Wildfire Smoke

A Guide for Public Health Officials

Acknowledgements

This document was written by Harriet Ammann, Washington Department of Health; Robert Blaisdell and Michael Lipsett, California Office of Environmental Health Hazard Assessment, Susan Lyon Stone, U.S. Environmental Protection Agency; and Shannon Therriault, Missoula County Health Department, with input from individuals in several other state and federal agencies, in particular Jed Waldman of the California Department of Health Services, Peggy Jenkins of the California Air Resources Board, and editorial support from Kate Lynch, Washington State Department of Health. It was developed in part as a result of a workshop held at the University of Washington in June 2001, under the auspices of the U.S. Environmental Protection Agency, Region X, and the Department of Environmental Health, School of Public Health and Community Medicine of the University of Washington. **The viewpoints and policies expressed in this document do not necessarily represent those of the various agencies and organizations listed. Mention of any specific product name is neither an endorsement nor a recommendation for use.**

Introduction

Smoke rolls into town, blanketing the city, turning on streetlights, creating an eerie and choking fog. Switchboards light up as people look for answers. Citizens want to know what they should do to protect themselves. Schools officials want to know if outdoor events should be cancelled. The news media want to know how dangerous the smoke really is.

Smoke events often catch us off-guard. This guide is intended to provide local public health officials with the information they need when wildfire smoke is present so they can adequately communicate health risks and precautions to the public. It is the product of a collaborative effort by scientists, air quality specialists and public health professionals from Federal, state and local agencies.

Composition of smoke

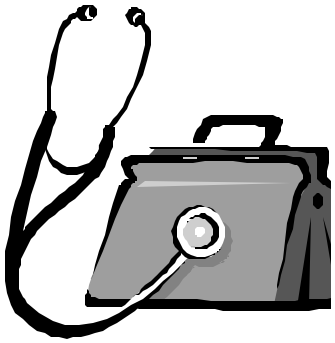
Smoke is composed primarily of carbon dioxide, water vapor, carbon monoxide, particulate matter, hydrocarbons and other organics, nitrogen oxides, trace minerals and several thousand other compounds. The actual composition of smoke depends on the fuel type, the temperature of the fire, and the wind conditions. Different types of wood and vegetation are composed of varying amounts of cellulose, lignin, tannins and other polyphenolics, oils, fats, resins, waxes and starches, which produce different compounds when burned.

Particulate matter is the principal pollutant of concern from wildfire smoke for the relatively short-term exposures (hours to weeks) typically experienced by the public. Particulate matter is a generic term for particles suspended in the air, typically as a mixture of both solid particles and liquid droplets. Particles from smoke tend to be very small - less than one micrometer in diameter. For purposes of comparison, a human hair is about 60 micrometers in diameter. Both because smaller particles can be inhaled into the deepest recesses of the lung and because of their chemical composition, they may be more of a health concern than larger particles. Particulate matter from wood smoke has a size range near the wavelength of visible light (0.4 – 0.7 micrometers). Thus, smoke particles efficiently scatter light and reduce visibility.

Another pollutant of concern during smoke events is carbon monoxide. Carbon monoxide is a colorless, odorless gas, produced by incomplete combustion of wood or other organic materials. Carbon monoxide levels are highest during the smoldering stages of a fire. Other air pollutants, such as acrolein, benzene, and formaldehyde, are present in smoke, but in much lower concentrations than particulate matter and carbon monoxide.

Health effects of smoke

The effects of smoke range from eye and respiratory tract irritation to more serious disorders, including reduced lung function, bronchitis, exacerbation of asthma, and premature death. Studies have found that fine particles are linked (alone or with other pollutants) with increased mortality and aggravation of pre-existing respiratory and cardiovascular disease. In addition, particles are respiratory irritants, and laboratory studies show that high concentrations of particulate matter can cause persistent cough, phlegm, wheezing and difficulty breathing. Particles can also affect healthy people, causing respiratory symptoms, transient reductions in lung function, and pulmonary inflammation. Particulate matter can also affect the body's immune system and make it more difficult to remove inhaled foreign materials from the lung, such as pollen and bacteria. The principal public health threat from short-term exposures to smoke is considered to come from exposure to particulate matter.



Carbon monoxide (CO) enters the bloodstream through the lungs and reduces oxygen delivery to the body's organs and tissues. The CO concentrations typical of population exposures related to wildfire smoke do not pose a significant hazard, except to some sensitive individuals and to firefighters very close to the fire line. Individuals who may experience health effects from lower levels of CO are those who have cardiovascular disease: they may experience chest pain and cardiac arrhythmias. At higher levels, as might be observed in a major structural fire, carbon monoxide exposure can cause headaches, dizziness, visual impairment, reduced work capacity, and reduced manual dexterity, even in otherwise healthy individuals. At even higher concentrations (seldom associated solely with a wildfire), carbon monoxide can be deadly.

Wildfire smoke also contains significant quantities of respiratory irritants. Formaldehyde and acrolein are two of the principal irritant chemicals that add to the cumulative irritant properties of smoke, even though the concentrations of these chemicals individually may be below levels of public health concern.

One concern that may be raised by members of the general public is whether they run an increased risk of cancer or other long-term health impacts of exposure to wildfire smoke. People exposed to toxic air pollutants at sufficient concentrations and durations may have slightly increased risks of cancer or of experiencing other chronic health problems. However, in general, the long-term risk from short-term smoke exposure is quite low. Epidemiological studies have shown that urban firefighters exposed to smoke over an entire working lifetime have about a three-fold increased risk of developing lung cancer (Hansen 1990). This provides some perspective on the potential risks. The major carcinogenic components of smoke are polycyclic aromatic hydrocarbons (PAH). Although the carcinogens benzene and formaldehyde are also present in smoke, they are thought to present a lesser risk.

Not everyone who is exposed to thick smoke will have health problems. The level and duration of exposure, age, individual susceptibility and other factors play significant roles in determining whether or not someone will experience smoke-related health problems.

Sensitive populations

Most healthy adults and children will recover quickly from smoke exposures and will not suffer long-term consequences. However, certain sensitive populations may experience more severe short-term and chronic symptoms from smoke exposure. Much of the information about how particulate matter affects these groups has come from studies done on airborne particles in cities, though a few studies examining the effects of exposure to smoke suggest that the health effects of wildfire smoke are likely to be similar. More research is needed (and some of it is underway) to determine whether particles from wildfires affect susceptible subpopulations differently.

Individuals with asthma and other respiratory diseases: Levels of pollutants that may not affect healthy people may cause breathing difficulties for people with asthma or other chronic lung diseases. Asthma, derived from the Greek word for panting, is a condition characterized by chronic inflammation of the airways, with intermittent bronchoconstriction and airflow obstruction, causing shortness of breath, wheezing, chest tightness, coughing, sometimes accompanied by excess phlegm production. During an asthma attack, the muscles tighten around the airways and the lining of the airways becomes inflamed and swollen, constricting the free flow of air. Because children's airways are narrower than those of adults, irritation that would create minor problems for an adult may result in significant obstruction in the airways of a young child. However, the highest mortality rates from asthma occur among older adults.

Individuals with chronic obstructive pulmonary disease (COPD), which is generally considered to encompass emphysema and chronic bronchitis, may also experience a worsening of their conditions because of exposure to wildfire smoke. Patients with COPD often have an asthmatic component to their condition, which may result in their experiencing asthma-like symptoms. However, because their pulmonary reserve has typically been seriously compromised, additional bronchoconstriction in individuals with COPD may result in symptoms requiring medical attention. Epidemiological studies have indicated that individuals with COPD run an increased risk of requiring emergency medical care after exposure to particulate matter or forest fire smoke. Exposure to smoke may also depress the lung's ability to fight infection. People with COPD may develop lower respiratory infections after exposure to wildfire smoke, which may require urgent medical care as well. In addition, because COPD is usually the result of many years of smoking, individuals with this condition may also have heart disease, and are potentially at risk from both conditions.

Individuals with airway hyperresponsiveness: A significant fraction of the population may have airway hyperresponsiveness, an exaggerated tendency of the bronchi and bronchioles to constrict in response to respiratory irritants and other stimuli. While airway hyperresponsiveness is considered a hallmark of asthma, this tendency may also be found many nonasthmatics, as

well; for example, during and following a lower respiratory tract infection. In such individuals, smoke exposure may cause bronchospasm and asthma-like symptoms.

Individuals with cardiovascular disease: Diseases of the circulatory system include, among others, high blood pressure, cardiovascular diseases, such as hardening of the arteries, coronary artery disease, and congestive heart failure, and cerebrovascular conditions, such as atherosclerosis of the arteries bringing blood to the brain. These chronic conditions can render individuals susceptible to attacks of angina pectoris, heart attacks, sudden death due to a cardiac arrhythmia, acute congestive heart failure, or strokes. Cardiovascular diseases represent the leading cause of death in the United States, responsible for about 30 percent of all deaths each year. The vast majority of these deaths are in people over the age of 65. Studies have linked particulate pollution to increased risk of heart attacks, cardiac arrhythmias, and other adverse effects in those with cardiovascular disease. People with chronic lung or heart disease may experience one or more of the following symptoms: shortness of breath, chest tightness, pain in the chest, neck, shoulder or arm, palpitations, or unusual fatigue or lightheadedness. Chemical messengers released because of particle-related lung inflammation may increase the risk of blood clot formation, angina episodes, heart attacks and strokes.

The elderly. In several studies researchers have estimated that tens of thousands of elderly people die prematurely each year from exposure to particulate pollution, probably because the elderly are more likely to have pre-existing lung and heart diseases, and therefore are more susceptible to particle-associated effects. The elderly also seem to be more affected than younger people because important respiratory defense mechanisms may decline with age. Particulate pollution can compromise the immune system, increasing susceptibility to bacterial or viral respiratory infections.

Children. Children, even those without any pre-existing illness or chronic conditions, are considered a sensitive population because their lungs are still developing, making them more susceptible to air pollution than healthy adults. Several factors lead to increased exposure in children compared with adults: they tend to spend more time outside; they engage in more vigorous activity, and they inhale more air (and therefore more particles) per pound of body weight. Studies have shown that particulate pollution is associated with increased respiratory symptoms and decreased lung function in children, including symptoms such as episodes of coughing and difficulty breathing. These can result in school absences and limitations of normal childhood activities.

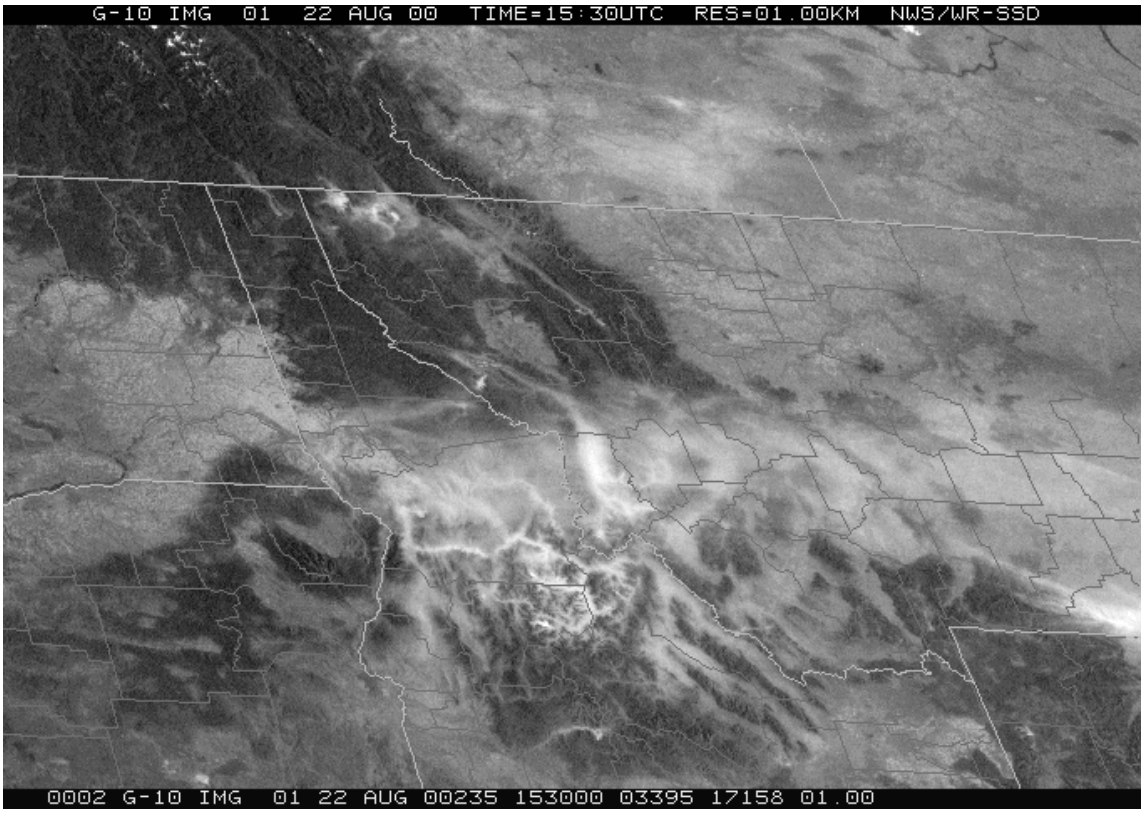
Pregnant women. While there have not been studies of the effects of exposure to wildfire smoke on pregnancy outcomes, there is substantial evidence of adverse effects of repeated exposures to cigarette smoke, including both active and passive smoking. Wildfire smoke contains many of the same compounds as cigarette smoke. In addition, recent data suggest that exposures to ambient air pollution in cities may result in low birthweight and possibly other, more serious, effects. Therefore, it would be prudent to consider pregnant women as a potentially susceptible population as well.

Smokers. People who smoke, especially those who have smoked for many years, have already compromised their lung function. However, due to adaptation of their lungs to ongoing irritation,

smokers are less likely to report symptoms from exposure to irritant chemicals than are nonsmokers. However, they may still be injured by wildfire smoke. Therefore, some smokers may unwittingly put themselves at greater risk of potentially harmful wildfire smoke exposures, believing that they are not being affected.

Characteristics of WILDFIRE smoke

The behavior of smoke depends on many factors, including the fire's size and location, the topography of the area and the weather. Inversions are common in mountainous terrain. Smoke often fills the valleys, where people usually live. Smoke levels are unpredictable: 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 public health officials can issue a warning or smoke advisory, the smoke may already have cleared. National Weather Service satellite photos, weather and wind forecasts, and knowledge of the area can all help in predicting how much smoke will come into an area, but predictions are rarely accurate for more than a few hours. The National Weather Service's Web site has a lot of information, including satellite photos that are updated throughout the day. For the western United States, the Web address is www.wrh.noaa.gov.



Estimating particulate matter levels

Particulate matter levels are measured as micrograms (*m*g) of particles per cubic meter of air. Most particle monitoring devices measure particulate matter with a median diameter of 10 micrometers or less (PM_{10}). An increasing number of monitors now measure smaller particles, also known as fine particles, which have median diameters of 2.5 micrometers or less ($PM_{2.5}$). In wildfire smoke, most particles are less than one micrometer, so the values obtained by measuring either PM_{10} or $PM_{2.5}$ are virtually interchangeable, and are treated as such in this document.

Communities with established air quality programs may issue public alerts based on predicted 24-hour average concentrations of particulate matter. Smoke emergencies need to be handled differently, however, as smoke concentrations tend to be very high for only a few hours at a time. These short-term peaks may cause some of the most deleterious health effects.

In addition, the particles in smoke are very small ($PM_{2.5}$), and are likely to have a greater public health impact than the larger particles that make up PM_{10}, which is what most regional air pollution emergency plans are based upon. Another factor is public perception. Since smoke is so effective at scattering light, visibility changes drastically as smoke concentrations increase. Even without being told, the public can tell when the smoke is getting worse, and they want authorities to respond to changes as they are happening.

Many communities don't have continuous PM monitoring, and therefore need to estimate particle levels. Continuous PM monitors give an instant reading of particulate matter concentrations. However, visibility can sometimes serve as a good surrogate. Even in areas with monitors, this index can be useful, since smoke levels change constantly and can vary dramatically even between monitors that are near one another. A visibility index gives members of the public a quick way to assess smoke levels for themselves.

Table 1: Estimating particulate matter concentrations from visibility assessment

Categories	**Visibility in Miles**	**Particulate matter levels* (1hour average, *m*g/m^3)**
Good	10 miles and up	0 - 40
Moderate	6 to 9	41 - 80
Unhealthy for Sensitive Groups	3 to 5	81 - 175
Unhealthy	1 1/2 to 2 1/2	176 - 300
Very Unhealthy	1 to 1 1/4	301 - 500
Hazardous	3/4 mile or less	over 500

*In wildfire smoke, most particles are less than one micrometer, so the values obtained by measuring either PM_{10} or $PM_{2.5}$ are virtually interchangeable, and are treated as such in this document. Therefore, in the table above, the different particle levels can be measured using either PM_{10} or $PM_{2.5}$ monitors.

Making personal observations to determine smoke concentrations

- Face away from the sun.
- Determine the limit of your visibility range by looking for targets at known distances (miles). The visible range is the point at which even high-contrast objects (e.g. a dark forested mountain viewed against the sky at noon) totally disappear.
- After determining visibility in miles, use Tables 2 and 3 to identify potential health effects and appropriate cautionary statements.

At times, the visibility index may be hard to use, especially if specific landmarks at known distances are not available for judging distances, or at dawn or dusk. *Furthermore, the above visibility categories for PM levels only apply in dry air conditions. For a given PM level, visibilities decrease substantially at relative humidity above 65%, when these estimates should not be used.* In such cases, individuals may have to rely on common sense in assessing smoke conditions (e.g., mild, moderate, heavy smoke) and the kinds of protective actions that might be necessary. At night or during periods when visibility cannot be used to estimate smoke levels, intense smoky odor may be used to indicate potentially harmful levels.

Additional information on estimating pollutant exposures from smoke can be obtained at http://fs.fed.us/pnw/pubs.htm, which contains an online version of "Smoke Exposures at Western Wildfires" (PNW-RP-525, July 2000). This link contains a series of photographs relating smoke levels near wildfires with measuring exposures to respirable particles, carbon monoxide, and formaldehyde.

Recommendations for the public

Pre-season public service announcements

In areas where fires are likely to occur, state and local public health agencies should consider running pre-season public service announcements (PSAs) or news releases to advise the public on how to prepare for the fire season. PSAs should be simple (e.g., the season for wildfires is approaching; there are things you can do now to help protect your health and prepare your home in the event of a wildfire), and should list a contact phone number or website for further information.

News releases should be used to provide more detailed information, including information for the general public and for people with chronic diseases.

General recommendations to the public should include at least the following:

1. Have a several day supply of nonperishable groceries that do not require cooking, since cooking can add to indoor pollutant levels.
2. If you develop symptoms suggestive of lung or heart problems, consult a health-care provider as soon as possible.
3. Be alert to PSAs.
4. Be aware that outdoor events, such as athletic games or competitions, may be postponed or cancelled if smoke levels become elevated.

Recommendations for people with chronic diseases should include at least the following:

1. Have an adequate supply of medication (more than 5 days)
2. People with asthma should have a written asthma management plan.
3. Contact a health-care provider if your condition worsens when you are exposed to smoke.
4. A news release could also include recommendations for preparing residences to keep smoke levels lower indoors, and on the appropriate use of facemasks. A sample news release developed by the Washington State Department of Health can be found in Appendix B.

Public advisories and protective measures

Table 2 provides a general list of health effects and cautionary statements for use in public advisories. The categories are based on the Environmental Protection Agency's Air Quality Index (AQI), as well as work done in Montana, California and Washington. (For more information on the AQI, see http://www.epa.gov/airnow/aqibroch/). The recommended $PM_{2.5}$ concentrations (1- to 3-hour averages) at which these advisories should be issued are listed in Table 3. If only PM_{10} measurements are available, and conditions are smoky, it should be assumed that the PM_{10} levels are composed primarily of fine particles ($PM_{2.5}$), and the AQI for PM_{10} should be used.

Table 3 provides guidance to public health officials on appropriate measures that can be taken to protect public health. These levels are intended for use in extraordinary circumstances to help public health authorities, the media, and the general public make decisions regarding appropriate strategies to mitigate exposure to smoke. It should be recognized that there are no directly relevant epidemiological or controlled human exposure studies that offer guidance in the selection of these levels, in part because studies of short-term effects of particulates generally have not been conducted and in part because the toxicity of smoke is likely related to gases in smoke as well as particles.

Table 2. Health Effects and Cautionary Statements

Category (defined in footnote, Table 3)	**Health Effects**	**Cautionary Statements**[1]	**Other Protective Actions**
Good	None expected	None	None
Moderate	Possible aggravation of heart or lung disease	Unusually sensitive individuals should consider limiting prolonged or heavy exertion. - People with heart or lung disease should pay attention to symptoms - If you have symptoms of lung or heart disease, including repeated coughing, shortness of breath or difficulty breathing, wheezing, chest tightness or pain, palpitations, nausea, unusual fatigue or lightheadedness, contact your health care provider.	- If symptomatic, reduce exposure to particles by following advice in box below.
Unhealthy for Sensitive Groups	Increasing likelihood of respiratory or cardiac symptoms in sensitive individuals, aggravation of heart or lung disease and premature mortality in persons with cardiopulmonary disease and the elderly.	*Sensitive Groups:* People with heart or lung disease, the elderly, children and pregnant women should limit prolonged or heavy exertion. - Limit time spent outdoors - Avoid physical exertion - People with asthma should follow asthma management plan - If you have symptoms of lung or heart disease that may be related to excess smoke exposure, including repeated coughing, shortness of breath or difficulty breathing, wheezing, chest tightness or pain, heart palpitations, nausea, unusual fatigue or lightheadedness, contact your health care provider.	- Keep doors and windows closed, seal large gaps as much as possible - If cooling is needed, turn air-conditioning to re-circulate mode in home and car, or use ceiling fans or portable fans (but do not use whole house fans that suck outdoor air into the home). - Avoid indoor sources of pollutants, including tobacco smoke, heating with wood stoves and kerosene heaters, frying or broiling foods, vacuuming, and using paints, solvents, and adhesives - Keep at least 5-day supply of medication available. - Have supply of non-perishable groceries that do not require cooking.

[1] Higher advisory levels automatically incorporate all of guidance offered at lower levels.

Table 2. Health Effects and Cautionary Statements

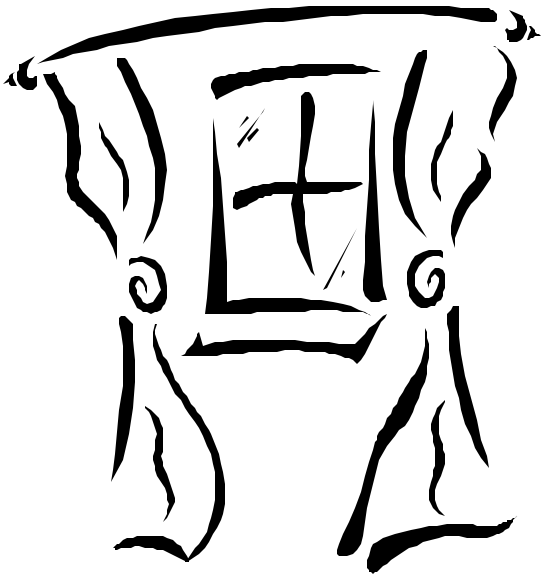
Category	Health Effects	Cautionary Statements [1]	Other Protective Actions
Unhealthy	Increased aggravation of heart or lung disease and premature mortality in persons with cardiopulmonary disease and the elderly; increased respiratory effects in general population.	*Sensitive Groups:* should avoid prolonged or heavy exertion - Stay indoors; avoid exertion. *General Population:* should limit prolonged or heavy exertion - Limit time spent outdoors - If you have symptoms of lung or heart disease that may be related to excess smoke exposure, including repeated coughing, shortness of breath or difficulty breathing, wheezing, chest tightness or pain, palpitations, nausea or unusual fatigue or lightheadedness, contact your health care provider.	*Sensitive Groups:* - Stay in a "clean room" at home (where there are no indoor smoke or particle sources, and possibly an air cleaner is used). - Go to a "cleaner air" shelter (see Appendix A) or possibly out of area *General Population:* - Follow advice for sensitive groups in box above. - Identify potential "cleaner air" shelters in the community (see Appendix A).
Very Unhealthy	Significant aggravation of heart or lung disease, premature mortality in persons with cardiopulmonary disease and the elderly; significant increase in respiratory effects in general population.	*General Population:* should avoid prolonged or heavy exertion - Stay indoors, avoid exertion	*General Population:* If symptomatic, evacuate to cleaner air shelter or leave area, if safe to do so.
Hazardous	Serious aggravation of heart or lung disease, premature mortality in persons with cardiopulmonary disease and the elderly; serious risk of respiratory effects in general population.	*General Population:* should avoid any outdoor activity.	*General Population:* If symptomatic, evacuate to cleaner air shelter or leave area, if safe to do so.

[1] Higher advisory levels automatically incorporate all of the guidance offered at lower levels.

Table 3. Recommended Actions for Public Health Officials

Category**	**$PM_{2.5}$ or PM_{10} Levels ($\mu g/m^3$, 1- to 3-hr avg.)**	**Visibility - Arid Conditions (miles)**	**Recommended Actions[1]**
Good	0 - 40	≥ 10	If smoke event forecast, implement communication plan
Moderate	41 - 80	6 – 9	- Issue public service announcements (PSAs) advising public about health effects/symptoms and ways to reduce exposure - Distribute information about exposure avoidance
Unhealthy for Sensitive Groups	81 - 175	3 – 5	- If smoke event projected to be prolonged, evaluate and notify possible sites for clean air shelters - If smoke event projected to be prolonged, prepare evacuation plans
Unhealthy	176 - 300	1.5 - 2.5	- Consider "Smoke Day" for schools (i.e., no school that day), possibly based on school environment and travel considerations - Consider canceling public events, based on public health and travel considerations
Very Unhealthy	301 - 500	1 – 1.25	- Consider closing some or all schools (newer schools with a central air cleaning filter may be more protective than older, leakier homes) - Cancel outdoor events (e.g., concerts and competitive sports)
Hazardous	> 500	≤ 0.75	- Close Schools - Cancel outdoor events (e.g., concerts and competitive sports) - Consider closing workplaces not essential to public health - If PM level projected to continue to remain high for a prolonged time, consider evacuation of sensitive populations

Specific strategies



Staying Indoors

The most common advisory issued during a smoke pollution episode is to stay indoors. The usefulness of this strategy depends entirely on how clean the indoor air is. Studies (almost none of which were conducted during forest fire smoke episodes) indicate that this strategy can usually provide some protection, especially in a tightly closed, air-conditioned house in which the air-conditioner can be set to re-circulate air instead of bringing in outdoor air. Staying inside with the doors and windows closed can usually reduce exposure to ambient air pollution by about a third. In homes without air conditioning, anywhere from 70 to 100 percent of fine particles will penetrate indoors from the outdoor air. In very leaky homes and buildings, the guidance of staying inside with doors and windows closed may offer little protection. If doors and windows are left open, particle levels indoors and outdoors will be about the same.

Increased risk of heat stress is also an important drawback of advising people to stay inside during smoke events. The fire season typically extends from mid-summer through the early fall, when high outside temperatures are common. For individuals who depend on open windows and doors for ventilation, keeping windows and doors closed can be problematic. Older individuals and others in frail health run the risk of heat exhaustion or heat stroke, which could have dire consequences. If outdoor temperatures are very high, it would be prudent to advise those without air conditioning to stay with friends or family who do, go to a cleaner air shelter in their community, or to leave the area. This and other options are discussed below.

Sometimes smoke events can last for several weeks or (rarely) months. These longer events are usually punctuated by times with relatively clean air. When air quality improves, even temporarily, residents should "air out" their homes to reduce indoor air pollution. People may also wish to clean their residences during such reduced smoke intervals, including mopping, dusting, and vacuuming, in order to reduce subsequent resuspension of particles that may have settled when the smoke was thicker.

Reduced activity

Reducing physical activity is an important and effective strategy to lower the dose of inhaled air pollutants and minimize health risks during a smoke event. During exercise, people can increase their air intake as much as 10 times their resting level. An endurance athlete can process as much as 20 times the normal air intake. Increased breathing rates bring more pollution deep into the lungs. Furthermore, while exercising, people tend to breathe

through their mouths, bypassing the natural filtering ability of the nasal passages, again delivering more pollution to the lungs. They also tend to breathe more deeply, causing the particles to deposit deeper into the lungs where they may cause more damage.

Reduce other sources of indoor air pollution

Many indoor sources of air pollution can emit large amounts of the same pollutants present in forest fire smoke. Indoor sources such as burning cigarettes, gas, propane and wood-burning stoves and furnaces, and activities such as cooking, burning candles and incense, and vacuuming can greatly increase the particle levels in a home and should be avoided during high pollution or when wildfire smoke is present. For instance, in room of 125 square feet, it takes only 10 minutes for the side-stream smoke of 4 cigarettes to create levels of particles in the hazardous ranges (644 mg/m^3). Frying or broiling some foods can produce even higher levels of particles in the kitchen and dining areas. 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 properly vent to the outdoors (including "room vented" or "vent-free" appliances) contribute most to indoor pollutant levels, and are of greatest concern. Reducing indoor air pollutant emissions during smoke events may reduce indoor particle levels by one quarter to one third or more. Levels of PAHs, VOCs and other pollutants can be reduced by an even greater proportion. These reductions can help compensate for the increased particle loading from the outdoor air.

Air conditioners

Little is known about the impact of using various types of air conditioners and air filters on indoor air pollutant concentrations. The conventional wisdom is that air conditioners reduce the amount of outdoor particles infiltrating indoors because air-conditioned homes usually have lower air exchange rates than homes that use open windows for ventilation. However, some air conditioners have both "outdoor air" and "re-circulate" settings; these air-conditioners need to be set on "re-circulate". If possible, replace the air-conditioner filter with a pleated medium efficiency filter. However, caution must be taken to assure that the system is able to handle the possible increased airflow resistance. Some air conditioners may also be fitted with filters. The more useful are HEPA (High Efficiency Particulate Arrestor) filters, which can capture most of the tiny particles associated with smoke and can further reduce the amount of outside air pollution that gets indoors and can further reduce the amount of outdoor air pollution that gets indoors.

Room air cleaners

Choosing to buy an air cleaner is a decision that ideally should be made ***before*** a smoke emergency occurs. During a smoke emergency, those who require such devices should not be going outside or driving in an attempt to locate an appropriate device, which may be in short supply. It is unlikely that local health officials will be able to buy or supply air cleaners to those who might need them.

Some air cleaners can be effective at reducing indoor particle levels, provided the specific air cleaner is adequately matched to the indoor environment in which it is placed. However, they tend to be expensive. Air cleaners are available as either a portable unit designed to clean the air in a single room ($50 - $300) or a larger central air cleaner intended to clean the whole house ($300 - $1000+). Most air cleaners are not effective at removing gases and odors. The two basic types of air cleaners for particle removal are:

> (a) Mechanical cleaners, which contain a fiber or fabric filter. The filters need to be sealed tightly in their holders, and cleaned or replaced regularly.
> (b) Electronic air cleaners, such as electrostatic precipitators (ESPs) 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 (which can damage lungs) 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 airflow. Together, these two factors equal the Clean Air Delivery Rate (CADR), which is a better measure of how a device will actually perform. For example, 99.99 percent efficiency sounds great, but if the air exchange rate is only 20 cubic feet per minute (cfm), one would be better off at 90 percent efficiency with 100 cfm air exchange rate (CADR: 20 vs 90 cfm).

Room air cleaner units should be sized to filter at least two or three times the room volume per hour. Most portable units will state on the package the unit's airflow rate, the room size it is suitable for, its particle removal efficiency and perhaps 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.

High and medium efficiency media filters and electrostatic precipitators can be added to central air conditioning systems to keep particle levels in indoor air within acceptable levels during a prolonged smoke event. However, these filters create greater air resistance in the air conditioning system, and may require modifications to the system. . In addition, electronic air-cleaners can increase indoor levels of ozone.

Devices that remove gases and odors are relatively costly, both to purchase and maintain. They force air through materials such as activated charcoal or alumina coated with potassium

permanganate. However, the filtering medium can become quickly overloaded and may need to be replaced often.

For more information about residential air cleaners:
www.epa.gov/iaq/pubs/residair.html
http://www.arb.ca.gov/research/indoor/acdsumm.htm
www.lungusa.org.pub/cleaners/

Ozone generators – a poor choice

Some devices, known as ozone generators, personal ozone devices, "energized oxygen" generators, and "pure air" generators, are sold as air cleaners, but the position of public health agencies, including the California Air Resources Board and US Environmental Protection Agency, is that they do more harm than good. These devices are designed to produce ozone gas to react with pollutants in the air. Ozone is composed of three atoms of oxygen. The third atom can detach from the molecule and reattach to molecules of other substances, altering their chemical composition. It is this ability to react with other substances that forms the basis of the manufacturers' claims.

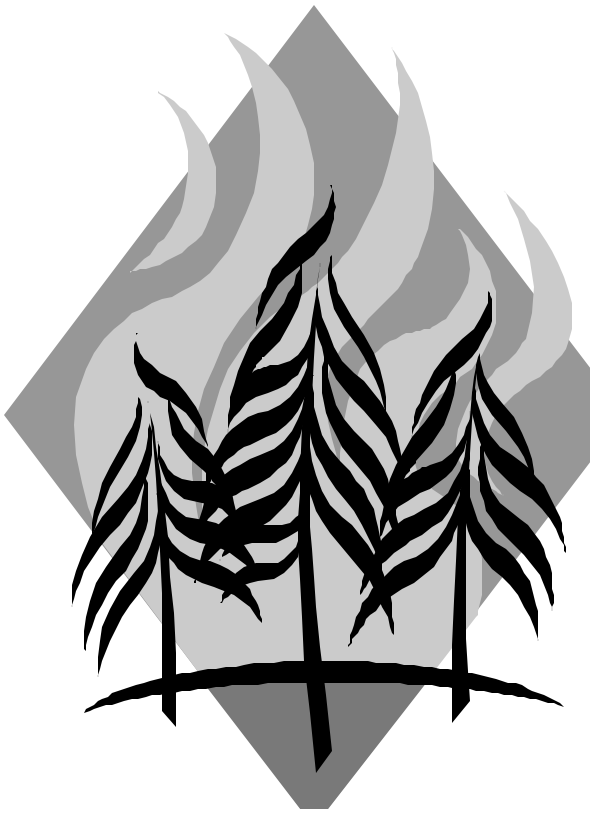
Ozone, whether in its pure form or mixed with other chemicals, can be harmful to health. When inhaled, ozone can damage the lungs. Relatively low amounts of ozone can irritate the airways, cause coughing, chest pain and tightness, and shortness of breath. It can also worsen chronic respiratory diseases such as asthma, as well as compromise the body's ability to fight respiratory infections. As a result, using an ozone generator during a smoke event may actually increase the adverse health effects from the smoke. In addition, ozone does not remove particles from the air, and would therefore not be effective during smoke events. (Some ozone generators include an ion generator to remove particles, but it would be far safer to buy the ionizer by itself.)

For more information about ozone generators marketed as air cleaners:
www.epa.gov/iaq/pubs/ozonegen.html
http://www.dhs.ca.gov/ps/dcdc/cm/pdf/cm9803pp.pdf.

Humidifiers

Humidifiers are not air cleaners, and will not significantly reduce the amount of particles in the air during a smoke event. Nor will they remove gases like carbon monoxide. However, humidifiers and dehumidifiers (depending on the environment) may slightly reduce pollutants through condensation, absorption and other mechanisms. In an arid environment, one possible benefit of running a humidifier during a smoke event might be to help the mucus membranes remain comfortably moist, which may reduce eye and airway irritation. However, the usefulness of humidification during a smoke event has not been studied.

Inside vehicles



Individuals can reduce the amount of smoke in their vehicles by keeping the windows and vents closed. However, in hot weather a car's interior can heat up very quickly to temperatures that far exceed those outdoors, and heat-related stress can result. Children and pets should ***never*** be left unattended in a vehicle with the windows closed. The car's ventilation system typically removes a small portion of the particles coming in from outside. Most vehicles can re-circulate the inside air, which will help keep the particulate levels lower. Drivers should check the owner's manual and assure that the system is set correctly to minimize entry of outdoor smoke and particles.

Masks

In general, the use of a mask is not an effective exposure reduction strategy during a smoke event. In order for a mask to provide protection, it must be able to filter very small particles (around 0.3 to 0.1 micrometer) and it must fit well, providing an airtight seal around the wearer's mouth and nose. Commonly available paper dust masks, which are designed to filter out larger particles, such as sawdust created by sanding, typically offer little protection. The same is true for bandanas (wet or dry) and tissues held over the mouth and nose. Surgical masks that trap smaller particles are also available, but these masks are designed to filter air coming out of the wearer's mouth, and do not provide a good seal to prevent inhalation of small particles or combustion gases. As a result, these tend to be no better than dust masks. In fact, masks may actually be detrimental, giving the wearers a false sense of security, which may encourage increased physical activity and time spent outdoors, resulting in increased exposures.

There are several additional 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. For instance, it is impossible to get a good seal on individuals with beards or mustaches. In addition, such masks aren't designed for use by the general public (including children). As a result, masks will provide little, if any, protection.

Masks are uncomfortable (they are more comfortable when they are leaky – but then they do not provide protection). They increase resistance to airflow. This may make breathing more difficult and lead to physiological stress, such as increased respiratory and heart rates. Masks can also contribute to heat stress. Because of this, mask use by those with cardiopulmonary

and respiratory diseases can be dangerous, and should only be done 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. A final problem with masks readily available to the public is that they do not filter out harmful irritant gases, such as acrolein or formaldehyde, or other toxic gases, such as carbon monoxide.

There are some situations in which 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 used in conjunction with other methods of exposure reduction, including staying indoors, reducing activity, and using HEPA air cleaners to reduce overall smoke exposure.

Some masks (technically called respirators, but they look more like paper masks) are good enough to filter out 95 percent of the particulate matter that is 0.3 micrometers and larger. Smoke particulate matter averages about 0.3 micrometers in diameter, so these masks can filter out a significant portion of the smoke if they are properly fit to the wearer's face. These masks, which may include an exhalation valve, do not require cartridge filters. They are marked with one of the following: "R95", "N95" or "P95." These are typically sold at home improvement stores, and tend to be more expensive than ordinary dust masks. Soft masks with higher ratings (R, N or P 99 and R, N, or P100) are also available and will filter out even more particles. As with masks, if a respirator does not provide a tight seal, it will not be effective (see preceding discussion on masks).

Respirators with purple HEPA filters offer the highest protection, but may be less comfortable and slightly more expensive than the flexible masks. Individuals who wish additional protection may purchase tight-fitting respirators that require cartridge filters. Respirator cartridges can be obtained that have a combination N95 or N99 filter with organic vapor backup. This combination can help reduce exposure to some gases, such as benzene and irritant aldehydes, as well as particles. Again, unless there is an airtight seal over the wearer's mouth and nose, the mask will provide little protection.

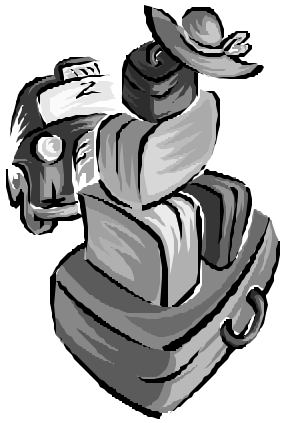
Cleaner Air Shelters

Public health officials in areas at risk from forest fires should identify and evaluate cleaner air shelters prior to the fire season. Guidance for identifying and setting up a Cleaner Air Shelter is provided in Appendix A. During severe smoke events, clean air shelters can be designated to provide residents with a place to get out of the smoke. Staying inside may not adequately protect sensitive individuals, however, since many houses and apartments do not have air conditioning, and depend on open windows and doors for cooling. Other homes may be so leaky that indoor pollution levels will quickly equal those outside. Cleaner air

shelters can be located in large commercial buildings, educational facilities, shopping malls or any place with effective air conditioning and particle filtration.

Closures

The decision to close or curtail business activities will depend upon predicted smoke levels, and other local conditions. One factor to consider is whether pollutant levels inside schools and businesses are likely to be similar to or lower than those in homes. The physical activity of children may also be better controlled in schools than in homes, making school closings a poor choice. On the other hand, in some school districts smoky conditions may make travel to school hazardous. In many areas it will not be practical to close businesses and schools, although partial closures may be beneficial. Closures and cancellations can target specific groups (e.g., the sensitive populations described earlier) or specific, high-risk activities, such as outdoor sporting events and practices. Curtailing outside activities can reduce exposures, as can encouraging people to stay inside and restrict physical activity. A decision to restrict industrial emissions should be based on local air pollution and the emission characteristics of particular industries. Curtailment may not be beneficial if eliminating industrial emissions will not markedly reduce local air pollution.



Evacuation

The most common call for evacuation during a wildfire is due to the direct threat of engulfment by the fire rather than by exposure to smoke. Leaving an 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. Even if smoky conditions are expected to continue for weeks, it may not be feasible to evacuate a large percentage of the affected population.

Moreover, the process of evacuation can entail serious risks, particularly if poor visibility makes driving hazardous. In these situations, the risks posed by driving with reduced visibility need to be weighed against the potential benefits of evacuation. Therefore, in areas where fires are likely to occur, public health officials are encouraged to develop plans for local protection of sensitive groups.

Summary of Strategies for Exposure Reduction

When wildfires are expected to create smoky conditions, people can pursue a number of strategies to reduce their exposure. Those with moderate to severe heart or respiratory disease might consider staying with relatives or friends who live away from the smoke during the fires. If smoke is already present in substantial quantities, such individuals may want to evaluate whether evacuation might actually cause greater exposure than staying at home using other precautions described above.

All people (except firefighters or emergency personnel) in a smoky area should avoid strenuous work or exercise outdoors. They should avoid driving whenever possible. If driving is necessary, people should run the air conditioner on the "recycle" or re-circulate mode to avoid drawing smoky air into the car.

Closing up a building by shutting windows and closing doors can give some protection from smoke. If the building has air conditioning, its controls should be set in the "recycle" mode, if possible, to prevent smoke-laden air from being drawn into the building.

Once people have closed up the building in which they live or work, they should avoid strenuous activity, which can make them breathe harder and faster. They should drink plenty of fluids to keep their respiratory membranes moist. They may even want to breathe through a moistened washcloth, as long as it does not interfere with their ability to breathe. Dust masks generally do not capture very fine particles and may make it more difficult to breathe, especially for people with chronic lung diseases such as chronic bronchitis or emphysema.

In preparation for the fire season or a smoke event, it is a good idea to have enough food on hand to last several days, so that driving can be minimized. It is also important to have at least a five-day supply of medication for the same reason. Foods stored for use during the fire season should not require cooking, since cooking can add particles to indoor air. Vacuuming should also be avoided, since most vacuum cleaners disperse very fine dust into the air.

If smoke levels increase to very unhealthy or hazardous levels, it may be appropriate for some individuals to stay in a clean room in the home, relocate temporarily to a cleaner air shelter, or to leave the area entirely if it is safe to do so.

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Resources/ LINKS

Montana Department of Environmental Quality: **www.deq.state.mt.us/FireUpdates/index.asp**
EPA/University of Washington Fire, Smoke and Health Website: **www.firesmokehealth.org**
National Fire Weather: **www.boi.noaa.gov/firewx.htm**
National Weather Service: **www.wrh.noaa.gov**
National Wildland Fire Information: **www.nifc.gov/information.html**
Forest Service Wildland Fire Morning Report: **www.fs.fed.us/news/fire/mornrpt.html**
Current Map of Large Fires: **wildfire/usgs.gov/website/fireinfo**
Satellite Images of Fires: **www.osei.noaa.gov/Events/Fires**

Appendix A

Identification of Cleaner Air Shelters for protection from wildfire smoke:

1. Identify one or more facilities with tight-sealing windows and doors and public access (for example, public schools, fire stations, hospitals, etc.). As a rule of thumb, newer buildings will generally be more desirable than older ones.
2. Facilities with a ventilation system able to significantly reduce, or even eliminate, intake of outdoor air are desirable. If possible, reduce the intake of outdoor air by the ventilation system when the building is used as a Cleaner Air Facility. Open the damper and flush the building when the air is clear.
3. At a minimum, a Cleaner Air Shelter should have a central air filtration system that is at least medium or high-efficiency. If needed, filters should be upgraded prior to the fire season, after assuring that the system can handle the increased airflow resistance.
4. Install/inspect a room air cleaner or preferably a central air cleaner with sufficient capability, i.e., a Clean Air Delivery Rate (CADR) that is twice the room volume for room units, or ASHRAE filter efficiency greater than 80%[1] for central air cleaners. Ensure proper maintenance of air cleaners, keep spare filters on hand, and provide instructions on changing the filter to trained personnel available to change the filter.
5. Assure that the facility can handle the increased cooling load due to high occupancy.
6. Install a properly calibrated carbon monoxide (CO) alarm that has a digital display and battery backup function (available at most hardware stores).
7. Provide a radio for updates on fire status and access to a telephone in case of emergency.

SOURCE: American Society of Heating, Refrigeration, and Air-conditioning Engineers (ASHRAE) Standard 52.1-1992. "Gravimetric and Dust-Spot Procedures for Testing Air-Cleaning Devices Used in General Ventilation for Removing Particulate Matter".

Appendix B

Washington State Department of Health

News Release

For Immediate Release: July 19, 2001 (01-75)

Contacts:	Denise LaFlamme, Environmental Health Assessment	360-236-3174
	Kate Lynch, Communications Office	360-236-4078
	Lori Albert, Okanogan Health Department	509-422-7156

Smoke from forest fires can create problems for asthmatics, others with chronic diseases

OLYMPIA ¾ An early forest fire season and predictions for a drier-than-normal summer can mean trouble for asthmatics and others with chronic lung or heart diseases. Forest fires present health risks for everyone, especially people with lung or heart diseases, whose health can be seriously affected by smoke.

The Okanogan County Health District, where the Thirtymile Fire still continues to burn, has been monitoring smoke in the county, and issued a health warning last week. "We found that air pollution levels from the fire changed radically within hours, depending on weather conditions," said Lori Albert, a health administrator for Okanogan County. "We have been urging residents who have respiratory or heart conditions to take precautions when smoke is present." She added that "so far, remarkably, we have experienced few problems related to smoke in populated areas because of the direction of the wind."

The Department of Health reminds people with asthma to develop an asthma management plan with their physicians. An asthma management plan involves tracking symptoms to determine when to use additional medications or seek further medical treatment. National Institutes of Health has comprehensive information on managing asthma on their Web site: http://www.nhlbi.nih.gov/health/public/lung/index.htm Those with other lung diseases or infections should contact their physicians to learn how to avoid serious complications that may result from forest fires.

Often people who have not been previously diagnosed with lung or heart disease may begin having problems in smoky conditions. Symptoms of potential lung and/or heart problems include chest tightness, chest pain, shortness of breath, or sudden, overwhelming fatigue.

Be prepared: People with asthma, bronchitis, emphysema, and other lung diseases should make sure they are on medication and have at least a five-day supply on hand at all times through fire season. Talk to your doctor about an asthma management plan and stick to it during unusually smoky conditions. Listen for radio and television messages about fires in your area. Keep a supply of non-perishable groceries on hand, especially foods that do not require cooking. In the event of a wildfire, stay indoors and limit your activity. Check for a "recirculation" function on your furnace or air conditioner. If smoke is present, it will be easier to breathe indoors if air is recirculating instead of drawing smoky air from outdoors.

What to do if there is smoke present:

- **Stay inside with windows and doors shut.**
- **Use the recycle or re-circulate mode on the air conditioner in your home or car.**
- **Avoid cooking and vacuuming, which can increase pollutants indoors.**
- **Avoid physical exertion.**
- **Asthmatics should follow their asthma management plan.**
- **Keep at least a five-day supply of medication on hand.**
- **Contact your doctor if you have symptoms such as chest pain, chest tightness, shortness of breath, or severe fatigue. This is important for not only for people with chronic lung or heart disease, but also for individuals who have not been previously diagnosed with such illnesses. Smoke can "unmask" or produce symptoms of such diseases.**
- **Keep airways moist by drinking lots of water. Breathing through a warm, wet washcloth can also help relieve dryness.**
- **A fitted mask (OSHA N95) can be used to reduce smoke exposure unless it interferes with breathing. A dust mask is generally ineffective with smoke.**
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