisk, rabbit brush, heavy pinon growth, and juniper. This crew also noted humidity concentrations of 8, 18, and 20% (twice) during four of the data collection periods. Wind speed during each of these four fires was noted at approximately 5 miles per hour. That crew also noted such things as: "Most readings came while working hot spots," "CO went up with areas of good activity," and "CO around pump exhaust always bad."

During 8 of the 41 exposure monitoring periods, CO exposure concentrations exceeded the NIOSH recommended ceiling exposure limit of 200 ppm. During 10 of the 41 sessions, measured CO concentrations exceeded the ACGIH excursion limit of 125 ppm. No time-weighted average exposures exceeded current occupational exposure limits. During 2 of the 41 periods (each 480 minutes in length), CO exposure concentrations of 21 and 22 ppm were measured. These exposures approached the ACGIH time-weighted TLV of 25 ppm.

# Results of the Pilot Program as a Whole:

Data collection was only one aspect of this project. All participating groups (BLM, USFS, CDPHE, and NIOSH) were interested in the field application of a program proposed during the Hazards of Smoke conference discussed earlier in this report. The many useful lessons (both positive and negative) learned in this pilot program are outlined below.

## *Strengths of having firefighters collect CO exposure data*

- A learning experience was provided for the firefighters that makes them much more aware of their exposures.
- CO monitors enabled firefighters to take an active role in controlling their exposures (re: the gasoline-powered pump example listed above).
- This program got firefighters thinking about other sources of exposure beyond fires (again, the above pump example).
- The program allowed for efficient data collection. Data from many fires in several states were collected without the need for additional travel time/money/personnel. In addition, data were gathered from the initial firefighting efforts which have been difficult to gather otherwise.
- The program generated curiosity among firefighters about occupational exposures in general because they were measuring exposures themselves, as compared to outside professionals conducting the measurements.
- Firefighters received immediate positive feedback regarding extent of exposure, how to reduce that exposure, and how their actions impact on that exposure.

## *Limitations of having firefighters collect CO exposure data*

### Equipment limitations:

- Generally speaking, the firefighting crews had inadequate computer resources to fully carry out the data logging aspects of this program (lack of readily available computer support, outdated computers, etc.).

- Again, generally speaking, the crews had inadequate computer knowledge to carry out the data logging aspects of this program. In the training session, it became apparent that these firefighters, who were very adept at their job (which did not involve the use of computers), did not know how to turn the computer on, go between DOS and Windows, save files, set their computer clock, etc. All of these things are necessary for downloading data stored by the CO monitors.

- Radio frequency (RF) interference was a problem for all groups. Each of these firefighting crews used two-way radios for communication. These CO monitors respond when two-way radios are triggered for transmission purposes (i.e., incoming communication is not a problem, only outgoing). The CO monitor alarms when the microphone is triggered and records a high peak of CO (usually off-scale, and appearing as a peak with no width). Crews had to compensate for this interference by changing the placement of the dosimeter so that their body acted as a shield against the RF interference. (Initial placement of the dosimeter was on the shoulder strap of their pack, which put it near their transceivers.)

- The warning alarm on the CO monitors caused problems during radio communications.

### Attitude limitations:

- Some of the firefighters displayed a reluctance to use unfamiliar technology (specifically when faced with calibrating the monitors and downloading data). This was evidenced by the fact that one crew never used the technology, even after further encouragement to do so throughout the project.

- Monitors were often left behind when crews went to fight fires. This was evidenced by a number of facts. First, firefighters made such verbal comments as "We should have had these on during that last big fire where we were crawling on the ground to get away from the smoke it was so bad" during interim conversations with the investigators. Second, one crew never used the monitors, but fought several fires during the season. And finally, the 41 fires to which these crews were assigned were only partially represented in the collected data.

### Administrative limitations:

Note-taking problems:

- Firefighters were not able/willing to take notes during data collection. This may have been due to the fact that firefighters were given too much to learn and do all at once. This resulted in difficulties correlating data with activities, and fire and fuel type.

- Time limitations for the firefighters was a factor in quality and quantity of data collection. (Some crews were dispatched to fires two hours after returning from a previous fire. There was often no time to add CO monitoring to their already packed schedule between fires.)

Smoke management limitations:

- While firefighters were willing/able to reduce CO exposure from the gasoline-powered pump, they were less willing/able to reduce fire-related exposures, especially in the absence of specific guidance about what to do when the alarms sounded.

## DISCUSSION

Data collected by the wildland firefighters participating in this pilot project documented that CO exposures exceeded the ACGIH recommended excursion limit in 25% of the listed data recording sessions, exceeded the NIOSH recommended ceiling limit in 20% of the data recording sessions, and approached (but did not exceed) the ACGIH TLV for CO during 5% of the sessions. No time-weighted average exposures were in excess of the OSHA standard.

To ensure that the recorded peak exposures did not represent RF interference from the firefighters' radios, individual data points associated with the peaks were examined. All recorded peak exposures were associated with an incremental rise and fall over a number of minutes (i.e., the peaks had width) and were not off the recording scale for the CO monitors. As stated earlier, RF interference peaks typically appear with no width and go off the recording scale. For these reasons, and because firefighters verbally reported peak exposures that caused the monitors to sound, the peak exposure measurements were judged to represent true exposures.

These data certainly justify implementation of a smoke exposure management program. With some limitations, this project demonstrated that field implementation of a smoke management program is feasible.

Previous investigators have indicated that wildland firefighters are overexposed to CO during 1 to 5% of their firefighting efforts.[2] The data collected in this investigation indicates that these estimates may be low if excessive peak exposures are included in the figures. Differences in those estimates may be related to the fact that the data reported here were collected by the firefighters from the beginning of the firefighting effort, during direct attack (both of which would be expected to result in high exposures), and through hot spot mop up. Previous data collection efforts have been poorly suited to the mobility and responsiveness needed to capture smoke exposure during initial fire attack, and thus may have underestimated overall exposure. Differences in estimates of overexposure may also be related to differences in fire fuel types, and use of time-weighted average exposures only in calculated estimates.

The limitations of the data collected were basically in two areas - quality control and accountability. There was no indication that firefighters were consistently able to calibrate the dosimeters following the one training session with which they were provided. Further, variations between verbal reports and the scant notes available made it difficult to establish that the monitors were always used when exposure was expected. Thus, it was difficult to differentiate between low CO exposure at a fire, versus low CO exposure when the monitor was activated at the beginning of a shift during which no fire occurred. Conversely, graphs of data that indicated significant CO exposure were consistent with what would be expected during firefighting efforts.

Administrative and other limitations of the project as a whole indicate improvements are needed to maximize the use of this type of smoke management program. However, the strengths of the project combined with the data collected indicate that this program is both needed and feasible.

Smooth operation of this type of CO monitoring program may take several fire seasons to accomplish. If all crews are similar to the ones participating in this project, the first season will involve familiarizing administrators and firefighters with the CO monitoring concept, including how it works and why it is needed. During the second season there should be some converts to the concept, all will need refresher training, and data collection will be more meaningful. By the third season, the CO monitoring program administrator's expectations should be more realistic, and unless there are significant personnel changes, the firefighters will have experience and a higher level of involvement.

# CONCLUSIONS

Wildland firefighters may be exposed to CO concentrations in excess of current occupational exposure ceiling or excursion limits during as much as 25% of their firefighting efforts. Sources of CO exposure include smoke, vehicle, and other engine exhaust.

Given the proper financial and administrative support, managers and safety officers can establish CO exposure monitoring programs to aid in the reduction of firefighter exposures to smoke components. However, several issues will need to be further evaluated and addressed including availability of equipment and training, consistent documentation of monitoring conditions among firefighters; a written smoke exposure management plan containing a response strategy when CO monitors alarm, health surveillance programs, and training and tactics to minimize exposures.

# RECOMMENDATIONS

The following recommendations are offered toward effective implementation of a CO-based smoke management program. Fire management and safety officers responsible for the health and safety of firefighting personnel should:

1. Strongly consider using CO monitors primarily to manage firefighters' **acute** overexposure to components of smoke. To monitor acute exposures, field staff simply need to know how to calibrate a CO monitor and activate it. There are no computers involved. The monitors are already set to alarm at certain levels, and can be used as an "early warning device" to trigger actions to reduce exposures.

2. Develop a written smoke exposure management plan. This plan should focus on a strategy to respond to CO monitor warning alarms and should discuss health surveillance, training, and tactics to minimize exposure. The plan should also take into account the various sources of CO exposure during firefighting efforts.

3. Consider the following recommendations **if the CO monitors are to be used as part of an overall exposure monitoring/recording program**. (The use of CO monitors to record data over a long period requires more thorough knowledge about the operation of CO monitors, transferring and storing data, and relating the collected data to recommended and required standards.)

a. Select a designated person to have prime responsibility for the CO monitoring program at each fire. The duties of this designated person would include maintaining, calibrating, and assigning the CO monitor; coordinate recording of exposure information (i.e., fuel type, wind speed, duties of the person wearing the monitor - specifically duties when the monitor sounds an alarm); downloading and storing the accumulated data; developing signed and dated records for compliance purposes; and spearheading the development of a protocol for action to be taken when a monitor alarms.

b. Provide designated personnel with repeated training on the operation of CO monitors and related computer functions. Training should be repeated one month after initial training, using the data that has been gathered during that month to demonstrate the need to take notes, refresh previous training, address problems experienced in using the CO monitors, and catch errors that will adversely affect the entire fire season's data collection effort (i.e., writing over files because of errors in data transfer, etc.). Training on the operation of the CO monitors should then be repeated at the beginning of each fire season to refresh previous training and to ensure that new personnel are familiar with the program.

c. Have designated personnel then train firefighting crews about the goals of the monitoring program, the fundamentals of operating the CO monitors, what it means when the monitor alarm sounds, and what to do when the alarm sounds. This training should be repeated at the beginning of each new fire season.

d. Designated personnel should look for other ways to get information about exposure conditions while firefighters wear CO monitors. This pilot project demonstrated that the full use of exposure data for intervention purposes is limited if information about tasks and fire characteristics cannot be correlated with the data. The pilot project also demonstrated that getting this information is one of the more difficult aspects of exposure monitoring by firefighters who have high demands during firefighting efforts. This information might be verbally gathered during debriefings through the use of miniature recorders, for example.

# REFERENCES


1. USFS [1997]. Health hazards of smoke: recommendations of the consensus conference April 1997. Brian Sharkey, ed. Tech. Rep. 9751-2836-MTDC. Missoula, MT: Missoula Technology and Development Center. p. 84.

2. Reinhardt TE, Ottmar RD [1997]. Smoke exposure among wildland firefighters: A review and discussion of current literature. USDA Forest Service, Pacific Northwest Research Station: General Technical Report PNW-GTR-373. Seattle WA. February 1997: 61p.

3. NIOSH [1992]. Recommendations for occupational safety and health: compendium of policy documents and statements. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 92-100

4. ACGIH [1999]. 1999 TLVs® and BEIs®: threshold limit values for chemical substances and physical agents. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

5. CFR [1997]. 29 CFR 1910.1000. Code of Federal regulations. Washington, DC: U.S.

Government Printing Office, Office of the Federal Register.

6. NIOSH [1972]. Criteria for a recommended standard: occupational exposure to carbon monoxide. Cincinnati, OH: U.S. Department of Health, Education, and Welfare, Health Services and Mental Health Administration, National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No. 73-11000.

7. NIOSH [1977]. Occupational diseases: a guide to their recognition. Revised ed. Cincinnati, OH: U.S. Department of Health, Education, and Welfare, Public Health Service, Center for Disease Control, National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No. 77-181.

8. NIOSH [1979]. A guide to work-relatedness of disease. Revised ed. Cincinnati, OH: U.S. Department of Health, Education, and Welfare, Public Health Service, Center for Disease Control, National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No. 79-116.

9. Proctor NH, Hughes JP, Fischman ML [1988]. Chemical hazards of the workplace. Philadelphia, PA: J.B. Lippincott Company.

10. ACGIH [1986]. Documentation of threshold limit values and biological exposure indices (with 1990 supplements). 5th ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

11. NIOSH [1990]. Pocket guide to chemical hazards. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 90-117.

12. CDC [1988]. NIOSH recommendations for occupational safety and health standards 1988. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control; National Institute for Occupational Safety and Health. MMWR 37 (supp. S-7).

13. Code of Federal Regulations [1989]. 29 CFR 1910.1000. Washington, DC: U.S. Government Printing Office, Federal Register.

**Table 1**
**CO Exposures Monitored by Wildland Firefighters**
**USDI BLM Grand Junction District, and USFS White River National Forest**
**May - August 1998**
**HETA 98-0173-2782**

| Crew | Minutes of CO Monitoring | TWA CO Exposure (ppm) | Peak CO Exposure (ppm) | Notes |
|---|---|---|---|---|
| 2 | 65 | 0 | 10 | |
| | 480 | 21 | 319 | |
| | 431 | 10 | 164 | |
| | 480 | 6 | 365 | |
| | 480 | 2 | 43 | |
| | | | | |
| 3* | 108 | 0 | 0 | |
| | 2857 | 0 | 3 | |
| | 104 | 0 | 1 | |
| | 97 | 0 | 2 | |
| | 241 | 0 | 15 | |
| | 425 | 1 | 10 | |
| | 477 | 1 | 76 | |
| | 209 | 1 | 16 | |
| | 242 | 1 | 22 | |
| | 480 | 1 | 22 | |
| | 480 | 2 | 12 | |
| | 645 | 0 | 3 | |
| | 480 | 10 | 171 | |
| | 205 | 0 | 6 | |
| | | | | |
| 4 | 175 | 2 | 5 | |
| | 390 | 2 | 392 | |
| | 222 | 0 | 29 | |
| | 277 | 2 | 120 | |
| | 764 | 0 | 4 | |
| | 167 | 0 | 9 | |
| | 133 | 4 | 59 | |
| | 270 | 0 | 3 | |
| | 480 | 4 | 104 | |
| | 196 | 0 | 14 | |

**Table 1 - Continued**
**CO Exposures Monitored by Wildland Firefighters**
**USDI BLM Grand Junction District, and USFS White River National Forest**
**May - August 1998**
**HETA 98-0173-2782**

| | | | | |
|---|---|---|---|---|
| | 480 | 6 | 365 | |
| | 480 | 2 | 68 | Fuel - grass, light fuels, cottonwood; windspeed 5-7 mph; humidity 20%. Monitor activated when crew flew in to work hot spots and continued operating throughout this and next shift. |
| | 208 | 1 | 60 | Second shift of the above fire. |
| | 480 | 0 | 28 | Fuel - tamarisk, rabbit brush, cottonwood; windspeed 5-7 mph; humidity 20%. Monitor activated soon after arriving at the fire location. Fire suppression/mop up activities. |
| | 415 | 12 | 207 | |
| | 480 | 4 | 56 | Fuel - grass, brush; windspeed 5-10 mph; humidity 8%. Monitor activated as crew started towards the fire, and ran through mobile attack/ burnout. |
| | 480 | 6 | 450 | Fuel - heavy pinon, juniper; windspeed 3-5 mph; humidity 18%. Monitor worn by driver/pump operator. "CO around pump exhaust always bad." |
| | 480 | 6 | 51 | |
| | 370 | 1 | 86 | |
| | 483 | 3 | 286 | |
| | 480 | 22 | 260 | |
| | 397 | 2 | 53 | |
| | 112 | 4 | 17 | |

*Crew 3 was the Helitack crew. The tasks of this crew are quite different than those of the other crews.

# Attachment 1

## Written Materials Provided to Firefighters

Exposure Monitoring Note-Taking Sheet

Quality Control Check

Instruction Sheets for Calibration

Instruction Sheet for Transferring Logged Data to a Computer

Instructions for Measuring CO in Breath Samples

Down-Loading Data from the CO Monitor

# Exposure Monitoring Note-Taking Sheet

| **Date:** | **Fire name:** | **Location:** |
|---|---|---|

| **Site Data** | | |
|---|---|---|
| Windspeed: | Humidity: | Fuel type/loading: |

| **Carbon Monoxide Exposure Monitoring Data** | | | | | |
|---|---|---|---|---|---|
| Datalogger | Firefighter: | | Datalogger | Firefighter: | |
| **A** | Time | Activities/Smoke | **B** | Time | Activities/Smoke |
| shift start: | | | shift start: | | |
| log start: | | | log start: | | |
| log stop: | | | log stop: | | |
| shift stop: | | | shift stop: | | |
| Notes: | | | Notes: | | |
| | | | | | |
| Datalogger | Firefighter: | | Datalogger | Firefighter: | |
| **C** | Time | Activities/Smoke | **D** | Time | Activities/Smoke |
| shift start: | | | shift start: | | |
| log start: | | | log start: | | |
| log stop: | | | log stop: | | |
| shift stop: | | | shift stop: | | |
| Notes: | | | Notes: | | |
| | | | | | |
| Datalogger | Firefighter: | | Datalogger | Firefighter: | |
| **E** | Time | Activities/Smoke | **F** | Time | Activities/Smoke |
| shift start: | | | shift start: | | |
| log start: | | | log start: | | |
| log stop: | | | log stop: | | |
| shift stop: | | | shift stop: | | |
| Notes: | | | Notes: | | |
| | | | | | |
| Data Recorder (signature) | | | Location/date: | | |

# Quality-Control Check

## Conduct a quick quality control check before and after each sampling period to ensure accurate data.

**Procedure for the quality control check:**

**1. Activate on the CO monitor by pressing the "on/off mode" button.**

**2. Check the zero reading of the datalogger in clean ambient air. If the ambient air is not free of CO, as during atmospheric inversions or near engine exhaust, attach the zero air to the monitor using the calibration cup assembly. Unlike calibration, it is important to leave the zero levels unadjusted.**

**3. If the CO monitor reads within $\pm$3 ppm of 0, proceed to step 4. If the difference is greater than 3 ppm, start this procedure again with another CO monitor, or recalibrate the monitor if time permits.**

**4. If the zero check is within 3 ppm of zero, remove the zero gas and attach the 50 ppm CO gas to the CO monitor, again using the calibration cup assembly.**

**5. If the CO monitor reads within $\pm$3 ppm of 50, it has passed the quality control check and is ready for use.**

# PROCEDURE FOR 0 PPM CALIBRATION

**1. Remove the back cover of the CO monitor.**

**2. Activate the CO monitor by pressing the "on/off mode" button until the monitor beeps.**

**3. Depress the "CAL" lever that is on the back of the monitor under the cover you have removed. The monitor screen will display "ZERO GAS."**

**4. If you suspect that there is CO in the environment, or if the monitor displays >3 ppm CO, then use the zero calibration gas at this point. Attach the calibration hood assembly tubing to the zero calibration gas, open the regulator valve, and place the hood over the CO sensor on the monitor.**

**If there is no CO in the outdoor environment where you are calibrating the instrument proceed to step 5 without zero gas.**

**5. Depress the "CAL" lever again. The monitor screen will display "WAIT ZERO."**

**6. After a short time, the monitor screen will display a "0."**

**7. Turn the monitor off by depressing the "on/off mode" button for three seconds.**

**Proceed to the next calibration concentration.**

# PROCEDURE FOR 100 PPM CALIBRATION

1. Set the 0 calibration point prior to this procedure. See the previous instructions.

2. Attach the calibration hood assembly tubing to the regulator of the 100 ppm calibration gas tank.

3. While the monitor is off, depress the "CAL" lever on the back of the monitor. While holding the lever down, press the "on/off mode" button until the monitor screen alternately displays "SPAN" and a number (should be "0" or close to it), at which point you let go of the lever and button. The monitor cannot be calibrated unless the screen displays "SPAN," so if you miss it on the first try, start step 2 over again.

4. Firmly hold the calibration hood over the CO monitor sensor, and open the regulator valve on the gas tank.

5. Wait for the monitor reading to stabilize.

6. Still holding the calibration hood on the sensor, adjust the display to read "100 ppm" with the "+" or "-" lever on the back of the monitor (whichever is appropriate).

7. After adjustment of the display, allow 30 seconds for the monitor to stabilize and ensure accuracy of the reading.

8. Still holding the calibration hood on the sensor, depress the "CAL" button until the display screen displays "DONE."

9. The monitor will automatically shut itself off.

10. Turn off the calibration gas.

11. Replace the back cover of the CO monitor.

# MEASURING PRE- AND POST-FIRE CARBON MONOXIDE IN BREATH SAMPLES

**While at base camp before the crew member goes out to the fire, collect a breath sample to establish a baseline for comparison with the same measurement taken when the crew member comes off the fire line.**

## Procedure for collecting breath samples:

1. **Attach the calibration hood tubing to the connector on the balloon assembly.**
2. **Ensure that the CO monitor is operating.**
3. **Collect a breath sample following the procedure listed below:**

**Have the firefighterer:**

- **Exhale completely**
- **Inhale rapidly until lungs are filled**
- **Hold breath for 20 seconds**
- **Exhale a small amount of breath into the ambient air**
- **Exhale the remainder of the breath into the balloon assembly.**
- **Repeat this process until the balloon is inflated to approximately 9 inches across.**

4. **Firmly hold the calibration hood over the sensor on the monitor.**
5. **Allow the balloon to deflate.**
6. **When the monitor stabilizes on one reading, record the measurement on the data sheet provided.**

**Repeat this procedure when the firefighterer returns to base camp.**

# Down-Loading Data from the CO Monitor

**Attach cradle to the serial port on the computer.**
**Plug in the AC adapter power supply and plug into the cradle.**

**Get to a DOS prompt on the computer.**
**At the DOS prompt (C:\) type *CD\Toxilog*. Press "enter" (DOS prompt should read (C:\toxilog).**
**Type *Toxilog* (Menu should appear on screen).**

**Select option 2 (datalogger).**
**Select option 1 (download data from instrument).**
**Place instrument in cradle making sure that optical interfaces are aligned and the instrument is turned off. Press "enter."**

**From Menu select option 6.**

**Type fire # and datalogger # (example: xxxxx-9). Press "enter."**
**The data should now be saved.**

**To check data select option 2 from menu.**
**Select option 1.**
**Highlight file to review. Press "enter."**
**Select option 5 from menu.**
**Select option 1 from menu.**
**Highlight session to review. Press "enter."**
**Select option 1.**
**Select option 1. Graph should appear.**

**Press "Escape" twice.**
**Select option 3 from menu to clear data from instrument.**
**Select option 0.**
**Select option 0.**

**For Information on Other Occupational Safety and Health Concerns**

**Call NIOSH at:**
**1–800–35–NIOSH (356–4674)**
**or visit the NIOSH Web site at:**
**www.cdc.gov/niosh**