



Fire, Smoke and Health

The 2001 summer fire season hadn't yet started, but the immense fires of 2000 prompted officials to convene a fire, smoke, and health workshop in June. Seventy-five environmental specialists and researchers working on the exposure health effects, management, and measurement of smoke came from Montana, Idaho, Washington, Oregon, California, Texas, Colorado, Wyoming, and as far away as Georgia, North Carolina, Florida, and Washington, DC. The workshop was held at the University of Washington with the support of an Environmental Protection Agency (EPA) grant and travel support by the Centers for Disease Control (CDC) and the United States Forest Service (USFS).

Dr. Michael Lipsett, a leader of the health research work group from the Office of Environmental Health Hazard Assessment in Oakland, California, spoke for all participants when he said the workshop's greatest benefit was the reinforcement of collaborative relationships between federal, state, local, and academic institutions to deploy research projects. The workshop also brought public health professionals (e.g., CDC, Agency for Toxic Substances Disease Registry (ATSDR), state, and local health agencies) together with fire and smoke management specialists (USFS, EPA, and other state and federal agencies). Workshop goals included developing health advisory information (included with this newsletter) and information to assist local officials in reaching out to and communicating with the public.

Capturing data from smoke events can be likened to attempting to catch fireflies one at a time in a jar. Every time you open the lid to snag a firefly, one or more fly out. Vegetative burning events ranging from planned or wild forest fires to agricultural burns (e.g., wheat stubble or grass seed) often result in very high exposures to smoke for relatively short time periods. These exposures often occur in rural communities without adequate air monitoring. Researchers hope that networks established at this workshop and shared scarce public resources will ensure that usable field data can be gathered that will help describe the health effects of particulate matter in vegetative smoke.

The workshop was initiated by a congressional request to EPA and CDC from former congressman Rick Hill from Montana who asked for assistance in understanding the public health impacts of the 2000 fires in Montana and other western states. Joellen Lewtas, senior scientist with EPA's Office of Research and Development, developed EPA's initial plans for the workshop after visiting Missoula and Helena, Montana and meeting with state and local public health and air pollution monitoring

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Courtesy of J. Lewtas

Dr. Joellen Lewtas

Work Group Leaders

Outreach

Alison Davis, EPA
davis.alison@epa.gov

Rick Kreutzer, CA Dept. of Health Services
rkreutze@dhs.ca.gov

Carol Trenga, Univ. of WA
ctrenga@u.washington.edu

Research/Monitoring & Forecasting

Tim Larson, Univ. of WA
tlarson@u.washington.edu

Janice Peterson, US Forest Service
jlpeterson@fs.fed.us

Research/Health & Exposure

Joellen Lewtas, EPA
lewtas.joellen@epa.gov

Josh Mott, CDC
zum9@cdc.gov

Jeff Sullivan, Univ. of WA
sulljh@u.washington.edu

Health Advisory

Michael Lipsett, OEHHA
mlipsett@oehha.ca.gov

Susan Stone, EPA
stone.susan@epa.gov

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officials as well as the USFS fire research laboratory. Dave Kalman, Chair of the Department of Environmental Health at the University of Washington and many of the staff of the EPA NW Research Center for Particulate Air Pollution and Health made the workshop a reality in record time. The Seattle workshop was followed by a workshop held in Missoula, Montana with the support of the Montana participants and the Center for Environmental Health Sciences at the University of Montana.

Information shared by these attendees can be accessed on the workshop website: <http://depts.washington.edu/wildfire/> or <http://firesmokehealth.org/>. This newsletter is devoted to making available substantial portions of the summaries generated by each of the four work groups: Outreach, Research/Monitoring & Forecasting, Research/Health & Exposure, and Health Advisory. ■

Holian Heads New Research Center

Researchers at the year-old Center for Environmental Health Sciences (CEHS) at the University of Montana strive to understand the mechanisms and genetics of lung and neurological diseases and how environmental and occupational exposures contribute to these diseases. One CEHS research goal is to help shed light on the human health effects of vegetative burning.



Courtesy of A. Holian

Dr. Andrij Holian

Andrij Holian was appointed the first director of CEHS in July, 2000. His primary area of research interest is determining mechanisms of lung inflammation, fibrosis, and asthma in response to particles, which include particulate matter, silica, and asbestos. Holian was Director of Research of the Mickey Leland National Urban Air Toxics Research Center from its inception in 1990 until 2000.

For more information about research plans at the Center for Environmental Health Sciences at the University of Montana contact Dr. Holian at: aholian@selway.umt.edu or Dr. Jean Pfau at: jpfau@selway.umt.edu. ■

Research Proposal Products on Firesmokehealth Web Site

A number of documents outlining study objectives, proposed target populations, logistical difficulties, and needed resources will be posted on the firesmokehealth web site.

- Study design, monitoring plan, and research protocols for the evaluation of very short-term exposures to particulate matter from forest fire smoke, including health effects in asthmatics.
- A protocol for the validation of a urinary biomarker of exposure to forest fire smoke among USDA National Forest Service fire fighters.
- Protocol for assessment of off-shift smoke exposures among firefighters at a wildfire.
- A protocol to evaluate voluntary clean room sanctuaries during an acute air pollution episode.
- Study design for a panel study to assess cardiac effect in persons with coronary artery disease (Holter monitoring for analyses of ST segment abnormalities, arrhythmias, and heart-rate variability)
- Study proposed for a retrospective assessment of the birth weight of children conceived or exposed *in utero* during forest fire smoke episodes. This could include an assessment of birth outcome, as spontaneous abortion rates may also have increased.
- A possible assessment of long-term health effects of smoke exposure that makes use of a database of USDA Forest Service retirees.
- A proposed questionnaire assessment on a larger population for short-term and more chronic health effects.
- Future tools for assessing exposure, health effects, and intervention effectiveness will be available to all work group members on the web site.

What is Smoke?

This article was compiled by Shannon Therriault, R.S., Air Quality Specialist of the Missoula City-County Health Department in Missoula, Montana, for the Public Outreach Group of the Fire, Smoke and Health Workshop, Seattle, WA.

Smoke is made up primarily of carbon dioxide, water vapor, carbon monoxide, particulate matter, hydrocarbons and other organics, nitrogen oxides, and trace minerals. What is in smoke varies by the fuel source. Different types of wood and vegetation are made up of varying amounts of cellulose, lignin, tannins and other polyphenolics, oils, fats, resins, waxes and starches. Depending on the amounts of each substance burned, different compounds are produced.

Today, the major pollutant of concern from wildfire smoke is particulate matter or PM. PM is a mixture of solid particles and liquid droplets found in air. Particulate matter found in smoke tends to be very small (less than one micron in diameter), and is more of a health concern than coarser particles usually found in road dust. The size range of particulate matter from smoke is close to the wavelength of visible light (0.4–0.7 micrometers). This makes smoke particles good at scattering light and reducing visibility.

Hazardous air pollutants, such as acrolein, benzene, and formaldehyde, are present in smoke at concentrations less than particulate matter and carbon monoxide. Carbon monoxide, a colorless and odorless gas, is produced as a product of incomplete combustion, especially during the smoldering stage.



Collen Marquist

Kerry Shearer, Sacramento Metropolitan Air Quality Division, and Dr. Carol Trenga, UW

Characteristics of Smoke

How smoke behaves depends on many factors, including the fire's size and location, topography of the area, and weather. In mountainous terrain, where inversions are common, smoke often fills the valleys, where people usually live. Smoke levels can be hard to predict; a wind that usually clears out a valley may simply blow more smoke in or may fan the fires causing a worse episode the next day. Smoke concentrations change constantly. By the time a warning is issued, the smoke may have cleared out.

National Weather Service satellite photos, weather and wind forecasts, and knowledge of the area help to predict how much smoke will affect an area, but predictions are rarely accurate for more than a few hours. The National Weather Service's website provides a great deal of information, including satellite photos continually updated throughout the day. For the western United States, the web address is www.wrh.noaa.gov.

Health Effects of Smoke

Smoke causes eye and respiratory tract irritation along with asthma, bronchitis, and reduced lung function, and can contribute to premature death. Studies have found that fine particulate matter is linked (alone or with other pollutants) with a number of significant respiratory and cardiovascular-related effects, including increased mortality and aggravation of existing respiratory and cardiovascular disease.

Airborne particles are respiratory irritants, and laboratory studies show that high concentrations of particulate matter (PM) cause persistent cough, phlegm, wheezing, and physical discomfort in breathing. PM can alter the body's immune system and affect removal of foreign materials from lungs, such as pollen or bacteria.

Carbon monoxide (CO) enters the bloodstream through the lungs and reduces oxygen delivery to the body's organs and tissues. Even low levels of CO are serious for those with cardiovascular disease. At higher levels, carbon monoxide exposure can cause headaches, dizziness, visual impairment, reduced work capacity, and reduced manual dexterity even in otherwise healthy individuals. At even higher levels (seldom associated solely with a forest fire), carbon monoxide can be deadly.

People exposed to toxic air pollutants at sufficient concentrations and durations potentially have an increased risk of cancer or other serious health problems. However, in general, the long-term risk of toxic air pollutants from most vegetative fires such as forest fires is believed to be low due to the short exposure duration. More research is needed in this area to

measure exposures to toxic air pollutants from wild fires and other vegetative burning exposures.

Some components of smoke, such as many polycyclic aromatic hydrocarbons (PAHs), are carcinogenic. One of the most carcinogenic is benzo-a-pyrene (BaP). Other components, such as the aldehydes, are acute irritants.

Examples of three air toxics of concern from wildfires are:

- Acrolein—an aldehyde with a piercing, choking odor. Even at low levels, acrolein can severely irritate the eyes and upper respiratory tract. Symptoms include stinging and tearing eyes, nausea, and vomiting.
- Formaldehyde—low-level exposure can cause irritation of the eyes, nose, and throat. Higher levels of exposure cause irritation to spread to the lower respiratory tract. Long-term exposure is associated with nasal and nasopharyngeal cancer.
- Benzene—a hydrocarbon that causes headaches, dizziness, nausea, and breathing difficulties, is a potent carcinogen. Benzene causes anemia, liver and kidney damage, and leukemia.

Recommendations

Stay Indoors

The most common advisory issued during a smoke pollution episode is to stay indoors. The usefulness of this strategy depends on the quality of the indoor air. Indoor air-quality studies indicate that this strategy can usually provide some protection, especially in a tightly closed, air-conditioned house. Staying inside can usually reduce ambient air pollution by about a third.

In homes that are not air-conditioned, anywhere from 70–100% of fine particulate will penetrate indoors from the outside air. In very “leaky” homes and buildings, staying inside with doors and windows closed may offer little protection. Certainly, if doors and windows are left open, indoor and outdoor air will be about the same.

One of the biggest problems with people staying indoors during smoke events is the risk of heat stress. Fire season is often accompanied by high temperatures, and for those who depend on open windows and doors for ventilation, keeping them closed can be a problem. Older individuals and those in frail health run the risk of heat exhaustion or heat stroke.

Smoke events can last several weeks or months. These longer events are usually punctuated by times of relatively clean air. When air quality improves, even temporarily, residents should “air out” their homes to reduce indoor air pollution.

Air conditioners

The effect of air conditioners and air filters on indoor air pollutant concentrations is limited to a few pollutants. The evidence is that air conditioners reduce the amount of outside particulate matter coming indoors, if for no other reason than air conditioned homes usually have lower air exchange rates than homes that use open windows for ventilation. Some air conditioners can be fitted with HEPA (high efficiency particulate air) filters that can capture most of the tiny particles associated with smoke and reduce the amount of outside particulate air pollution coming indoors, however filters alone do not remove the gaseous organics. Organic gases can be reduced using charcoal or carbon impregnated filters, however these are not normally found in home air conditioners or cleaners.

Air cleaners

Air cleaners can be effective at reducing indoor particulate levels, provided the specific cleaner is adequately matched to the indoor environment. However, most air cleaners are not effective at removing gases and odors. The two basic types of air cleaners for particle removal are:

- (a) Mechanical—containing a fiber or fabric filter. The filters need to be sealed tightly in their holders and cleaned or replaced regularly.
- (b) Electronic—such as electrostatic precipitators (ESP) and ionizers. ESPs use a small electrical charge to collect particles from air pulled through the device. Ionizers, or negative ion generators, cause particles to stick to materials (such as carpet and walls) near the device. Electronic air cleaners usually produce small amounts of ozone as a byproduct.

The effectiveness of an air cleaner is usually reported in terms of efficiency, which can be misleading, as it only tells half of the story. The other important factor is air flow. Together, these two factors equal the Clean Air Delivery Rate (CADR), which is a better measure of how a device will actually perform.

Most portable units have packaging that states the unit’s air flow rate, the size room it cleans, and perhaps its particle removal efficiency and its CADR. Central system air units should handle at least 0.5 air changes per hour, the air exchange rate necessary to reasonably ventilate a house continuously under most conditions.

For central air conditioning systems and electrostatic precipitators, high efficiency and medium-efficiency media filters can be added to keep particle level in indoor air within acceptable levels during a prolonged smoke event. However, these filters create more air resistance, and may require

modifications to the system.

Some devices, known as ozone generators, personal ozone devices, “energized oxygen” generators, and “pure air” generators, are sold as air cleaners, but they probably do more harm than good. These devices intentionally produce ozone gas to react with pollutants in the air. The EPA has found that ozone is generally ineffective in controlling indoor air pollution at concentrations that do not greatly exceed public health standards. In addition, ozone does not remove particles from the air, and would not be effective during smoke events. For more information about ozone generators that are sold as air cleaners, see www.epa.gov/iaq/pubs/ozonegen.html.

Humidifiers are not air cleaners and will not significantly reduce the amount of particulate in the air nor remove gases such as carbon monoxide. However, humidifiers and dehumidifiers may slightly reduce pollutants through condensation, absorption, and other mechanisms. The benefit of running a humidifier in an arid environment during a smoke event would be to reduce stress on the respiratory system by keeping mucus membranes moist.

For more information about residential air cleaners, see www.epa.gov/iaq/pubs/residair.html. For more information about reducing air pollution indoors, see www.healthhouse.org or www.lungusa.org

In vehicles

Particulate levels in vehicles can be reduced by keeping



Collen Marquist

Patti Hirami, United States Forest Service

windows closed. However, cars heat up quickly in warm weather, and heat stress can be an issue. Children and pets should never be left in a vehicle with the windows closed. The car’s ventilation system typically removes a portion of the particulate coming in from outside. Most cars can recirculate inside air, which will help keep particulate levels lower.

Reduced activity

Reducing physical activity minimizes the dose of inhaled air pollutants, and may reduce the risk of health impacts. Exercise during exposure causes more particulate matter to be inhaled more deeply into the lungs, and increases the risk of harmful respiratory effects.

Other sources of air pollution

Many indoor sources of air pollution can emit large amounts of the same pollutants present in forest fire smoke. Cigarette smoke, gas, propane, woodburning stoves and furnaces, and activities such as cooking, burning candles and incense, and vacuuming can greatly increase the particulate matter levels in a home. Some of these sources can also increase the levels of polycyclic aromatic hydrocarbons (PAHs), carbon monoxide, and nitrogen oxides.

Besides cigarette smoke, combustion sources that do not vent to the outdoors contribute most to indoor pollutant levels and are of greatest concern. On average, reducing indoor air emissions as much as possible during smoke events may reduce indoor particulate levels by one quarter to one third or more, and levels of PAHs, volatile organic compounds (VOCs) and other pollutants by an even greater amount. These reductions can help compensate for the increased loading from the outdoor air.

Masks

In order for a mask to provide protection during a smoke event, it must be able to filter very small particles (0.3–0.1 microns), and provide an airtight seal around the wearer’s face. Commonly available paper dust masks, which are designed to filter out larger particles, typically offer little protection. The same is true for bandanas and tissues held over the mouth and nose. In fact, they may actually be detrimental by giving the wearers a false sense of security.

Surgical masks trap smaller particles, but are designed to filter air coming out of the wearer’s mouth, and do not provide a good seal. They perform no better than dust masks.

Some masks (technically called respirators, but that look more like paper masks) filter out 95% of the particulate matter



that are 0.3 microns and larger. Smoke particulate matter averages about 0.3 microns, so these masks will filter out a significant portion of the smoke if they fit properly. These masks, which may include an exhale valve, do not require cartridge filters. Soft masks which filter out even more particulates are also available.

Respirators with HEPA (high efficiency particulate air) filters offer the highest protection, but may be less comfortable than flexible masks. Again, unless there is an airtight seal over the wearer's face, the HEPA filter provides little protection.

There are several drawbacks to recommending widespread mask use in an area affected by wildfire smoke. Most people won't use the masks correctly and won't understand the importance of having an airtight seal. And, people with beards cannot get a good seal.

Masks are uncomfortable. They increase resistance to air flow, which makes breathing more difficult and may lead to physiological stresses, such as increased respiratory and heart rates. Mask use by those with cardiopulmonary and respiratory diseases should only be contemplated under a doctor's supervision. Even healthy adults may find that the increased effort required for breathing makes it uncomfortable to wear a mask for more than short periods of time. Breathing resistance increases with respirator efficiency. Most healthy adults can use a 95% efficient respirator without undue breathing resistance.

Another problem with masks is that most of them will not reduce carbon monoxide.

There are instances where mask use can be beneficial. For outdoor workers, or others who will be outside regardless of the smoke, properly fitted masks can afford some protection. In cases where people are generally staying indoors, wearing a mask to go outside briefly might be useful. Masks can also be useful in conjunction with other methods of exposure reduction, such as staying indoors, reducing activity, and using HEPA air cleaners, to reduce overall smoke exposure.

Clean Air Sanctuaries

Staying inside may not adequately protect susceptible individuals. Many homes do not have air conditioning and depend on open windows and doors for cooling; other homes may be so leaky that pollution levels will soon equal that of outside air. During severe smoke events, clean air sanctuaries or shelters can be designated to provide a place to get out of the smoke. These can be in large commercial buildings, schools, shopping malls, or anyplace with effective air conditioning and particle filtration.

Closures

The decision to close or curtail business activities will depend on considerations of traffic, health, environmental and socioeconomic factors, and other local conditions. Depending on building design and presence of air filtration, exposures inside schools and businesses may be similar to or better than those in homes. Children's physical activity may also be better controlled in schools than in homes. Curtailing outside activities, such as sporting events and practices, can reduce exposures by encouraging people to stay inside and reducing physical activity. Restrictions on industrial emissions may be warranted.

Evacuation

The most common call for evacuation during a wildfire is due to the direct threat of the fire instead of smoke. Leaving the area of thick smoke may be a good protective measure for members of sensitive groups, but it is often difficult to predict the duration, intensity, and direction of smoke, making this an unattractive option to many people. For fires that go on for months, evacuation may not be possible for a large percentage of the population.

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- May 22, 2000. Summary of Forest Fire/Prescribed Burning Smoke Meeting. Oakland, California. www.firesmokehealth.org.
- June 5 & 6, 2001. Reports from Fire, Smoke, and Health Workshop. ■

News, events & publications

2001 Events & visitors

February

seminar: Alex Polissar, PhD, Clarkston University, *Comparison of CAMS, RAMS, TEOM and nephelometer measurements at Beacon Hill during winter*

March

seminar: Delbert Eatough, PhD, Brigham Young University, *Assessment of semi-volatile sampling artifacts at selected sites using RAMS and PC-BOSS samplers*

Judson Kenoyer, Battelle, Discussion of research collaboration

April

Dr. Richard Corley/Dr. Charles Timchalk, Battelle

May

Assessment of Exposures to Fine Atmospheric Particulates: Challenges and Progress, PM Center/Continuing Education Course, David V. Bates, MD, Chair, PM Center External Science Advisory Committee

Ralph Delfino, PhD, MD, Department of Medicine, University of California at Irvine, *Assessment of exposures to fine atmospheric particulates: Challenges and progress*

Jonathan Samet, MD, MPH, Chair Epidemiology, Johns Hopkins University School of Public Health, member PM Center External Science Advisory Committee

John Williamson, Washington Department of Ecology, *DOE's Seattle Air Toxics Study*

June

seminar: Andrij Holian, PhD, Director University of Montana Center for Environmental Health Sciences, *Mechanisms of particulate-induced lung inflammation*

Larry Cupitt, Acting Associate Director for Health at the National Exposure Research Laboratory, EPA, *Exposure Research at EPA –Past, present & future*

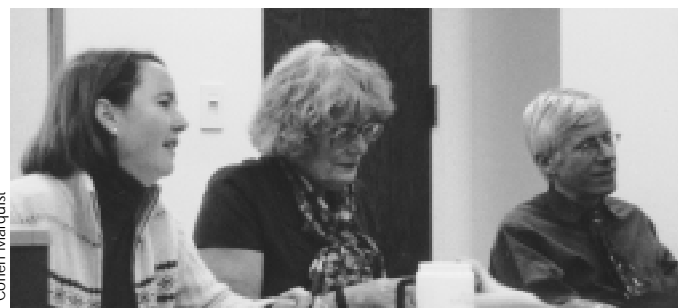
3rd PM Center's Directors Meeting, Boston, MA

July

Judson Kenoyer/Dr. Bob Stenner, Battelle

August

Naydene Maykut, PhD, Member External Science Advisory Committee, Puget Sound Clean Air Agency, *Seattle Speciation Modeling*



Collen Marquist

Lianne Sheppard, Jane Koenig, and Jonathan Samet

Publications & presentations

Publications

Dills, R.L., X. Zhu and D.A. Kalman, Measurements of Urinary Methoxyphenols and Their Use for Biological Monitoring of Wood Smoke Exposure. *Environ. Res.*, 2001. 85(2):145–158.

Levy, D., et al., A Case-Crossover Analysis of Particulate Matter Air Pollution and Out-of-Hospital Primary Cardiac Arrest. *Epidemiology*, 2001. 12(2): 193–199.

Levy, D., et al., Referent Selection in Case-Crossover Analyses of Acute Health Effects of Air Pollution. *Epidemiology*, 2001. 12(2): 186–192.

Lumley, T. and L. Sheppard, Assessing Seasonal Confounding and Model Selection Bias in Air Pollution Epidemiology Using Positive and Negative Control Analyses. *Environmetrics*, 2000. 11:705–717.

Lumley, T. and D. Levy, Bias in the Case-Crossover Design: Implications for studies of Air Pollution. *Environmetrics*, 2000. 11:689–704.

Sheppard, L., D. Levy, and H. Checkoway. Correcting for the Effects of Location and Atmospheric Conditions on Air Pollution Exposures in a Case-Crossover Study. *J Exp Anal Environ Epidemiol*, 2001. 11:86–96.

Presentations

May 8: Collen Marquist, Eaton School, *Environmental Careers*

May 20: Jeff Sullivan, American Thoracic Society, *Association Between Personal Levels of Fine Particulate Matter Exposure and Heart Rate Variability in Older Subject With and Without COPD*

May 20: Carol Trenga, American Thoracic Society, *Symptoms and Personal Particulate Matter Exposure in Subjects With and Without COPD*

May 22: Carol Trenga, American Thoracic Society. *Antioxidant Vitamin Intake, Diet, and Asthma*

June 11: Carol Trenga, III World Congress on Vitamin C, *Vitamin C and Asthma*

June 16: Jane Koenig, American Chemistry Society NW Section meeting

Where to Find Us

EPA NW Research Center for Particulate Air Pollution and Health
1107 NE 45th Street, Suite 355
University of Washington, Box 354803
Seattle, WA 98105

Director: Jane Q. Koenig, PhD
Phone: (206) 543-2026
E-mail: jkoenig@u.washington.edu
Web sites: <http://depts.washington.edu/pmcenter/>
<http://depts.washington.edu/envhlth/>
<http://firesmokehealth.org/>

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Principal Investigators

Atmospheric Sciences, UW: David S. Covert, PhD
Biostatistics, UW: Thomas Lumley, PhD; Lianne Sheppard, PhD
Civil & Environmental Engineering, WSU: Candis Claiborn, PhD
Civil & Environmental Engineering, UW: Timothy V. Larson, PhD
Environmental Health, UW: David A. Kalman, PhD; Joel D. Kaufman, MD, MPH; Terrence J. Kavanagh, PhD; Jane Q. Koenig, PhD; Lee-Jane Sally Liu, SD; Daniel L. Luchtel, PhD
Lawrence Berkeley Laboratories: Lara Gundel, PhD
Medicine, UW: Dave Siscovick, MD, MPH

Fire, Smoke, and Health Workshop

The intense and frequent smoke episodes of 2000 that occurred in Idaho, Montana, Northern California, and Oregon prompted an organizational collaboration to address the heightened sense of need for information, research data, and emergency preparedness and planning. The June 2000 PM Center workshop on public health aspects of wood smoke from wildfires or agricultural burning was intended to be a focused interaction between researchers and professionals from academic, public health, environmental quality and smoke management organizations.

Academic, federal, state, and local government professionals shared expertise on research topics and needs in characterizing and managing public exposures to wildfire smoke. They learned about available tools for predicting and monitoring smoky conditions, and developed consensus advisory guidelines to respond to short-term smoke episodes. In addition, they shared strategies for effective public communication regarding smoke hazards.



UW photography

Dr. Dave Kalman

Smoke, Dust & Haze



EPA NW Research Center
for Particulate Air Pollution and Health
University of Washington
Box 354803
Seattle, WA 98195-4803

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