
Health Effects of Wood Smoke



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INTRODUCTION

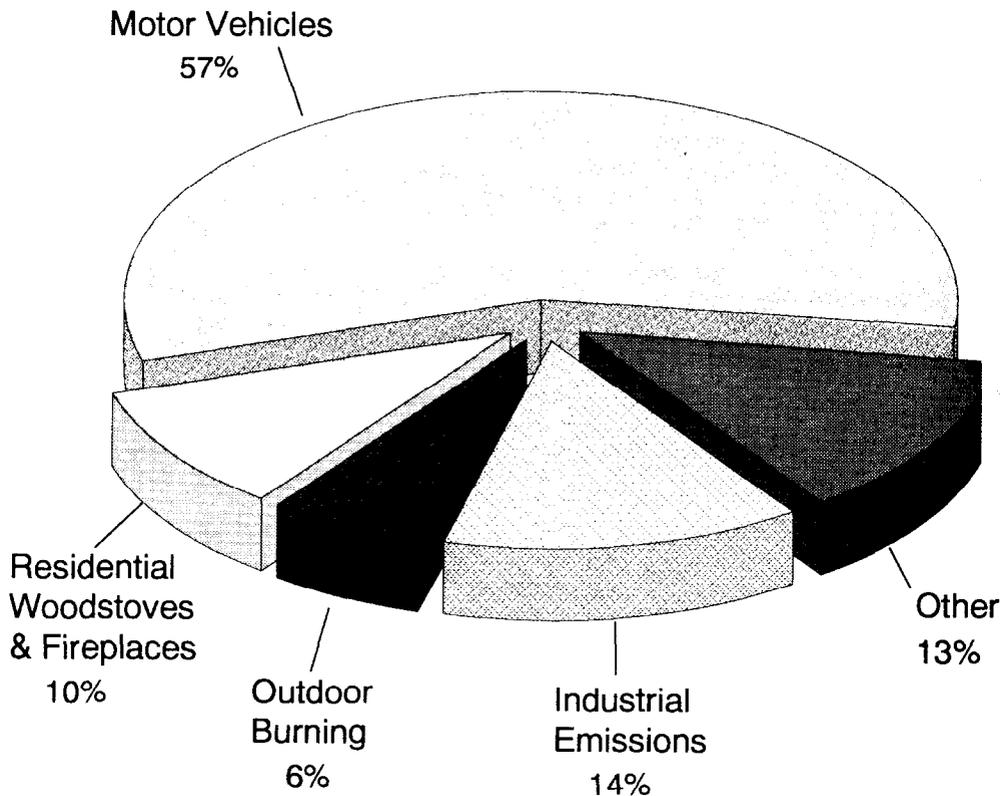
The smell of wood smoke evokes fond memories for many people, but for others it has become a danger signal. Wood smoke, largely from wood stoves, has become a major part of the air pollution problem in the United States. Smoke is composed of many small particles of carbon compounds from the burning of organic matter such as wood or coal. These small pieces of Organic matter from smoke, along with dust and other small particles of solid and liquid matter suspended in the air, are called particulate matter. Particulate matter is regulated by the federal government as one of the principal air pollutants.

In Washington State wood stoves and fireplaces release 10 percent of the total air pollution (see pie chart).¹³ Particulate pollution from wood stoves is produced mostly in the winter when stagnant air and temperature inversions limit air movement, “trapping” the pollution close to the ground and keeping it in our breathing space.

A growing body of evidence suggests that we cannot ignore the medical consequences of extensive exposure to wood smoke. This booklet presents some current air quality data, and information extracted from medical research on the health effects of household and neighborhood wood smoke.



**AIR POLLUTION SOURCES
AND THEIR CONTRIBUTIONS**



The category "Other" in this pie chart includes sources such as boats and other recreational vehicles, lawn mowers, etc.

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Glossary

ACUTE. Having a quick start and relatively serious characteristics, as an acute illness.

AIR. A mixture of gases containing about 78 percent nitrogen, 21 percent oxygen, and less than one percent carbon dioxide and other nonreactive gasses, with varying amounts of water vapor.

AIRSHED. The air supply of a given area defined by natural or topographic features, as well as by political or legal boundaries.

ALVEOLI. The numerous tiny air sacs at the end of the bronchioles in the lungs, where exchange of oxygen and carbon dioxide takes place across membranes with the blood.

ARTERIOSCLEROSIS. A chronic disease where thickening or hardening of the artery walls interferes with blood circulation.

ATMOSPHERE. The layer of air surrounding the Earth.

BACKDRAFTING. A downward flow of air into a fireplace or wood stove when outside air enters the exhaust opening. Most common in airtight dwellings where this becomes the only available source of combustion air, or when chimneys develop a creosote buildup, or when wood stoves are not properly installed.

BENZENE. A toxic chemical found in coal tar and used as an industrial solvent, as a gasoline additive, and in some paints or varnishes; a known carcinogen.

BRONCHIOLES. Small thin-walled branches of the bronchus, which branch further and lead to the tiny air sacs within the lungs.

BRONCHITIS. Inflammation of the mucous membrane of the bronchial tubes.

BRONCHIOLITIS. Inflammation of the mucous membrane of the bronchioles.

BRONCHUS. Either of two primary branches of the trachea or other branches with cartilage in their walls, which lead to the bronchioles in the lungs.

CARBON MONOXIDE (CO). A colorless, odorless gas produced by incomplete burning of carbon containing substances, especially by gasoline-powered vehicles. It is one of the six major air pollutants for which there is a national air quality standard.

CARCINOGEN. A substance or activity that causes cancer.

CARCINOGENIC. Capable of causing cancer.

CARDIAC. Of, near, or relating to the heart.

CERTIFIED WOOD STOVE. Models certified as relatively clean burning by the U.S. Environmental Protection Agency based on carbon monoxide and particulate matter emission testing at accredited laboratories.

CHRONIC. Marked by long duration or frequent recurrence, such as a chronic disease.

CILIA. Hairlike cells that line the passageways to the lungs. The motion of cilia propels tiny dirt particles and germs out of the respiratory tract.

COMBUSTION. The process of burning. More specifically, when a substance reacts with oxygen to produce heat and often light.

EMISSIONS. Waste substances or pollutants discharged into the air from sources such as automobiles, power plants, or wood stoves.

EMPHYSEMA. A swelling of the tiny air sacs or alveoli in the lungs resulting from destruction of the membranes which line the inside of the air sacs -- characterized by breathing difficulties and greater susceptibility to infections.

ENVIRONMENT. The aggregate of all outside conditions and influences affecting life, development, and survival of organisms.

ENVIRONMENTAL PROTECTION AGENCY (EPA). The independent federal government agency established in 1970 that regulates environmental matters and oversees environmental law enforcement.

HYDROCARBONS. A large family of compounds containing hydrogen and carbon. Can include many organic compounds in various combinations. Wood and fossil fuels are composed mainly of hydrocarbons. Many are air pollutants and some are carcinogenic.

INDOOR AIR POLLUTION. Air pollutants which are released inside buildings at concentrations often higher than in outdoor air. Common indoor air pollutants include radon, tobacco smoke, formaldehyde, and wood smoke.

INVERSIONS. An atmospheric condition occurring when a cool layer of air gets trapped below a layer of warm air and is unable to rise. This "ceiling" leads to a buildup of polluted air close to the ground and prevents vertical mixing and dispersion of smoke and other air pollutants.

LIFETIME CANCER RISK. The probability that someone will get cancer from a specific source at some time in their life.

LOWER RESPIRATORY TRACT INFECTIONS (LRTIs). Infections deeper in the respiratory tract than the nose and throat, such as bronchiolitis or pneumonia which involve the bronchioles or lung.

MICRON. A unit of length 1/1,000,000 of a meter.

MORTALITY RATE. Death rate.

MUCOUS MEMBRANE. The membrane lining all body channels that are exposed to air, such as the respiratory tract or the digestive tract. The glands of this membrane secrete mucus.

MUCUS. Organic compounds secreted by the mucous membrane, along with cells and inorganic salts suspended in water. This mixture acts as a lubricant and a protective coating.

MUTAGEN. An agent that causes biological mutation.

MUTATION. A change in the genes or chromosomes within the cells of living organisms.

MUTAGENICITY. A measure of the relative strength of different mutagens based on their ability to cause mutations.



NITROGEN OXIDES. Compounds of nitrogen and oxygen formed from high temperature burning. They contribute to acid rain and ozone formation. Nitric oxide (NO) and nitrogen dioxide (NO₂) contribute to lung and respiratory health problems. Nitrogen dioxide is the most toxic and is one of the six major air pollutants for which there is a national air quality standard.

ORGANIC. Concerning, related to, or derived from living organisms; in chemistry, a carbon containing compound.

OZONE (O₃). A form of oxygen consisting of three oxygen atoms per molecule. Ozone is a pungent, colorless, toxic gas that is a major component of smog. It is formed from nitrogen oxides and hydrocarbons in the presence of sunlight and heat. Ozone is one of six major air pollutants for which there is a national air quality standard.

PARTICULATE MATTER (PM). Small particles of solid and liquid matter found in the atmosphere including soot, dust, organic matter, smoke, or smog.

PM₁₀. Particulate matter that measures ten microns in diameter or less. One of six major air pollutants for which there is a national air quality standard.

PNEUMONIA. An acute or chronic disease caused by bacteria, viruses, or particulate matter and chemical agents characterized by inflammation of the lung tissue.

PULMONARY. Of or relating to the lungs.

RADON. A colorless, odorless radioactive gas formed by the decay of uranium, found in rocks and soil.

RESPIRATORY SYSTEM. The body's system for breathing, including the nose, throat, and lungs.

SINUS. Any of the air-filled cavities in the skull connected to the nostrils or external openings of the nose.

SINUSITIS. Inflammation of a sinus membrane, especially in the nasal or nose region.

SMOG. Air pollution consisting of fog mixed with smoke and or ozone, also called haze, or, in Los Angeles, smog ozone.

SLASH BURNING. The burning of woody debris left over from logging or land clearing operations.

STAGNATION. Lack of motion in a mass of air or water which tends to hold pollutants in place.

TOXIC. Poisonous, carcinogenic, or directly harmful to life.

TRACHEA. A passage through which air passes to and from the lungs.

VOLATILE. Unstable substances that evaporate rapidly at normal temperatures, such as benzene or gasoline.

WHAT IS WOOD SMOKE?

Wood smoke is a complex mixture of substances produced during the burning of wood. The major emissions from wood stoves are carbon monoxide, organic gases (containing carbon or derived from living organisms), particulate matter, and nitrogen oxides. Wood smoke contains many organic compounds known to cause cancer (such as benzopyrenes, dibenzanthracenes, and dibenzocarbazoles), and other toxic compounds (such as aldehydes, phenols, or cresols). The particulate fraction is composed of solid or liquid organic compounds, carbon char (elemental or soot carbon -- similar to charcoal), and inorganic ash.¹



WHY IS WOOD SMOKE A PROBLEM?

The particles in wood smoke are too small to be filtered by the nose and upper respiratory system, so they wind up deep in the lungs. They can remain there for months causing structural damage and chemical changes. Poisonous and cancer-causing chemicals often enter the lungs by adhering to tiny particulate matter (such as wood smoke particles).

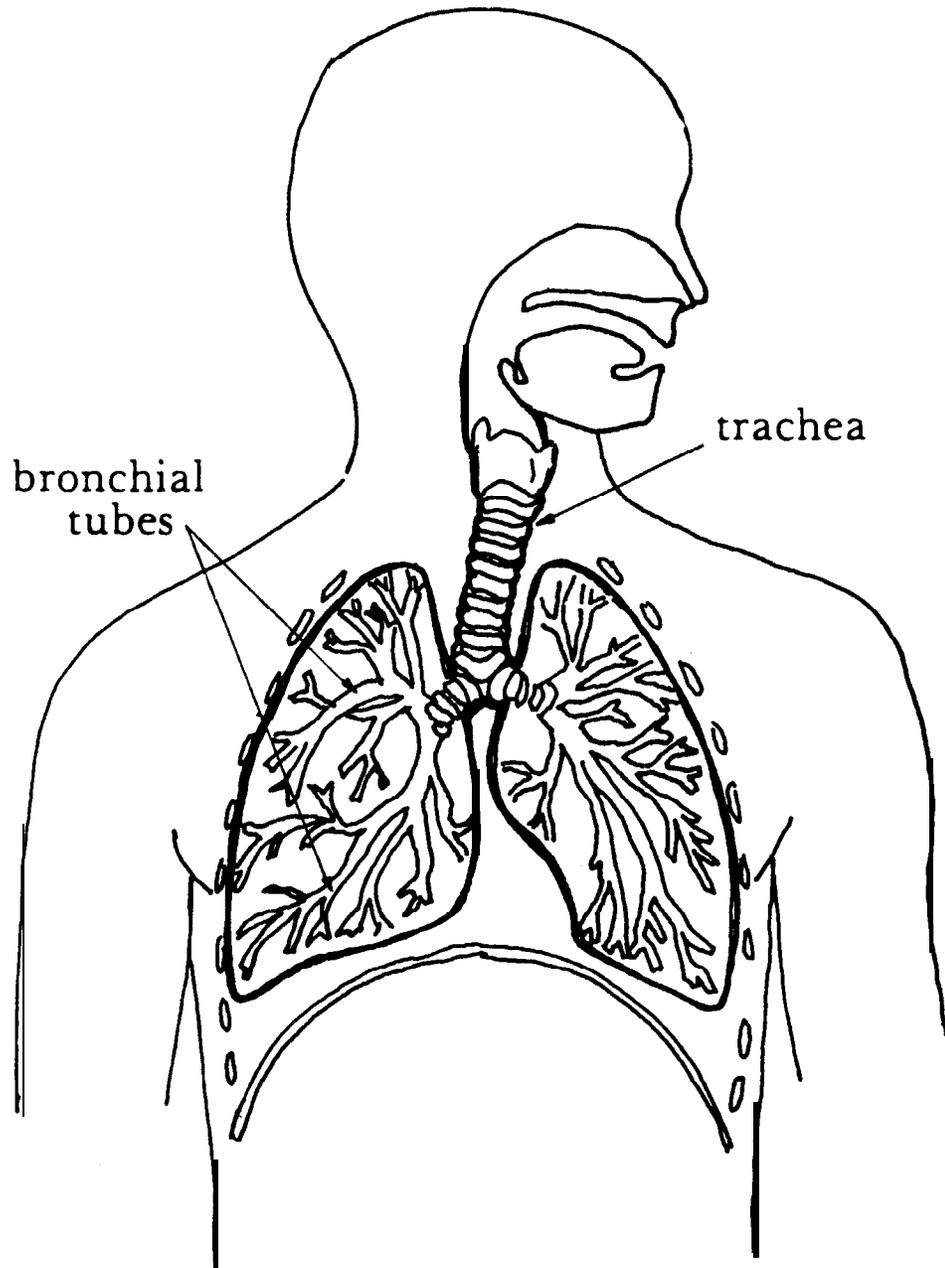
These tiny particles are emitted in neighborhoods, both indoors and out, where people spend most of their time. Unfortunately, wood smoke is not only in the outdoor air we breathe. The particulate matter in wood smoke leaving chimneys is so small that it is not stopped by closed doors and windows, and often seeps into neighbors' houses. Even more smoke is sometimes released inside homes which heat with wood.

GENERAL EFFECTS OF WOOD SMOKE

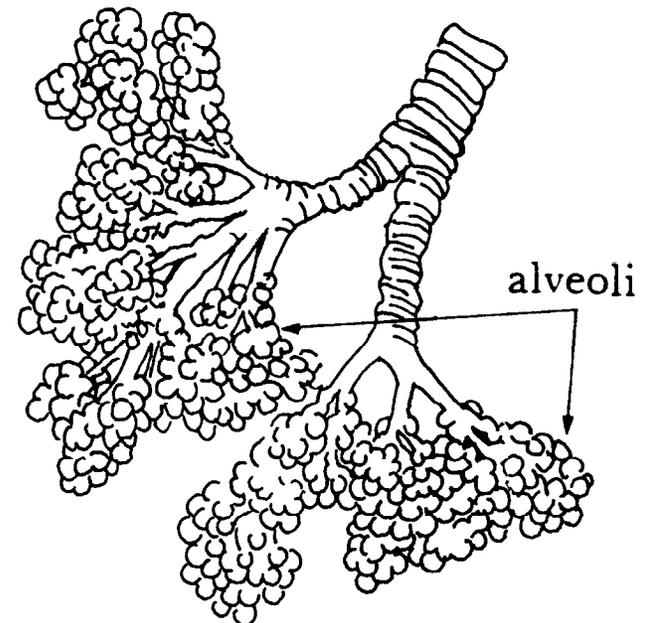
Wood smoke exposure causes a decrease in lung function and an increase in the severity of existing lung disease with increases in smoke concentration or exposure time.² It also aggravates heart conditions and carbon monoxide (a component of wood smoke) causes heart pain. The occurrence of respiratory illness in children has been shown to increase with increased exposure to wood smoke. This includes lower respiratory infections such as acute pneumonia, or bronchiolitis, which are major causes of disease and death in young children.²⁰ Wood smoke aggravates asthma, emphysema, pneumonia, and bronchitis. It irritates the eyes and triggers headaches and allergies. Long-term exposure may lead to emphysema, chronic bronchitis, arteriosclerosis, and nasal, throat, lung blood, and lymph system cancers (based on animal studies).^{2,4,17,25,27}



WHAT PARTS OF WOOD SMOKE CAUSE PROBLEMS?

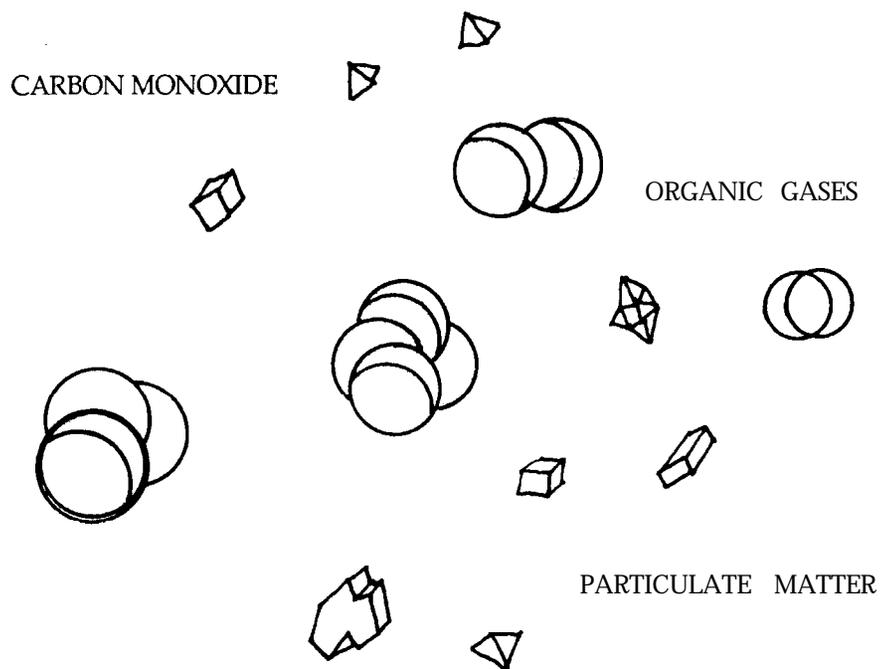


Many organic compounds are produced by combustion of wood. Some burn completely, some are changed chemically, and some leave the stove without burning. Some of these compounds deposit in the chimney as creosote, some condense as very tiny particles of smoke, and some are released into the air as gases. Some of these organic compounds are poisonous, some irritate the respiratory tract, and some may cause cancer or mutations. The primary pollutants from wood smoke are carbon monoxide, particulate matter, and organic gases (including aldehyde gases such as acrolein, which is a serious respiratory irritant).



Carbon monoxide is a colorless, odorless gas produced when any carbon-containing fuel such as gasoline or wood is burned. It reduces the ability of blood to carry oxygen to body tissues. High exposures can lead to death. Lower levels, common in highly polluted urban areas, lead to increased hospitalizations for individuals with heart and circulatory disease, lower birth weights, and increased deaths of newborns.³

Particulate matter larger than 10 microns in diameter collects in the upper respiratory system (throat and nose) and is eliminated by sneezing, coughing, noseblowing, spitting, or the digestive system. The particulate matter from wood smoke is a much more serious health threat due to the small particle size. Wood smoke particles are less than 10 microns (a micron is one millionth of a meter) in diameter. Most of them are less than 2.5 microns in diameter. The period at the end of this sentence is about 500 microns in diameter.



Wood smoke particles are so small that they get past the cilia or hair-like structures on the respiratory tract cells. Cilia clear mucous and catch and help remove larger particulate matter from the lungs with a rhythmic motion. Tiny wood smoke particles evade the cilia and collect in the most remote portions of the lungs, called alveoli - the tiny air sacs where oxygen enters the blood stream. Wood smoke particles cause structural and chemical changes deep in the lungs. Other toxic and cancer causing compounds can attach to the smallest smoke particles and enter the lungs at the same time.

Because of the health threat from tiny particulate air pollution, the federal government regulates all particulate matter less than 10 microns in diameter (PM_{10}) as one of six major air pollutants.

Irritants in wood smoke (such as phenols, aldehydes, quinones, nitrogen oxides, and sulphur oxides) contribute to health problems in the respiratory tract. Irritants interfere with the cilia and disrupt the flow of the particle-trapping mucus stream, resulting in more particulate matter entering the lungs. Exposure to wood smoke irritants can lead to inflammation and pulmonary edema (swelling of lung tissue). Irritants can also cause allergic reactions and may contribute to long-term health effects.¹



WOOD SMOKE AND CANCER

The cancer threat from air pollution is a serious public health concern. Most of the wood smoke cancer research before 1985 focused on identifying the components of soot or the particulate portion of wood smoke, including carcinogens such as benzo(a)pyrene, best known from tobacco smoke research. The first known human carcinogens were from coal tars and chimney soot. The particle or soot component of air pollution has been clearly implicated as a human carcinogen from studies of human cancer victims.²

Many substances on the U.S. Environmental Protection Agency's (EPA) priority pollutant list, many suspected human carcinogens, co-carcinogens (cancer initiators or promoters), and cilia-toxic agents (poisonous to the hair-equipped cells which filter most particles out of the respiratory tract) have been identified from wood smoke particles.¹⁴ However, many of the compounds in wood smoke particles have not been identified and even less is known about the toxic organic gases which are also released by wood burning.

Burning of fossil fuels, wood, tobacco, or garbage produces hundreds of different compounds associated with the soot, or particle phase of air pollution. Also produced are many gaseous compounds which are carcinogenic, such as benzene, aldehydes, alkenes, and numerous semi-volatile organic compounds.²¹ Recent research has focused on the health effects from wood smoke as a whole, rather than further studies of its component parts.

In 1985 the EPA started a major long-term research program to clarify the sources of air pollution and population exposure, and to estimate future cancer risk (the Integrated Air Cancer Project).¹⁰ Studies include human cancer victims, as well as laboratory mice, and bacteria and mammal cells exposed to the total mixture of particulate matter from urban air samples.

This research found motor vehicles and wood stoves to be the major sources of cancer risk from particulate air pollution in all the urban airsheds studied.^{8,34}

Human cancer risks have now been estimated for lifetime exposure to diesel vehicle, leaded and catalyst-equipped gas vehicle, wood stove, cigarette smoke, coke oven (coal), and roofing tar emissions.²³ EPA researchers suggest that the lifetime cancer risk from wood stove emissions may be 12 times greater than the lifetime cancer risk from exposure to an equal amount of cigarette smoke. We must keep in mind that this is not actual cancer risk, but rather an estimate based on bacteria and animal studies comparing the potency of wood smoke to cigarette smoke and other better documented carcinogens. The lifetime human cancer risk estimates from exposure to wood smoke and motor vehicle emissions are theoretical based on such comparative potency tests.

The lifetime cancer risk estimate from exposure to motor vehicle emissions is more than three times that from equal exposure to wood stove emissions, based on recent EPA research in Boise, Idaho.²³ However, we also know that wood stoves produce much more particulate air pollution in the winter than motor vehicles in all Pacific Northwest cities studied by the EPA.^{20,31,33,34}

With all of these cancer risk estimates we must also keep in mind that we do not yet have much information on actual yearly levels of human exposure to various types of particulate air pollution.



MUTAGENS IN WOOD SMOKE

Mutagens cause biological mutations or changes in cells such as chromosome defects or genetic damage. Mutagenicity is often used as a screening test for human cancer risk from compounds in air pollution. However, mutagens and carcinogens are not the same thing and not all mutagenic substances cause cancer. Motor vehicles and wood heating emissions cause mutations. These two sources are also major contributors to the human cancer risk from air pollution.⁸

A 1988 EPA study found that wood heat and motor vehicle emissions account for nearly all of the mutagenicity in winter air samples from Albuquerque, NM, Raleigh, NC, and Juneau, AK, over a wide range of climate and wood species.³⁴ This study found that biological mutations in bacteria exposed to winter air samples increased with higher concentrations of fine particulate matter and were most numerous at times of coldest temperatures, weekends and holidays -- when many wood stoves were in use. One would expect this to be true in Washington State as well.

In the United States more than 30% of mutagenic material emitted to the atmosphere each year comes from wood combustion, according to 1981 calculations.^{15,24} In Washington State the contribution from wood smoke is greater than this national average since Washington has the third highest percentage of households burning wood in the United States, behind Oregon and Maine, according to a 1983 U.S. Forest Service survey.³⁰

PARTICULATE AIR POLLUTION AND DEATH RATES

London's "Black Fog" in December 1952 killed 4,000 people and led to the British Clean-Air Act. Tiny particulate air pollution from coal stoves was largely to blame. London is once again in the news with a new study linking particulate air pollution to death rates.

This year an EPA researcher applied statistical techniques to daily particulate air measurements and daily death records in London, as well as U.S. cities where daily particulate measurements were available.²⁸ These cities vary vastly in size, climate, and mixes of air pollutants, including wood smoke. This study found an increase in deaths by 6% for each 100 micrograms of total particulate air pollution measured.

This same EPA study also found that, for every 100 micrograms of total particulate per cubic meter of air, the risk of dying goes up 32% from emphysema, 19% from bronchitis and asthma, 12% from pneumonia, and 9% from cardiovascular disease. Sulfur dioxide, an air pollutant which has often been suspected of causing deaths, showed no effect on death rates. These new findings suggest that particulate matter is more toxic than ozone (commonly called smog). Confirmation of these findings would make particulate air pollution the largest known "involuntary environmental insult" and should encourage a stricter federal particulate standard.²⁸



INDOOR AIR QUALITY

Wood smoke does not rise and disperse during winter temperature inversions. At these times, wood smoke hangs close to the ground and enters neighbors' yards and houses, schools and hospitals. Areas with winter atmospheric inversions and valley locations with poor air circulation are most affected. Wood smoke particles are so tiny that they remain suspended for long periods of time and readily penetrate into buildings with incoming cold air, even with today's "air-tight" construction.

Wood stove fumes are released into the outdoor air through chimneys, but fumes are also released directly into the homes where stoves are used. Wood smoke and fumes also enter homes where stoves are not used. Indoor PM₁₀ levels from wood smoke in homes without wood stoves reach at least 50% to 70% of outdoor levels, according to a recent University of Washington study in Seattle and an EPA study in Boise, Idaho neighborhoods.^{16,24}

Wood stove use not only degrades the air quality inside neighbors' homes, but causes additional air quality impairment in the home using the stove. Klamath Falls, Oregon has the highest measured PM₁₀ pollution from wood stoves in the United States. A 1991 study in Klamath Falls by the Oregon Health Division found that children with wood stoves in their own homes have even greater declines in lung function than other children living in the same smoky neighborhood.¹²

Indoor and outdoor air can be degraded significantly by the use of poorly designed noncertified airtight stoves and non airtight stoves.^{16,32} Poor burning practices, improper stove operation, improper stove installation, lack of maintenance, and burning wet wood create much indoor and outdoor air pollution even with the newest certified stove models. Backdrafting and "accidents" while loading fuel or opening stove doors can cause substantial amounts of indoor air pollution with any wood stove. Backdrafting can usually be eliminated by proper stove installation and/or regular chimney sweeping.

POPULATIONS MOST AT RISK

Infants, children, pregnant women, senior citizens, cigarette smokers and ex-smokers, and all those suffering from allergies, asthma, bronchitis, emphysema, pneumonia, or any other heart or lung illness are most affected by wood smoke and are sensitive to low levels.^{14,17,27,28} Even the most healthy citizens should refrain from heavy outdoor physical exercise (such as jogging) during periods of very poor air quality or high levels of particulate air pollution.

Lung ailments are the leading cause of disease and death in the United States among newborns, accounting for 37% of all deaths in the first year of life, according to the American Lung Association. Lung diseases accounted for 28.3% of all hospitalizations of children under 15 in the United States in 1988. A total of 738,000 children in this age group were hospitalized for lung disease in 1988.⁵

Wood smoke interferes with normal lung development in infants and young children. In addition, several studies have found that home use of wood burning stoves increases the risk of lower respiratory tract infections (LRTIs) such as bronchiolitis and pneumonia in young children.²⁶ LRTIs are a major cause of early childhood disease and death. Parental smoking, especially during the first year of life, is another well-demonstrated risk factor for lower respiratory tract infections.⁹



A 1990 study of American Indian children found that those living in homes with a wood burning stove have a higher risk of bronchiolitis and pneumonia (lower respiratory tract infections) than children living in homes without wood stoves.^{6,11,26} Childhood LRTIs have also been linked with chronic lung disease in later life. Wood smoke exposure causes a chronic reduction in lung function, increasing the rate of decline with age in adults.²⁵

Researchers at the University of Washington in 1990 documented more symptoms of respiratory disease in Seattle preschool children living in high wood smoke residential areas than in children living in areas with lower wood smoke levels.⁷ This demonstrates the effect of community wood smoke pollution on the occurrence of respiratory illness. Tests have also demonstrated measurable reductions in lung function among both healthy children and asthmatics in smoky Seattle neighborhoods in the winter.¹⁸

HIDDEN COSTS OF WOOD HEAT

Most people realize that direct costs of wood heat include the purchase price, installation, and maintenance of the heater. Floor protection, the building permit, installation, fuel supply, and chimney sweeping are other direct costs. Time spent cutting, splitting, stacking, and moving wood (as well as cleaning out ashes and maintaining the stove) are also direct costs. However, few people realize the possible extent of hidden or indirect costs.

Indirect costs of wood heat include both fire insurance and health insurance. Fire insurance costs have been climbing. The 1984 statistics from the Washington State Fire Marshall show that nearly half of all fires reported in one and two-family dwellings were caused by wood stoves or fireplaces. These insurance losses help push up the cost of insurance on a home.

Health insurance costs have been rising rapidly in recent years. Health insurance claims raise the cost of health insurance. Wood smoke exposure leads to more frequent and extended hospital visits, as well as more emergency ward or physician visits, and increased use of medications. Lung diseases are second only to heart disease as a cause of disability under social security.⁵ Wood smoke adversely affects the cardiovascular system and heart patients, as well as those suffering from lung disease.^{1,3,4,25,28}



In 1989 an estimated 85 million people -- more than one-third of the U.S. population -- were afflicted with chronic respiratory disease, from chronic sinusitis to chronic bronchitis and emphysema.⁵ The direct and indirect costs of lung disease were about \$45 billion in 1988 according to the American Lung Association.

The National Health Interview Survey estimates 25.6 million people suffer from severe lung diseases such as chronic bronchitis, emphysema, or asthma. The total number of deaths attributed to these diseases increased 57% between 1979 and 1987. Lung cancer now accounts for more cancer deaths in the United States for both men and women than any other form of cancer.⁵

Obviously wood smoke does not account for all of the lung disease in this country. Tobacco, radon, car and truck exhaust, asbestos, and other substances share much of the blame. However, the medical evidence is growing each year that wood smoke plays a larger role than was previously thought, and the tiny particulate matter from wood smoke cannot be kept out of your home if you live in a neighborhood where there is much wood stove use.

WHAT ABOUT OUTDOOR BURNING AND CERTIFIED WOOD STOVES?

Outdoor burning in Washington contributes roughly two-thirds as much particulate air pollution as wood stoves do each year (see graph). Agricultural burning, slash burning, backyard burning, and burn barrels all contribute to air pollution and are becoming more closely regulated under Washington's new clean air legislation. Outdoor burning is not as common in the winter when cooler temperatures lead to inversions and trap wood stove smoke close to the ground in our neighborhoods; but any time that citizens are exposed to smoke there is cause for concern.

About 85% of wood stoves in Washington State are not certified to meet federal particulate emission standards (based on a 1990 survey by the Washington State Energy Office). These noncertified stoves release most of the particulate air pollution statewide. The newer EPA certified models release much less smoke although they still require dry wood, and proper installation, operation, and maintenance to minimize air pollution. All smoke from any source adds to the air pollution problem.



HOW YOU CAN HELP FIGHT SMOKY AIR

Noncertified stoves should be scrapped if possible. Cleaner heating methods include the best technology certified wood stoves, gas stoves or gas inserts, and high efficiency gas and oil central heating systems. Energy conservation, insulation and weatherstripping can save money with any heating system and reduce pollution. Support burning bans and smoke regulations. Learn about composting, mulching, recycling, or other smokeless disposal strategies. Any smoke or odor from open fires or from home heating which affects our neighbors' health or enjoyment of their property is illegal and should be reported to the local county air pollution control authority.

We take pride in our quality of life in Washington. In light of current and ongoing health research, the smell of wood smoke no longer has the pleasant connotation it once had. Thoughts of sick children, and lung and heart disease victims are not pleasant. Less smoke means cleaner air for you, your family, and the environment.

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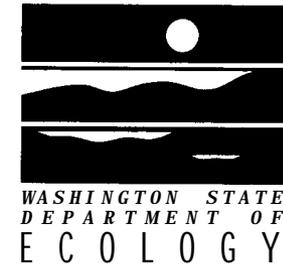
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