A REVIEW OF FACTORS AFFECTING THE HUMAN HEALTH IMPACTS OF AIR POLLUTANTS FROM FOREST FIRES

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SUMMARY

Although total emissions and adverse health effects have been documented in past studies, the overall toxicity of exposure to smoke or haze from forest fires has yet to be fully evaluated. A review of the literature identifies potential factors that influence forest fire emissions and allows for extrapolation of possible health effects. Fire dynamics involves fire, fuel, and climatological factors. The ecosystem's chemical and physical features combined with environmental parameters (humidity, temperature, and wind speed) and the type of ignition, affect the combustion factor and efficiency and, therefore, the amount of biomass consumed, the composition of smoke emissions, and the rate of release of emissions. Characteristics of fuel (e.g., arrangement, size distribution, moisture, and chemical composition) affect the phases of combustion, for which the quantities and rates of releases vary. Exposure to combustion products can have potentially detrimental short and long term effects on human health. These products, their known health effects, and the factors influencing their effects are described for (1) particulate matter; (2) polycyclic aromatic hydrocarbons; (3) carbon monoxide; (4) aldehydes; (5) organic acids; (6) semivolatile and volatile organic compounds; (7) free radicals; (8) ozone; (9) inorganic fraction of particles; (10) trace gases and other releases; and (11) radionuclides. The biological aspects of severe aerosol loading require further investigation.

INTRODUCTION

Given the objective of protecting public health, a complete understanding of the spectrum of health effects from biomass fires requires knowledge of the full range and potential of factors that might affect health outcomes and related impacts. Although total emissions and adverse health effects have been documented in public health and medical literature, the overall toxicity of exposure to smoke or haze has yet to be fully evaluated. A review of the current literature, primarily from atmospheric chemistry, identifies several factors that potentially influence the impact of air pollutants from forest fires on the susceptibility of individuals and vulnerable groups. Knowledge of adverse effects on public health from direct and indirect linkages is lacking, and efforts to elucidate the biological mechanisms by which exposures to biomass smoke affect human health have yet to be described. However, an extrapolation of potential factors on health effects can be attempted, taking into consideration biological plausibility, linkage between cause and effect, and coherence of past and current studies.

FIRE DYNAMICS AND THE COMBUSTION PROCESS

Fire dynamics is a complex process involving fire, fuel and climatological factors including altitude and meteorology. Under ideal conditions (i.e., complete combustion), the burning of organic material is an oxidation process that primarily produces water vapor and carbon dioxide (CO_2) (1). In natural and anthropogenic fires, combustion is incomplete due to an insufficient supply of oxygen (O_2). As a result, incompletely oxidized compounds (e.g., carbon monoxide) or reduced compounds (e.g., methane, nonmethane hydrocarbons, ammonia) are formed (1). These compounds are found in smoke, which often consists of irritant respirable particles and gases, and in some cases may be carcinogenic. Smoke itself is a complex mixture with components that depend on fuel type, moisture content, fuel additives such as pesticides sprayed on foliages or trees, and combustion temperature (2).

The combustion process involves two key parameters: the amount of biomass material burned and the proportion of a compound released during combustion, or emission factor, which is measured by grams (g) of pollutant per kilogram (kg) of fuel consumed. Combustion efficiency, defined as the ratio of carbon released by the fire as CO_2, is a fundamental parameter that integrates many of the variables affecting biomass volatilization and oxidation (3). The ecosystem's chemical and physical features combined with environmental parameters (humidity, temperature, wind speed) and the type of ignition, affect the combustion factor and combustion efficiency and, therefore, the amount of biomass consumed, the composition of smoke emissions, and the rate of release of emissions (4).

Combustion can consist of several phases relative to the time after ignition: (i) flaming phase, 0-20 minutes; (ii) initial smoldering phase, 20-80 minutes; and (iii) smouldering phase, 80-200 minutes. These processes are different phenomena involving different chemical reactions that result in diverse products (3). Characteristics of fuel (e.g., arrangement, size distribution, moisture, and chemical composition) affect the duration of each phase (3). The relative amount of biomass consumed through flaming and smoldering combustion can also vary due to these factors (4).

Exposure to combustion products can have potentially detrimental short and long term effects on human health. Although some of these products have been observed to occur in varying amounts after biomass fires (5, 6), little or no information exists about the intensity of human exposure and resulting health effects. The products, their known health effects, and the factors influencing their effects have been described for particulate matter (PM), polycyclic aromatic hydrocarbons (PAHs), carbon monoxide (CO), aldehydes, organic acids, semivolatile and volatile organic compounds (VOCs), free radicals, ozone, inorganic fraction of particles, trace gases and other releases, and radionuclides.

Particulate matter (PM)

Health effects

The solid component of smoke is PM, which at respirable size presents risks to human health. The PM mass is categorized into two modes: fine particle, with a mean-mass diameter of 0.3 micrometers (μm), and a coarse particle, with a mean-mass diameter greater than 10 μm. Even at low concentrations, fine particles have been observed to cause changes in lung function, leading to increases in respiratory and cardiovascular mortality and morbidity including asthma. Fine particles may reach the alveoli, and if not sufficiently cleared in the lungs and in great concentrations, may enter the bloodstream or remain in the lung, resulting in chronic lung disease such as emphysema. Airborne particulates may also contain toxic recondensed organic vapors, such as PAHs, which are indicated to be carcinogenic in animals (7).

Factors affecting health effects

The size of the fire event may influence resulting health effects. Particulate matter is produced abundantly, at least 0.6 tons per second after large fires, during forest fire combustion (8). 40 to 70 per cent of fine PM consists of organic carbon material, containing known carcinogens (9). 2-5 per cent is graphitic carbon; the remainder inorganic ash. Particulate matter may carry absorbed and condensed toxicants, and possibly, free radicals.

Polycyclic aromatic hydrocarbons (PAHs)

Health effects

PAHs comprise a group of organic compounds with two or more benzene rings, such as methyl anthracene, pyrene, chrysene, benzo(a)anthracene, fluroranthene, and methylchrysene. Benzo(a)pyrene is considered the most carcinogenic. Exposure to PAHs has been linked to lung cancer in railway workers exposed to diesel exhaust fumes and occupational lung cancer in coke oven and coal gas workers (7).

National Institute for Occupational Safety and Health limit is 35 ppm for 8 hours of exposure and 200 ppm for no defined time (5). Systematic studies of the effects of CO on human health should be performed, with carboxyhaemoglobin levels checked soon after exposure.

Aldehydes

Health effects

Aldehydes are primarily mucous membrane irritants. Some, such as formaldehyde, may be carcinogenic and in combination with other irritants may lead to an increase in the carcinogenicity of other compounds, such as PAHs (9). Formaldehyde and acrolein are the main aldehydes released during biomass burning. Formaldehyde, which is probably the most abundantly produced compound of this class, causes eye, nose, and throat irritation during smoke exposure (5). Low molecular weight aldehydes such as acrolein are thought to cause pulmonary lesions in rabbits (5).

Factors affecting health effects

These compounds have been poorly quantified as byproducts of the forest fuel combustion in the open environment. Sharkey (9) states that it is highly likely that acrolein is an irritant in smoke near firelines, with concentrations as high as 0.1 ppm to 10 ppm near fires.

Organic acids

Health effects

Organic acids, such as formic acid produced by the oxidation of formaldehyde, are known to form during the combustion of biomass fuels. Anticipated health effects include irritation of mucous membranes.

Factors affecting health effects

Organic acid production rates and combustion conditions, and the synergistic effects of some or all of these compounds, are unknown (9). It has been observed, however, that under equilibrium, high humidity could

drive reactions to the production of organic acids. Aldehydes, for example, can produce acidic groups (e.g., formic acid, acetic acid) under conditions of high moisture.

Semivolatile and volatile organic compounds (VOCs)

Health effects

Some VOCs may cause skin and eye irritation, drowsiness, coughing and wheezing, while others (e.g., benzene and 1,3-butadiene) may be carcinogenic. Benzene and benzo(a)pyrene may be genetoxic carcinogens (7).

Factors affecting health effects

VOCs may have significant vapor pressures at ambient temperatures. Some compounds, such as benzene, naphthalene, and toluene, are partitioned between gaseous, liquid, or solid phases at ambient temperatures. Little work has been done to characterize VOCs in forest fires. To date, methane and CO gases are produced in proportion to semivolatile and VOCs and serve as indicators of their abundance (9).

Free radicals

Health effects

Free radicals are abundantly produced during the combustion of forest fuels. Free radicals may react with human tissues. They have been observed to persist up to 20 minutes following formation and pose a problem for firefighters exposed to fresh aerosols. Additional research is needed to determine the types and quantities of free radicals emitted during the combustion of biomass fuels, their persistence in the atmosphere, and subsequent health effects (9).

Factors affecting health effects

None noted at this time.

Ozone (O_3)

Health effects

O_3 is an extremely reactive oxidant. At high concentrations, it may impair lung function and reduce respiratory resistance to infectious diseases. People at risk include those with chronic respiratory illness. At low levels, human health may be affected when physical exercise is combined with several hours of exposure, i.e., tissue dose is enhanced by increased respiratory rate (7). At low concentrations, O_3 can cause symptoms such as coughing, choking, shortness of breath, excess sputum, throat tickle, raspy throat, nausea, and impaired lung function when exercising. Long-term health effects include decreased lung function and chronic obstructive pulmonary disease (7).

Factors affecting health effects

Concentrations of concern are not expected in areas close to fires. O_3 is formed photochemically near the top of smoke plumes under high sunlight. It is also formed when smoke is trapped in valleys or where there is a temperature inversion. Additionally, increased levels of O_3 may be encountered at high elevations.

OSHA has established standards for occupational exposure to O_3; however, these regulations have yet to be evaluated, along with other chemicals for biomass burning.

Inorganic fraction of particles

Health effects

Toxicologic effects of inorganic fractions from biomass fires have not been quantified. Health effects are dependent on the substance in question, such as lead, asbestos, and sulphur.

Factors affecting health effects

Inorganic materials, which are generally present in trace levels in smoke particles, are dependent on the chemistry of the fuels burned and the

intensity at which the fire burns. Often, variability in the mineral content of fuels is enough to affect combustion. For example, in the United States, particles in the Los Angeles Basin were found to have a higher lead content than particles from fires in the Pacific Northwest due to deposition of lead deposits in those areas (5). Similarly, asbestos fibers were carried with smoke from areas that naturally contained high deposits of asbestos (5). Also, organic soils of the southeast and fuels in the Yellowstone geyser basins would have emissions with sulphur-containing gases because they contain naturally occurring areas of high sulphur deposition (5).

Savannah fire aerosols are characterized by enrichments in elements such as potassium (K), chlorine (Cl), zinc (Zn), and bromine (Br), whereas forest fire emissions are enriched in silicon (Si) and calcium (Ca). Of the trace elements, K is found in relatively high concentrations in wood smoke. The combustion of hardwoods produces more ash and therefore higher concentrations of trace elements than does the combustion of softwoods (19).

Trace gases and other releases

Health effects

Trace gases, particularly polychlorinated dibenzo-p-dioxins (PCDDs), are extremely persistent and widely distributed in the environment. Very little human toxicity data related to PCDD are available. Data of health effects in occupational settings are based on exposure to chemicals contaminated with 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD), which has a half-life of 7 to 11 years in humans. Dioxin exposures are associated with an increased risk of severe skin lesions (e.g., chloracne), and hyperpigmentation, altered liver function and lipid metabolism, general weakness associated with weight loss, changes in activities of various liver enzymes, immune system depression, and endocrine and nervous system abnormalities. TCDD also causes cancer of the liver and other organs in animals. Exposure to dioxin-contaminated chemicals has resulted in increased incidences of soft-tissue sarcoma and non-Hodgkin's lymphoma (20).

Methyl bromide and methyl chloride, which are sources of Br and Cl that destroy stratospheric ozone (21), may be carcinogenic (22). Health

effects resulting from the emission of these compounds from biomass fires have yet to be determined.

Factors affecting health effects

Smoke emitted during the global annual combustion of about 2 to 3 billion metric tons of plant materials contains numerous toxic materials, some of which are dioxins. Forest and brush fires are major sources of PCDDs (23, 24). If flame temperatures exceed 1000 °C, essentially no dioxins are produced; however, this is rarely the case. In a study that involved burning various wood specimens in different stoves, total dioxins released were as much as 160 μg dioxin/kg wood. Soot collected and analyzed by well-designed and documented procedures indicated the presence of tetrachlorinated, hexachlorinated, heptachlorinated, and octachlorinated dioxins (23, 24).

Wood combustion products are spread around the world by winds. Consequently, PCDDs are found in soils in remote areas and tend to be bioconcentrated in the food chain (23).

Biomass fires emit a complex mixture of particulates and gases into the atmosphere. Globally, the diversity of combustion products results from wide ranges in fuel types and fire behaviour, which are induced by large variations in ecological types and weather phenomena. For instance, forest fires have lower combustion efficiency than grass fires, and therefore a larger fraction of smouldering compounds. During less efficient smouldering combustion, a large number of organic compounds are formed (5).

Radionuclides and herbicides

Health effects

Radionuclides, such as iodine-129 (^{129}I), cesium-137 (^{137}Cs), and chlorine-36 (^{36}Cl), can be released into the atmosphere, soil, and water, with immediate and long term consequences on health (25). They can cause cancer, depending on where in the body they are localized. For example, iodine is concentrated in the thyroid gland and the radioactive isotopes can cause thyroid cancer.

Fire occurring immediately after the application of herbicides may lead to adverse health effects in forest workers; however, in one study, no herbicide residues from an application containing the active ingredients imazapyr, triclopyr, hexazinone, and pioloram were detected in 140 smoke samples and 14 fires (26).

Factors affecting health effects

Fires can mobilize radionuclides from contaminated biomass through suspension of gases and particles in the atmosphere or solubilization and enrichment of the ash. Loss to the atmosphere increased with fire temperature, and during a typical field fire, 80 per cent to 90 per cent of the I and Cl, and up to 40 per cent to 70 per cent of the Cs was lost to the atmosphere (25).

In assessing exposure, factors such as fire conditions (high density smoke versus low density smoke) and personnel location should be taken into consideration when assessing exposure to airborne herbicide residues in smoke from prescribed fires (26).

RADIATIVE EFFECTS THROUGH GLOBAL COOLING

Smoke particles affect the global radiation balance by reflecting solar radiation directly, acting as cloud condensation nuclei, and increasing cloud reflectivity. The radiative effects of aerosols generated from biomass burning, dust storms, and forest fires could increase global cooling (i.e., or reduce the rate of global warming). Anthropogenic increases of smoke emissions may help weaken the net greenhouse warming from anthropogenic trace gases (27).

The effect is measured by Direct Radiative Forcing (DRF), the perturbation in the energy balance of the earth-atmosphere system; positive and negative values indicate warming and cooling, respectively, of the troposphere. For comparison, the net incoming solar radiation at the top of the atmosphere is 342 watts per square meter (W/m^2). Radiative forcing due to aerosols is comparable in magnitude to current anthropogenic greenhouse gas forcing but opposite in sign. The DRF due

to long-lived greenhouse gases is 2.45 ± 0.37 W/m²; the global average of DRF due to anthropogenic aerosols is -0.5 W/m², largely attributed to sulphate particles from fossil fuel combustion and smoke particles from biomass burning (28).

Severe aerosol loading results in immediate health effects, specifically respiratory disease from particle inhalation. It also may lead to a reduction in photosynthesis, which may affect the incidence of infectious and mosquito-borne diseases in the long-term. In regions of intensive biomass burning, the photosynthetically active spectrum of sunlight (wavelengths of 400-700 nanometers (nm)) is reduced by 35 per cent to 40 per cent for two months (27). In one study, smoke from biomass burning caused significant aerosol optical thickness and up to an 81 per cent reduction in ultraviolet-B (UV-B) rays (29).

UV-B in natural sunlight kills airborne bacteria (27). The bactericidal effects of solar UV-B are well-known, and significantly reduced UV-B resulting from severe air pollution in regions where UV-B levels are ordinarily high might enhance the survivability of pathogenic organisms in air and water and on surfaces exposed to sunlight. In one study, exposing drinking water to normal intensities of UV-B has reduced diarrhea in children in Kenya by 33 per cent (30).

An increased incidence of respiratory, cardiopulmonary and other diseases are known to be associated with severe air pollution, but the biological mechanisms remain unknown.

The increased incidence of infectious and mosquito-transmitted disease has been raised as a possible consequence of severe aerosol loading. The larvae and pupae of some disease-transmitting mosquitoes are highly photophobic to ultraviolet-A (UV-A) rays and green wavelengths of sunlight. In 1995, in Brazil, smoke reduced sunlight in UV-A (340 nm range) as much as 45 per cent in an area peripheral to the region of maximum burning (29). Experiments with Culex pipiens, a vector for encephalitis, indicated that the females deposited eggs in the darkest nurseries and that their larvae avoided UV light (27).

The biological aspects of severe aerosol loading require further investigation. Estimates of emission factors of pollutants from forest fires

and biological mechanisms leading to adverse health effects will improve global accounting of radiation-absorbing gases and particles that may be contributing to climate change and will provide strategic data for fire management.

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GUIDANCE ON METHODOLOGY FOR ASSESSMENT OF FOREST FIRE INDUCED HEALTH EFFECTS

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INTRODUCTION

Air pollution has been linked to human morbidity and mortality in many parts of the world. The most famous air pollution episode occurred in London, England in December, 1952 and resulted in 3500 excess deaths. This watershed event in air pollution epidemiology was related to high levels of particulate and sulfur dioxide air pollution emanating from coal burning and exacerbated by an atmospheric inversion which trapped the pollutants in the city for almost one week. This episode, along with subsequent ones in other parts of the world, resulted in more research into the effects of air quality on human health and governmental intervention to monitor air quality with a view to decrease the levels of air pollutants.

Several factors are critical in ascertaining health effects of air pollution exposure. These factors include characteristics of the pollutants; population exposures; individual exposures; susceptibility of the exposed individual; potential confounding factors; and the range of health effects being studied. The availability of data on these factors greatly affects the type of study that one might be able to undertake.

This paper will focus on the assessment of forest fire related health effects (1). Forest fire related pollutants are similar, in many ways, to other combustion-generated fine particulate pollutants (2, 3). Thus, we will describe the methods used to ascertain the health effects of particulate pollution on human health (4). The types of study designs in air pollution epidemiology vary widely and include short-term controlled exposure studies (chamber studies); short-term exposure studies; and long-term exposure studies. This paper will focus on the latter two study designs, as they reflect a typical epidemiological approach to the problem of air pollutant exposure (5).

IMPORTANT COMPONENTS OF ALL STUDIES

Community level air pollution measurements

Having population-based monitors (as opposed to source-based monitors) is important to obtain better information on population exposures.

Particulate matter (PM_{10}, $PM_{2.5}$)

The current trend is to get more data on the finer particulate fraction. Coarser fractions, in some parts of the world, can contain dust from windblown earth or sand which can affect visibility but has only a small effect on human health. The fine particulate fraction is probably the best indicator of transported fire smoke.

Volatile organic compounds (VOCs)

Certain VOCs may serve as markers for fire-related pollutant exposure. Better characterization of the fire smoke and transported pollutants is needed to determine which VOCs are the best markers.

Other pollutants (ozone, carbon monoxide, etc.)

There is some evidence that ozone levels may increase in conjunction with forest fires.

Personal level pollutant exposure data

Such data are less likely to be available.

Personal or home-based air sampling

While this method gives the best data, it is impractical for large population studies. Some studies have used personal monitors to validate the use of population-based monitors.

Biomarkers of exposure

If an appropriate VOC was identified, one might be able to obtain blood and look for this compound as a marker of recent exposure.

Non-pollutant environmental factors associated with both air quality and health outcomes

Most of the health outcomes studied (respiratory disease exacerbation or hospitalization) are affected by changes in the weather. These weather changes can also affect air pollution due to factors such as inversions and wind speed. Important environmental factors include temperature, wind speed and direction, humidity, seasonality, and the presence of pollen and other allergens.

Personal factors affecting exposure to outdoor air pollutants

Time activity patterns

In the US, 90 per cent of the time is spent in indoor environments. This proportion may vary in other parts of the world.

Housing characteristics

This factor relates to the question of how much of the outdoor pollution comes indoors. Many tropical regions do not have a true "indoor" environment.

Interventions to reduce pollutant exposures

Although interventions such as masks or respirators or staying indoors have been recommended, their efficacy is still unclear.

Masks or respirators

Masks or respirators typically increase the work of breathing.

Personal factors affecting outcomes (and pollutant exposure)

Age, ethnicity, gender

Health effects tend to be more dramatic in the very young and the very old.

Existing diseases

People with preexisting respiratory disease (asthma and chronic obstructive pulmonary disease (COPD)) or heart disease are usually more susceptible to air pollutants.

Socioeconomic status

This factor can affect both exposure to pollutants (because of location or type of housing) and health outcomes (due to access to care and treatment)

Occupational exposures

Some occupational exposures are associated with chronic respiratory disease.

Tobacco smoking

Smoking is a confounding variable associated with respiratory and pulmonary disease.

Nutritional status may influence health status and susceptibility to air pollution.

Health outcomes

The type of outcome used depends on what types of data are available and the type of analysis planned.

Mortality

Data on total mortality and cardio-pulmonary mortality are usually available, although the quality of cause-specific data may vary in different parts of the world.

Hospitalisation

Hospitalisation data are frequently obtained from available administrative or billing data. It can also be available from the hospital directly, but may require manual searches.

Emergency room/outpatient visits

Data are sometimes available using administrative information. Many studies have been done using emergency room log books to extract data.

Symptomatic exacerbation

Symptomatic exacerbation is a component of panel or cohort studies that can be linked to emergency room visits or hospitalizations. It can also be part of an exposed/unexposed study.

Changes in lung function

Such changes are part of a panel study which requires the use of peak flow or portable spirometry measurement. It can also be part of an exposed/unexposed study.

Cardiopulmonary symptoms

Such symptoms (cough, wheezing, shortness of breath, angina) are part of a panel study and can also be part of an exposed/unexposed study.

Upper respiratory illnesses

These illnesses are part of a panel study and can also be part of an exposed/unexposed study

Mucous membrane irritations

Mucous membrane irritations (conjunctivitis, ear, nose and throat irritation) are part of a panel study.

SHORT-TERM EXPOSURE-RELATED HEALTH EFFECTS

These effects can include death, hospitalisation, exacerbation of disease, worsening of preexisting disease, worsening of symptoms, and worsening of physiological parameters such as lung function.

Population-based studies

These study models typically focus on endpoints such as mortality or hospitalization for either specific diseases or all diseases. The prototype study in this category is the study of deaths in the London smog episode of 1952

Time series studies

In recent years, numerous time series studies have been published focusing on the effect of particulate air pollution on mortality due to cardiovascular and respiratory diseases and hospitalizations due to diseases such as asthma, pneumonia, COPD, coronary artery disease and congestive heart failure. These types of studies can be very complicated analytically.

Cohort or individual-based studies

These studies typically focus on endpoints such as symptoms or exacerbation of disease, or worsening of lung function.

Panel studies

This type of study involves the collection of data (peak flows, use of bronchodilators, asthma symptoms, possible personal monitoring) among a small group of people (people with asthma) over a relatively short period of time. Typically, it depends on self-reporting and may also be analytically challenging.

Case-control study

The study involves collecting data on individuals with a specific acute health endpoint (such as an exacerbation of or hospitalization for lung disease, or death from cardiopulmonary disease) and similar individuals without these endpoints and assessing previous exposures to pollutants and other risk factors. Limitations include problems of assessing retrospective exposures. The method might be a useful model to examine the effects of preventive interventions.

LONG-TERM EXPOSURE-RELATED HEALTH STUDIES

These health effects can include mortality (life-shortening as opposed to acute death), hospitalization rates, disease rates (specifically for diseases such as COPD, heart disease and lung cancer), and presence of symptoms or lower levels of lung function.

Population-based study

Ecological Studies

In these studies, we do not know the specific exposure to any individual, but we have information on what the community exposures were. The goal in this type of studies is to look at outcomes (long-term mortality rates or disease rates) in areas with large differences in air

pollution levels. Limitations of these studies are large potentials for confounding and questions about the validity of the data.

Cohort or individual-based study

Cohort study

In this type of study, baseline data (sex, age, smoking status, occupation, presence of underlying disease, etc.) on groups of subjects are collected and the groups are followed over time to look for outcomes such as early mortality, development of cardiopulmonary disease, or declines in lung function. While these studies have the potential to yield very important data in a well-defined population with reasonably defined exposures, they are limited by being very costly and difficult to perform.

Case-control study

This type of study involves assessing individuals with a specific chronic health endpoint (such as development of COPD, lung cancer or congestive heart failure) and similar individuals without these endpoints on previous exposures to pollutants and other risk factors. Limitations of this type of study include problems in assessing retrospective exposures.

EVALUATION OF STUDY DATA

Data collected in any of these types of studies needs to be analysed very carefully, accounting for appropriate confounding factors and covariates. Analytic techniques vary with the type of study design used, and is well beyond the scope of this paper. New analytic computer programmes have been developed that allow us to better account for the important factors that determines health effects related to pollutant exposures.

CONCLUSION

Determining the health effects related to forest fires is a difficult task. There are a variety of different study models that can be used, depending on the resources and data available. Any model, though, requires careful planning and analysis.

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