Scientific Studies on Health Effects of Woodsmoke and Particulate Matter Air Pollution

[Editors Note 2004: This reference document combines studies of symptoms associated with households using wood heat (Indoor Air Quality), studies relating outdoor concentrations of woodsmoke to adverse health effects in the whole population. (Ambient Air Quality), and laboratory studies of physiological responses to woodsmoke.

Authors by Date	Summary of Findings
2004	
Gauderman et al. 2004	New findings from the Children's Health Study in the New England Journal of Medicine confirm reduced lung function growth in children exposed to higher levels of air pollution (including PM 2.5) from ages 10 to 18.
Samet, J, et al 2004	The study assessed the effects of five major outdoor-air pollutants on daily mortality rates in 20 of the largest cities and metropolitan areas in the U.S. from 1987 to 1994. There is consistent evidence that the levels of fine particulate matter in the air are associated with the risk of death from all causes and from cardiovascular and respiratory illnesses.
Brook, RD, et al, 2004	A panel of experts conducted a comprehensive review of almost 200 scientific studies on air pollution and cardiovascular disease – including heart attacks, abnormal hear rythyms, strokes, hardening of the arteries. The American Heart Association issued a scientific statement on air pollution, concluding "because a number of studies have demonstrated associations between particulate air pollution and adverse cardiovascular effects even when levels of ambient PM2.5 were within current standards, even more stringent standards for PM2.5 should be strongly considered by the EPA."
2003	
Gullett et al., 2003	Emissions from residential fireplace and woodstove appliances burning fuels available from the San Francisco Bay area were sampled for polychlorinated dibenzodioxins and dibenzofurans (PCDDs/Fs), polychlorinated biphenyls (PCBs), hexachlorobenzene (HxCBz), particulate matter (PM), polycyclic aromatic hydrocarbons (PAHs), oxygenated PAHs, and the monosaccharide levoglucosan. A total of 32 PAH compounds, ranging in concentration from 0.06 to 7 mg/kg, amounted to between 0.12 and 0.38% of the PM mass, depending on the wood and facility type.
2002	
Dubick MA, et al. 2002	This study investigated antioxidant status in lavage fluid, lung, liver, heart and kidney in a rat model to simulate an inhalation injury as might be encountered by firefighters and burn victims. Data suggest that smoke inhalation, independent of burn injury, induces an oxidant stress that persists for at least the first 48 h after smoke exposure.
Zelikoff et al, 2002	The toxicology of inhaled woodsmoke. This is a "mini-review article (which) brings together many of the human and animal studies performed over the last three decades in an attempt to better defined the toxicological impact of inhaled woodsmoke on exposed children and adults..."
Tesfaigzi et al, Jan 2002	This study of health effects of subchronic exposure to low levels of wood smoke in rats suggests that exposure to wood smoke caused minor but significant changes in pulmonary function. Further studies are needed to establish whether exposure to wood smoke exacerbates asthmalike symptoms that resemble those described for children living in homes using wood stoves for heating and cooking.
Mahalanabi S D et al. 2002	We evaluated the risk factors for childhood pneumonia with particular reference to indoor air-pollution associated with solid fuel use for cooking (e.g. coal, wood, dung), using a case-control study in a children's hospital in Calcutta. Solid fuel use (and other factors) were associated with high risk of pneumonia
Kim J, Hanley JA.	This study was to determine the role of environmental pollutants in the etiology of nasal polyposis, 55 patients in rural northeastern Quebec. Forty-five (82%) of the cases, but only 14 (25%) of the controls, reported using woodstoves, yielding a crude odds ratio (OR) of 13.1. There is a strong association between the use of woodstoves as a principal source of heating and the development of nasal polyposis.
Kim O, et al. 2002	In this study in Thailand, smoke samples, in both gas and particulate matter (PM) phases, of the three domestic stoves were collected using U.S. EPA modified method 5 and were analyzed. The study compared emissions of

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	polycyclic aromatic hydrocarbons (PAH), toxicity, and mutagenicity from domestic cooking using sawdust briquettes, wood, and kerosene. The total toxicity emission factor was the highest from sawdust, followed by kerosene and wood fuel. The tests could be used for a quick assessment of potential health risks.
2001	
Schwartz J. Jun 2001	This study by the Harvard School of Public Health examined the association between blood markers of cardiovascular risk and air pollution in a national sample of the U.S. population. In single-pollutant models, PM(10) was associated with all three outcomes (white cell counts, platelet counts and fibrinogen). Air pollution and blood markers of cardiovascular risk. PM(10), but not gaseous air pollutants, is associated with blood markers of cardiovascular risk, and this may explain epidemiologic associations with early deaths.
Hsu TH, Kou YR. May 2001	Airway hyperresponsiveness to bronchoconstrictor challenge after wood smoke exposure in guinea pigs.
Kjallstrand J, Petersson G. Sept. 2001	Phenolic antioxidants in wood smoke. Phenolic antioxidants are scavengers of oxygen radicals and should be considered when health hazards of small-scale incomplete biomass burning are estimated. Sci Total Environ. 2001 Sep 28;277(1-3):69-75. PMID: 11589408
Kjallstrand J, Petersson G. Apr. 2001	Phenols and aromatic hydrocarbons in chimney emissions from traditional and modern residential wood burning. Environ Technol. 2001 Apr;22(4):391-5. PMID: 11329802
Schauer JJ, et al, May 2001	Measurement of emissions from air pollution sources. 3. C1-C29 organic compounds from fireplace combustion of wood. Environ Sci Technol. 2001 May 1;35(9):1716-28. PMID: 11355184
Nolte CG, Schauer JJ, Cass GR, Simoneit BR. May 2001	Highly polar organic compounds present in wood smoke and in the ambient atmosphere. Environ Sci Technol. 2001 May 15;35(10):1912-9. PMID: 11393968
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Lin YS, Ho CY, Tang GJ, Kou YR.	Alleviation of wood smoke-induced lung injury by tachykinin receptor antagonist and hydroxyl radical scavenger in guinea pigs. Eur J Pharmacol. 2001 Aug 10;425(2):141-8. PMID: 11502280
Fine PM, Cass GR, Simoneit BR.	Chemical characterization of fine particle emissions from fireplace combustion of woods grown in the northeastern United States. Environ Sci Technol. 2001 Jul 1;35(13):2665-75. PMID: 11452590
Perez-Padilla R, et al. 2001	Cooking with biomass stoves and tuberculosis: a case control study. Int J Tuberc Lung Dis. 2001 May;5(5):441-7. PMID: 11336275
Tzanakis N, et al. 2001	Short-term effects of wood smoke exposure on the respiratory system among charcoal production workers. Chest. 2001 Apr;119(4):1260-5. PMID: 11296197

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Utell MJ, 2000	A strong and consistent association has been observed between adjusted mortality rates and ambient particle concentration. The strongest associations are seen for respiratory and cardiac deaths, particularly among the elderly. Particulate air pollution is also associated with asthma exacerbations, increased respiratory symptoms, decreased lung function, increased medication use, and increased hospital admissions. J Aerosol Med. 2000 Winter;13(4):355-59. PMID: 11262441
Leonard SS, et al 2000	Wood smoke particles generate free radicals and cause lipid peroxidation, DNA damage, NFkappaB activation and TNF-alpha release in macrophages. PMID: 10996671
Gold JA, et al 2000	Hut lung. A domestically acquired particulate lung disease. Medicine (Baltimore). 2000 Sep;79(5):310-7. PMID: 11039079
Malats N, Camus-Radon AM, et al. 2000.	Lung cancer risk in nonsmokers and GSTM1 and GSTT1 genetic polymorphism. Cancer Epidemiol Biomarkers Prev. 2000 Aug;9(8):827-33. PMID: 10952100
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Kou YR, Lin YS, Ho CY, Lin CZ.	Neonatal capsaicin treatment alters immediate ventilatory responses to inhaled wood smoke in rats. Respir Physiol. 1999 Aug 3;116(2-3):115-23. PMID: 10487297
Perez-Padilla JR, et al. 1999	[The domestic inhalation of the smoke from firewood and of other biological materials. A risk for the development of respiratory diseases] Gac Med Mex. 1999 Jan-Feb;135(1):19-29. Spanish. PMID: 10204309
Schoket B.	DNA damage in humans exposed to environmental and dietary polycyclic aromatic hydrocarbons. Mutat Res. 1999 Mar 8;424(1-2):143-53. PMID: 10064857
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Pintos J, et al, Dec 1998	Use of wood stoves and risk of cancers of the upper aero-digestive tract: a case-control study. Int J Epidemiol. 1998 Dec;27(6):936-40. PMID: 10024184
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1997	
Betchley et al., 1997	Forest firefighters had significant declines in lung function (FEV(1)). Average declines, pre-shift to mid-shift of 0.089 L, 0.190 L, and 0.439 L/sec in TVC, FEV(1) and FEF (25-75). The use of wood for indoor heat also was associated with the declines in FEV(1).
Janigan DT, et al Apr 1997	Bronchiolitis obliterans in a man who used his wood-burning stove to burn synthetic construction materials. CMAJ. 1997 Apr 15;156(8):1171-3. PMID: 9141990
Hogg JC Apr 1997	Bronchiolitis obliterans and wood-burning stoves. CMAJ. 1997 Apr 15;156(8):1147-8. No abstract available. PMID: 9141985
Hogg, 1997	The author comments on the case report by Dr. David T. Janigan and colleagues of classic bronchiolitis obliterans in a man who used a wood-burning stove to dispose of construction materials in Canada.
Glovsky M, et al, May-Jun 1997	Particulate air pollution: possible relevance in asthma. Allergy Asthma Proc. 1997 May-Jun;18(3):163-6. PMID: 9194943
Lipsett et al., 1997	Conclusion from abstract: "These results demonstrate an association between ambient wintertime PM10 and exacerbations of asthma in an area where one of the principal sources of PM10 is Residential Wood Combustion." Santa Clara County, California.
Betchley, et al., 1997	Forest firefighters had significant declines in lung function (FEV(1)). Average declines, pre-shift to mid-shift of 0.089 L, 0.190 L, and 0.439 L/sec in TVC, FEV(1) and FEF (25-75).). The use of wood for indoor heat also was associated with the declines in FEV(1).
Kou et al. , 1997	"These results suggest that an increase in OH burden following smoke inhalation is actively involved in evoking the acute irritant effects of wood smoke on breathing in rats."
Churg et al., 1997.	Autopsies were carried out of lung tissue from 10 never-smoking long-term residents of Vancouver. Retained particles in human lung parenchyma were counted, sized, and identified by analytical electron microscopy. 96% of particles had aerodynamic diameter less than 2.5microns.
Kataoka H, Kurisu M, Shindoh S.	Determination of volatile N-nitrosamines in combustion smoke samples. Bull Environ Contam Toxicol. 1997 Oct;59(4):570-6. No abstract available. PMID: 9307421
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Maier WC, Arrighi HM, Morray B, Llewellyn C, Redding GJ.	Indoor risk factors for asthma and wheezing among Seattle school children. Environ Health Perspect. 1997 Feb;105(2):208-14. PMID: 9105796
Betchley C,	Pulmonary function and respiratory symptoms in forest firefighters. Am J Ind Med. 1997 May;31(5):503-9.

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et al 1997	PMID: 9099351
1996	
Robin et al., 1996	Matched pair analysis revealed an increased risk of Acute Lower Respiratory Infection (ALRI) for children living in households that cooked with any wood (odds ratio 5.0; 95% confidence interval 0.6 to 42.8. Cooking with wood-burning stoves was associated with higher indoor air concentrations of respirable particles and with an increased risk of ALRI in Navajo children. Studied 45 children under 2 years.
Robin LF, et al. 1996	Wood-burning stoves and lower respiratory illnesses in Navajo children. Pediatr Infect Dis J. 1996 Oct;15(10):859-65. PMID: 8895916
Ramage et al., 1996	Case study of 61-yr-old woman suffering shortness of breath on exertion and interstitial lung disease. Bronchoalveolar lavage revealed numerous carbonaceous particulates and fibers, as well as cellular and immunoglobulin abnormalities. Inflammation and fibrosis were found surrounding them on open biopsy. The particle source was traced to a malfunctioning wood-burning heater in the patient's home.
Wesley AG, Loening WE.	Assessment and 2-year follow-up of some factors associated with severity of respiratory infections in early childhood. S Afr Med J. 1996 Apr;86(4):365-8. PMID: 8693374
Dennis RJ, et al 1996	Woodsmoke exposure and risk for obstructive airways disease among women. This study showed that among elderly women of low socioeconomic status in Bogota, woodsmoke exposure is associated with the development of OAD and may help explain around 50% of all OAD cases. The role of passive smoking remains to be clarified. This work may set the basis for interventional studies in similar settings.
Wang CY, Lai CJ, Kou YR. 1996	Inhibitory influence of lung vagal C-fiber afferents on the delayed ventilatory response to inhaled wood smoke in rats. Chin J Physiol. 1996;39(1):15-22. PMID: 8902300
Godleski et al., 1996	Rats with bronchitis were exposed for 6 hours per day to 272ug/m3 PM2.5. 37% of rats exposed to particles died, compared to none exposed to filtered air.
1995	
Stone, 1995	Rats were exposed to no pollution or 800 ug/m3 wood smoke for 1 hour, then to golden staph bacteria. The bacteria were more virulent in animals which breathed the woodsmoke. This was attributed to a suppression in activity of the rats' macrophages, immune cells that roam the body, looking to engulf and destroy foreign particles.
Rao et al 1995	Metabolites of woodsmoke condensate accumulate in cultured rat eye lenses, compromising ability to accumulate rubidium-86 (mimic of K) and choline. Says may explain implication of smoke in cataract.
Nieman GF, Clark WR Jr, Paskanik A, Feldbaum D. 1995	Segmental pulmonary vascular resistance following wood smoke inhalation. Crit Care Med. 1995 Jul;23(7):1264-71. PMID: 7600836
1994	
Ostro BD, et al Jun 1994	Indoor air pollution and asthma. Results from a panel study. Am J Respir Crit Care Med. 1994 Jun;149(6):1400-6. PMID: 8004290
Larson & Koenig, 1994.	"We conclude that the preponderance of the data suggest a causal relationship between elevated wood smoke levels and adverse respiratory health outcomes in young children."
Kou YR, Lai CJ 1994	Reflex changes in breathing pattern evoked by inhalation of wood smoke in rats. J Appl Physiol. 1994 Jun;76(6):2333-41. PMID: 7928855

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1993	
Schwartz, 1993	Significant association between visits to 8 hospital emergency departments in Seattle for asthma and PM10 pollution. In 1993, wood burning was found to be the dominant source of PM10 pollution in Seattle in all seasons of the year, ranging from 60% in summer to 90% in winter.
Koenig et al., 1993	Significant association in Seattle (where the majority of particulate air pollution originates from woodsmoke) between outdoor fine particle pollution and decreased lung function (measured by spirometry) in asthmatic children aged 8-11.
Lal et al., 1993	Rats exposed to woodsmoke suffered "bronchiolitis, hyperplasia and hypertrophy of bronchiolar epithelial lining cells, some necrosed lining cells desquamated into lumens, congestion of parenchymatous blood vessels, oedema, hyperplasia of lymphoid follicles, peribronchiolar and perivascular infiltration of polymorphonuclear cells, and mild emphysema" Conditioned worsened with accumulated exposure ."The results indicate progressive pathomorphological pulmonary lesions with subsequent exposure to wood smoke in controlled conditions."
1992	
Dean et al., 1992	Case of methemoglobinemia, sudden onset of cyanosis, irritability, metabolic acidosis, and a lethal methemoglobin level of 71.4% in a 10 week old infant. Family history revealed a wood-burning stove which emitted pine tar fumes as the potential environmental methemoglobin-producing source. The infant's cradle was situated five feet from the stove. The baby was treated and recovered.
Pryor WA., 1992	Biological effects of cigarette smoke, wood smoke, and the smoke from plastics: the use of electron spin resonance. Free Radic Biol Med. 1992 Dec;13(6):659-76. Review. PMID: 1334034
1991	
Honicky RE, Osborne JS 3rd. 1991	Respiratory effects of wood heat: clinical observations and epidemiologic assessment. Environ Health Perspect. 1991 Nov;95:105-9. PMID: 1821363
Lipsett et al., 1991	Presence of woodstove or fireplace in the home was associated with shortness of breath in females and both shortness of breath and moderate or severe cough in males ($p<0.01$ for all cases). 182 asthmatics living in Denver, Colorado.
Daigler et al., 1991	A comparison of patients in New York with physician-diagnosed otitis media (n = 125, 74% response), and controls (n = 237, 72% response) showed exposure to a woodburning stove was significantly associated ($P<.05$ with increased otitis (an inflammation of the middle ear marked by pain, fever, dizziness, and abnormalities of hearing.)
Heumann et al., 1991	Children with the highest exposure to wood smoke had a significant decrease in lung function, measured by FEV1 and FVC. 410 children aged 8-11 in Klamath Falls, Oregon.
Lewtas et al., 1991	Mutagenicity testing of air containing smoke emitted from woodheaters in Boise, Idaho, US, using the Ames test on salmonella and tumor initiation assays in mice found that woodsmoke was 12 times more carcinogenic than an equal concentration of cigarette smoke.
1990 and earlier	
Morris et al., 1990	58 Navajo children under 2 years with diagnosed pneumonia or bronchiolitis were compared with matched control children. Use of a wood burning stove was associated with a 4 times higher risk of lower respiratory tract infection ($P<.001$).
Johnson, 1990	Particle pollution from woodsmoke in the air was associated with significant decreases in lung function in children aged 8-11. 495 subjects in Montana.
Browning, et al., 1990	No statistically significant differences, but a pattern of increased symptoms and chronic illness in children aged 1-5 in the area with high wood smoke.

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Butterfield, et al., 1989	Significant correlation (P<.01), between woodstove use and frequency of wheeze, severity of wheeze, frequency of cough and waking up at night with cough , based on 59 subjects aged 1 to 5.5 years.
Boone et al., 1989	"Woodsmoke prove to be a major source of indirect genotoxins in homes. The increase is probably due to higher concentrations of polycyclic aromatic hydrocarbons in the wood smoke aerosol …" USA.
van Houdt et al., 1986	"The use of wood stoves caused an increase of indoor mutagenicity in 8 out of 12 homes."
Honicky et al., 1985	Moderate and severe respiratory symptoms were significantly greater (P<.001) in 34 children, aged 1-7 years in houses with woodstoves than in 34 children houses without. Conclusion: "Present findings suggest that indoor heating with wood-burning stoves may be a significant etiologic factor in the occurrence of symptoms of respiratory illness in young children." Michigan, US.
Tuthill, 1984.	Risk of respiratory symptoms increased by 10%, but this was not statistically significant. Study of children aged 5-11, 258 with woodstoves, 141 without. Exposure to formaldehyde from any source, including wood burning, significantly increased risk.
Alfheim et al, 1984	"Whereas wood heating in an "airtight" stove was found to cause only minor changes in the concentration of PAH and no measurable increase of mutagenic activity of the indoor air, both these parameters increased considerably when wood was burned in an open fireplace, yielding PAH concentrations comparable to those of ambient urban air. Woodburning in the closed stove did, however, result in increased concentrations of mutagenic compounds and PAH on particles sampled in the vicinity of the house."

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