characteristics of the ventilation system, including the efficiency of air filters.

Air cleaners

Offermann et al (117) conducted chamber tests to evaluate portable air cleaners for their effectiveness in controlling indoor levels of respirable particles. Mixing fans, ion generators and small panel-filter devices were ineffective for particle removal. In contrast, electrostatic precipitators, extended surface filters and HEPA filter units worked well, with effective cleaning rates (for removal of 98 per cent of particles in a room) of 100-300 m^3/hr.

The Ministry of the Environment (ENV) of Singapore conducted an assessment of the use of portable air cleaners for homes, during period of biomass air pollution (118). The ENV found that several models of portable air cleaners were able to reduce the level of fine particles in a typical living room or bedroom to an acceptable level when there is an intense biomass episode. The ENV also suggest that households can add a special filter to window or split-unit air-conditioners to achieve similar results for particle removal. For central air conditioning systems, electrostatic precipitators, high-efficiency media filters and medium-efficiency media filters can be added so that the particle level in the indoor air can be kept within acceptable levels during a prolonged biomass smoke period.

Portable air cleaners were also discussed in a US EPA report (119). Studies have been performed on portable air cleaners, assessing particle removal from the air in room-size test chambers or extensively weatherized or unventilated rooms. All of the tests addressed removal of particles from cigarette smoke, which is similar in size to biomass smoke. The studies show varying degrees of effectiveness of portable air cleaners in removing particles from indoor air. In general, units containing either electrostatic precipitators, negative ion generators, or pleated filters, and hybrid units containing combinations of these mechanisms, are more effective than flat filter units in removing cigarette smoke particles. However, effectiveness within these classes varies widely. The use of a single portable unit would not be expected to be effective in large buildings with central heating, ventilating, and air-conditioning (HVAC) systems. Portable units are designed to filter the air in a limited area only.

The effectiveness of air cleaners in removing pollutants from the air is a function of both the efficiency of pollutant removal as it goes through the device and the amount of air handled. A product of these two factors (for a given pollutant) is expressed as the unit's clean air delivery rate (CADR). The Association of Home Appliance Manufacturers (AHAM) has developed an American National Standards Institute (ANSI)-approved standard for portable air cleaners (ANSI/AHAM Standard AC-1-1988)25. This standard may be useful in estimating the effectiveness of portable air cleaners. Under this standard, room air cleaner effectiveness is rated by a CADR for each of three particle types: tobacco smoke, dust, and pollen. For induct systems, the atmospheric dust spot test of ASHRAE Standard 52-76 and the DOP method in Military Standard 282 may be used, respectively, to estimate the performance of medium and high efficiency air cleaners (119).

Table 7 shows the percentage of particles removed from indoor air in rooms of various size by rated CADR, as estimated by AHAM. The table provides estimates of the percent of particles removed by the air cleaner and the total removal by both the air cleaner and by natural settling. If the source is continuous, the devices would not be expected to be as effective as suggested by Table 7. In addition, the values represent a performance that can be expected during the first 72 hours of use. Subsequent performance may vary depending on conditions of use.

RECOMMENDATIONS OF HEALTH PROTECTION MEASURES

As discussed above, the hierarchy for health protection is control or prevention of fires followed by administrative controls such as reduced physical activity and remaining indoors. To enhance the protection offered by remaining indoors, individuals/building managers should take action to reduce the air exchange rate. Clearly there are comfort and economic costs associated with reduced air exchange, as well as potential health effects due to increased impact of indoor pollution sources. It is not possible at this time to recommend more specific measures which would be feasible to employ on a population-wide basis. There is evidence that air conditioners, especially those with efficient filters, will substantially reduce indoor particle levels. To the extent possible, effective filters should be installed in existing air conditioning systems and individuals should seek environments protected by such systems. There is strong evidence that portable air cleaners are effective at reducing indoor particle levels, provided the specific cleaner is adequately matched to the indoor environment in which it is placed. Fortunately most air cleaners have been evaluated by manufacturers and their effectiveness in known. Unfortunately, economics will limit the distribution of such devices throughout the population. As with air conditioners the increased use of such devices by a large segment of the population will have a significant impact on energy consumption, and may in turn have negative impacts on ambient air quality. The least desirable measure is the use of personal protective equipment, such a dust masks. While these are relatively inexpensive and may be distributed to a large segment of the population, at present their effectiveness for general population use must be questioned. Education of the population regarding specific mask types to purchase, how to wear masks and when to replace them will increase their effectiveness as well as the development of new masks designed for general population use.

REFERENCES

1. Pierson W, Koenig J, et al. Potential adverse health effects of wood smoke. West J Med, 1989;151: 339-42.

2. Vedal S. Health effects of wood smoke. Report to the Provincial health Officer of British Columbia. Vancouver, BC. The University of British Columbia, 1993.

3. Larson T, Koenig J. Wood smoke: Emissions and non-cancer respiratory effects. Ann Rev Public Health, 1994;15: 133-56.

4. Andrae M, Browell E, et al. Biomass burning emissions and associated haze layers over Amazonia. J of Geophys Res, 1988;93: 1509-27.

5. Delany A, Haagensen P, et al. Photochemically produced ozone in the emission from large-scale Tropical Vegetation Fires. J of Geophys Res, 1985;90:2425-29.

6. Kirchoff V. Biomass burning in the Brazil Amazon region: Measurements of CO and O_3. In Levine JS (ed). Global biomass burning: Atmospheric climatic and biospheric implications. Cambridge, MA, MIT Press, 1991.

7. Cheng L, McDonlad K, et al. Forest fire enhanced photochemical air pollution. A case study. Atmos Environ, 1998;32: 673-81.

8. Samberg D, Martin R. Particle size in slash fire smoke. Portland OR US Department of Agriculture, Forest Service, Pacific Northwest Research Station, 1975.

9. Hueglin C, Gaegauf C, et al. Characterisation of wood combustion particles: Morphology, mobility and photoelectric activity. Environ Sci Technol, 1997;31: 3439-47.

10. Echalar F, Gaudichet A, et al. Aerosol emission by tropical forest and savanna biomass burning:characteristic trace elements and fluxes. Geophy Res Letters, 1995;22(22): 3039-42.

11. Rogge W, Hildemann L, et al. Sources of fine organic aerosol. 9. Pine, Oak and Synthetic Log Combustion in Residential Fireplaces. Environ Sci Technol, 1998;32: 13-22.

12. Daisey J, Spengler J, et al. A comparison of the organic chemical composition of indoor aerosols during wood burning and non-wood burning periods. Environ Int 1989;15: 435-42.

13. Murphy D, Buchan-RM, et al. Ambient total suspended particulate matter and benzo (a) pyrene, 1984.

14. Artaxo-P GF, Yamasoe-MA, Martin-J. Fine mode aerosol composition at three long-term atmospheric monitoring sites in the Amazon Basin. J of Geophys Res, 1994;99(D11): 22857-68.

15. Schwartz J, Dockery DW, et al. Is daily mortality associated specifically with fine particles? J Air Waste Manag Assoc, 1996;46(10): 927-39.

16. Vedal S. Ambient particles and health: lines that divide, J Air Waste Manag Assoc, 1997;47(5): 551-81.

17. Perez-Padilla R, Regalado J, et al. Exposure to biomass smoke and chronic airway disease in Mexican women. Am J Respir Crit Care Med, 1996;154(3 Pt 1): 701-6.

18. Smith K and Liu Y. Indoor air pollution in developing countries. Epidemiology of lung cancer. J Samet, New York, Marcel Dekker, 1993: 151-84.

19. Wafula E, Onyango F, et al. Indoor air pollution in a Kenyan village. East Afr Med J, 1990;67: 24-32.

20. Armstrong JR, Campbell H. Indoor air pollution exposure and lower respiratory infections in young Gambian children. Int J Epidemiol, 1991;20(2): 424-9.

21. Smith K. Fuel combustion air pollution exposure and health: The situation in developing countries. Annual Review of Energy and Environment, 1993;18: 529-66.

22. Brauer M, Bartlett K, et al. Assessment of particulate concentrations from domestic biomass combustion in rural Mexico. Environmental science and technology, 1996;30(1): 104-9.

23 Reinhardt T, Ottmar R. Smoke exposure among wildland firefighters: A review and discussion of current literature, United States Department of Agriculture, Forest Service. Pacific Northwest Research Station, 1997

24. Griggs TR, Mage D, et al. Carbon monoxide exposure associated with fighting a peat ground fire. Fire Management Notes. 1983;44(1):6-8

25. Brotherhood J, Budd G, et al. Fire fighters' exposure to carbon monoxide during Australian bushfires. Am Ind Hyg Assoc J, 1990;51(4): 234-40.

26. Reh C, Deitchman. Health Hazard Evaluation Report No. HETA-88-320-2176, US Department of the Interior, National Park Service, Yellowstone National Park, Wyoming, Hazard Evaluations and Technical Assistance Branch, NIOSH, US Department of Health and Human Services, Cincinnati, Ohio, 1992: 41.

27. Materna B, Jeffery RJ, et al. Occupational exposures in California Wildland Fire Fighting. Am Ind Hyg Assoc J, 1992;53: 69-76.

28. Reh C, Letts D, et al. Health Hazard Evaluation Report No HETA-90-0365-2314, US Department of the Interior, National Park Service, Yosemite National Park, California. Cincinnati, Ohio, US Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, 1994.

29. Reinhardt T. Smoke exposure from biomass combustion in Rondonia, Brazil, 1996.

30. Heumann M, Foster L, et al. Wood smoke air pollution and changes in pulmonary function among elementary school children. 84th Annual Meeting of the Air and Waste Management Association, Vancouver, BC, Air and Waste Management Association, 1991.

31. Stone R. Wood smoke fires infections. Science, 1995;267: 1771.

32. Betchley G, Koenig J, et al. Pulmonary function and respiratory symptoms in forest firefighters. American Journal of Industrial Medicine, 1997;31: 503-9.

33. Sutton P, Castorina J, et al. Carbon monoxide exposure in wildland firefighters. Berkely, CA, Occupational Health Surveillance and Evaluation Program, Epidemiologic Studies and Surveillance Section, California Department of Health Services, 1988.

34. Letts D, Fidler A, et al. Health hazard evaluation report No. HETA 91 152-2140, US Department of the Interior, National Park Service, Southern California, Hazard Evaluators and Technical Assistance Branch, NIOSH, US, Department of Health and Human Services, Cincinnati, Ohio, 1991: 24.

35. Rothman N, Ford D, et al. Pulmonary function and respiratory symptoms in wildland firefighters. J Occup Med, 1991;33: 1163-7.

36. Liu D, Tager IRA B, et al. The effect of smoke inhalation on lung function and airway responsiveness in wildland fire fighters. Am Rev Respir Dis, 1992;146: 1469-73.

37. Serra A, Mocci F, et al. Pulmonary function in Sardinian fire fighters. American Journal of Industrial Medicine, 1996;30: 78-82.

38. Chen BH, Hong CJ, et al. Indoor air pollution in developing countries. World Health Stat Q, 1990;43: 127-38.

39. Collings D, Sithole S, et al. Indoor woodsmoke pollution causing lower respiratory disease in children. Trop Doct, 1990;20: 151-5.

40. Ellegard A. Cooking fuel smoke and respiratory symptoms among women in low-income areas in Maputo. Environ Health Persp, 1996;104(9): 980-5.

41. Regalado J, Perez-Padilla V, et al. The effect of biomass burning on respiratory symptoms and lung function in rural Mexican women. American Journal of Respiratory and Critical Care Medicine, 1996;153: A701.

42. Dennis R, Maldonado D, et al. Woodsmoke exposure and risk for obstructive airways disease among women. Chest, 1996;109: 115-9.

43. Sandoval J, Salas J et al. Pulmonary arterial hypertension and cor pulmonale associated with chronic domestic wood smoke inhalation. Chest, 1993; 103: 12-20.

44. Cassano P, Hu G, et al. Cooking fuels and pulmonary function in the Peoples Republic of China. American Journal of Respiratory and Critical Care Medicine, 1994;149(4): A663.

45. Wilson R and Spengler J. Particles in our air: concentrations and health effects. Cambridge, MA, Harvard University Press, 1996.

46. Dockery DW, Pope CA. Acute respiratory effects of particulate air pollution. Annu Rev Public Health, 1994;15: 107-32.

47. Pope CA III, Bates DV, et al. Health effects of particulate air pollution: time for reassessment? Environ Health Perspect, 1995;103: 472-80.

48. Logan W. Mortality in London fog incident. Lancet, 1953;1:336-338.

49. Schwartz J and Marcus A. Mortality and air pollution in London: a time series analysis. Am J Epidemiol, 1990;131: 185-94.

50. Dockery DW, Pope III AC, et al. An association between air pollution and mortality in six US cities. N Engl J Med, 1993;329: 1753-9.

51. Schwartz J. Particulate air pollution and daily mortality in Detroit. Environ Res, 1991;56: 204-13.

52. Dockery DW, Schwartz J, et al. Air pollution and daily mortality associations with particulates and acid aerosols. Environ Res, 1992;59: 362-73.

53. Pope CA III, Schwartz J, et al. Daily mortality and PM_{10} pollution in Utah Valley. Arch Environ Health, 1992;47:211-7.

54. Schwartz J, Dockery DW. Increased mortality in Philadelphia associated with daily air pollution concentrations. Am Rev Respir Dis, 1992;145: 600-4.

55. Schwartz J, Dockery DW. Particulate air pollution and daily mortality in Steubenville, Ohio [published erratum appears in Am J Epidemiol 1995;141: 87]. Am J Epidemiol, 1992;135: 12-9; discussion 20-5.

56. Schwartz J. Air pollution and hospital admissions for the elderly in Birmingham, Alabama. Am J Epidemiol, 1994;139: 589-98.

57. Spix C, Heinrich J, et al. Air pollution and daily mortality in Erfurt, East Germany, 1980-1989. Environ Health Perspect, 1993;101: 518-26.

58. Pope CA, III, Thun M J, et al. Particulate air pollution as a predictor of mortality in a prospective study of US adults. Am J Respir Crit Care Med, 1995;151: 669-74.

59. Schwartz J. PM_{10}, ozone and hospital admission for the elderly in Minneapolis- St Paul, Minnesota. Arch Environ Health, 1994;49:366-74.

60. Schwartz J. What are people dying of on high air pollution days? Environ Res, 1994;64: 26-35.

61. Bobak M, Leon DA. Air pollution and infant mortality in the Czech Republic, 1986-88. Lancet, 1992;340: 1010-4.

62. Woodruff TJ, Grillo J, et al. The relationship between selected causes of postneonatal infant mortality and particulate air pollution in the United States. Environ Health Perspect, 1997;105: 608-12.

63. Wang X, Ding H, et al. Association between air pollution and low birth weight: a community-based study. Environ Health Perspect, 1997;105: 514-20.

64. Pope CA III. Respiratory disease associated with community air pollution and a steel mill, Utah Valley. Am J Public Health, 1989;79: 623-8.

65. Pope CA III. Respiratory hospital admissions associated with PM_{10} pollution in Utah, Salt Lake, and Cache Valleys. Arch Environ Health, 1991;46: 90-7.

66. Schwartz J, Slater D, et al. Particulate air pollution and hospital emergency room visits for asthma in Seattle. Am Rev Respir Dis, 1993;147: 826-31.

67. Schwartz J. Short term fluctuations in air pollution and hospital admissions of the elderly for respiratory disease. Thorax, 1995;50: 531-8.

68. Schwartz J. Air pollution and hospital admissions for respiratory disease. Epidemiology 1996;7: 20-8.

69. Hefflin B Jalaludin B, et al. Surveillance for dust storms and respiratory diseases in Washington State, 1991. Arch Environ Health, 1994;49: 170-174.

70. Buist A, Johnson L, et al. Acute effects of volcanic ash from Mount Saint Helens on lung function in children. Am Rev Respir Dis Jun, 1983;127(6): 714-719.

71. Abbey DE, Mills PK, et al. Long-term ambient concentrations of total suspended particulates and oxidants as related to incidence of chronic disease in California Seventh-Day Adventists. Environ Health Perspect, 1991;94: 43-50.

72. Abbey DE, Moore J, et al. Estimating cumulative ambient concentrations of air pollutants: description and precision of methods used for an epidemiological study. Arch Environ Health, 1991;46: 281-7.

73. Abbey DE, Ostro BE, et al. Estimating fine particulates less than 2.5 microns in aerodynamic diameter ($PM_{2.5}$) from airport visibility data in California. J Expo Anal Environ Epidemiol, 1995;5: 161-80.

74. Schwartz J, Dockery DW, et al. Is daily mortality associated specifically with fine particles. J Air Waste Manag Assoc, 1996; 46: 927-39.

75. Churg A, Brauer M. Human lung parenchyma retains PM2.5. Am J Respr Crit CareMed, 1997; 155: 2109-11.

76. Dockery D, Spengler J, et al. Association of health status with indicators of indoor air pollution from and epidemiologic study in six US cities. International Conference on Indoor Air Quality and Climate, Berlin, Institute for Water, Soil and Air Hygiene, 1987.

77. Honicky-RE OJ, Akpom-CA. Symptoms of respiratory illness in young children and the use of wood burning stoves for indoor heating. Pediatrics, 1985;75: 587-593.

78. Honicky-RE AC, Osborne-JS. Infant respiratory illness and indoor air pollution from a woodburning stove. Pediatrics, 1983;71: 126-8.

79. Pandey M. Domestic smoke pollution and chronic bronchitis in a rural community of the Hill Region of Nepal. Thorax, 1984;39: 337-9.

80. Ramage JJ, Roggli V, et al. Interstitial lung disease and domestic wood burning. Am Rev Respir Dis, May 1988;137: 1229-32.

81. Tuthill R. Woodstoves, formaldehyde and respiratory disease. American Journal of Epidemiology, 1984;120: 952-955.

82. Butterfield P, LaGava G, et al. Woodstoves and indoor air: the effects on preschoolers' upper respiratory systems. Journal of Environmental Health, 1989;52(3): 172-3.

83. Cupitt L, Glen W, et al. Exposure and risk from ambient particle-bound pollution in an Airshed dominated by residential wood combustion and mobile sources. Environmental Health Perspetives, 1994;102 (Suppl 4): 75-84.

84. Morris K, Morgenlander M, et al. Wood-burning stoves and lower respiratory tract infection in American Indian Children. Am J Dis Child, 1990;144: 105-8.

85. Robin L. Wood-burning stoves and lower respiratory illness in Navajo children. Pediatric Infectious Diseases Journal, 1996;15: 859-65.

86. Ostro B, Lipsett M, et al. Indoor air pollution and asthma: Results from a panel study. Am J Respir Crit Care, 1994;149:1400-6.

87. Johnson K, Gideon R, et al. Montana air pollution study: Childrens' Health Effects. Journal of Official Statistics, 1990;5: 391-408.

88. Browning K, Koenig JQ, et al. A questionnaire study of respiratory healthy areas of high and low ambient wood smoke pollution. Pediatric Asthma, Allergy and Immunology, 1990;4: 183-191.

89. Koenig J, Larson TV, et al. Pulmonary function changes in children associated with fine particulate matter. Environ Res, 1993;63: 26-38.

90. Fairley D. The relationship of daily mortality to suspended particulates in Santa Clara County, 1980-1986. Environmental Health Perspectives, 1990; 89: 159-68.

91. Lipsett M, Hurley S, et al. Air pollution and emergency room visits for asthma in Santa Clara County, California. Environmental Health Perspectives, 1997;105: 216-22.

92. From L, Bergen L, et al. The effects of open leaf burning on spirometric measurements in asthma. Chest, 1992;101: 1236-9.

93. Long W, Tate RB, et al. Respiratory symptoms in a susceptible population due to burning of agricultural residue. Chest, 1998;113: 351-7.

94. Chew F, Ooi B, et al. Singapore's haze and acute asthma in children. Lancet, 1995;346: 1427.

95. Copper C, Mira M, et al. Acute exacerbations of asthma and bushfires. Lancet, 1994;343:1509.

96. Smith M, Jalaludin B, et al. Asthma presentations to emergency department in western Sydney during the January 1994 Bushfires. Int J Epidemiol, 1996;25: 1227-36.

97. Duclos P, Sanderson, et al. The 1987 Forest Air Disaster in California: Assessment of Emergency Room visits. Arch Environ Health, 1990;45: 53-8.

98. Cohen AJ, Pope, CA III. Lung cancer and air pollution. Environmental Health Perspectives, 1995;103 (suppl):219-24.

99. Lewis C, Baumgardner R, et al. Contribution of woodsmoke and motor vehicle emissions to ambient aerosol mutagenicity. Environ Sci Technol, 1988;22(8): 968-71.

100. De Koning, Smith, KR Last, JM. Biomass fuel combustion and health, Bulletin of the World Health Organization, 1985;63(1):11-26

101. Mumford J. Recent results in cancer research, 1990;120: 106-21.

102. Chapman R, Mumford J, et al. The epidemiology of lung cancer in Xuan Wei, China: Current progress, issues, and research strategies. Arch of Environ Health, 1988;43: 180-5.

103. Mumford J, He XZ, et al. Lung cancer and indoor air pollution in Xuan Wei, China, Science 1987;9: 217-20.

Nuisance Dust Respiratory against respirable and non-respirable aerosols. Annals of Occupational Hygiene, 1988;32: 295-315.

105. Qian Y, Willeke K, et al. Performance of N95 respirators: filtration efficiency for airborne microbial and inert particles. Am Ind Hyg Assoc J, 1998;59: 128-132.

106. Chen S, Vesley D, et al. Evaluation of single-use masks and respirators for protection of health care workers against mycobacterial aerosols. American J of Infection Control, 1994;22: 65-74.

107. Tuomi T. Face seal leakage of half masks and surgical masks. American Industrial Hygiene Association Journal, 1985;46: 308-12.

108. Hinds W, Kraske G. Performance of dust respirators with facial seal leaks: I, Experimental. American Industrial Hygiene Association Journal, 1987;48: 836-41.

109. Jones J. The physiological cost of wearing a disposable respirator. Am Ind Hyg Assoc J, 1991;52: 219-25.

110. Ministry of the Environment, Singapore. http://www.gov.sg/env/sprd/Red- Mask: html; 24 Sep 1997.

111. Suh H, Spengler J, et al. Personal exposures to acid aerosols and ammonia. Environmental Science and Technology, 1992;2507-17.

112. Chia HP, Chia KS, Ooi PL, Ng TP, Goh KT, Lee HP. Effects of the recent haze in Singapore on the frequency of attacks among group of known asthmatics. In Goh KT, Ooi PL (eds), Health and the Built Environment, Institute of Environmental Epidemiology, Singapore, 1995;87-93.

113. Anuszewski J, Larson T, et al. Simultaneous indoor and outdoor particle light-scattering measurements at homes using a portable nephelometer. 11th Annual Meeting of the American Association for Aerosol Research, October 12-16, 1992.

114. Brauer M, Koutrakis P, et al. Indoor and outdoor concentrations of inorganic acidic aerosols and gases. J Air Waste Manage Assoc, 1991;41: 171-81.

115. Ozkaynak H, Xue J, et al. Personal exposure to airborne particles and metals: results from the Particle TEAM study in Riverside, California. J Expo Anal Environ Epidemiol, 1996;6: 57-78.

116. Wallace L. Indoor particles: a review. J Air Waste Manag Assoc, 1996;46: 98-126.

117. Offermann F, Sextro R, et al. Control of respirable particles in indoor air with portable air cleaners. Atmos Environ, 1985;19(11): 1761-71.

118. Ministry of the Environment, Singapore. http://www4.gov.sg/env/Sprd/haze-re-22-98-htm, 26 Sep 1998.

119. USEPA. Residential air cleaning devices: A summary of available information. Washington, DC, United States Environmental Protection Agency, Indoor Air Division, 1990.

120. Ward D and Hardy C. Smoke emissions from wildland fires. Environment International, 1991;17: 117-34.

121. Abbey D, Peterson F, et al. Long-term ambient concentrations of total suspended particulates, ozone and sulfur dioxide and respiratory symptoms in a nonsmoking population. Archives of Environmental Health, 1993;48: 33-46.

122. Anderson H. Respiratory abnormalities in Papua New Guinea children; The effects of locality and domestic wood smoke pollution. International Journal of Epidemiology, 1978;7: 63-72.

123. Anderson H. Respiratory abnormalities, smoking habits and ventilator capacity in a highland community in Papua New Guinea: Prevalence and effect on mortality. International Journal of Epidemiology, 1979;8: 127-35.

124. Kossove D. Smoke filled room and lower respiratory disease in infants. South Africa Medical Journal, 1982;61: 622-24.

125. Pandey M, Neupane R, et al. Domestic smoke pollution and acute respiratory infections in a rural community of the hill region of Nepal. Environment International, 1989; 5: 337-42.

126. Azizi B, Henry R. Effects of indoor air pollution on lung function of primary school children in Kuala Lumpur. Pediatric Pulmonology, 1990;9(1): 24-9.

127. Azizi B, Henry R. The effects of indoor environmental factors on respiratory illness in primary school children in Kuala Lumpur. International Journal of Epidemiology, 1991;20: 144-50.

128. Norboo T, Yahya M, et al. Domestic pollution and respiratory illness in a Himalayan village. International Journal of Epidemiology, 1991;20: 749-57.

Table 1
Summary of major biomass pollutants

Compound	Examples	Source	Notes
Inorganic Gases	Carbon monoxide (CO)	Incomplete combustion of organic material	Transported over distances
	Ozone (O_3)	Secondary product of nitrogen oxides and hydrocarbons	Only present downwind of fire, transported over distances
	Nitrogen dioxide (NO_2)	High temperature oxidation of nitrogen in air	Reactive-concentrations decrease with distance from fire
Hydrocarbons	Benzene	Incomplete combustion of organic material	Some transport - also react to form organic aerosols
Aldehydes	Acrolein	Incomplete combustion of organic material	
	Formaldehyde (HCHO)	Incomplete combustion of organic material	
Particles	Inhalable particles (PM_{10})	Condensation of combustion gases; incomplete combustion of organic material; entertainment of vegetation and ash fragments	Coarse and fine particles. Coarse particles are not transported and contain mostly soil and ash
	Respirable particulate matter	Condensation of combustion gases; incomplete combustion of organic material	For biomass smoke, approximately equal to fine particles
	Fine particles (PM2.5)	Condensation of combustion gases; incomplete combustion of organic material	Transported over long distances; primary and secondary production
Polycyclic aromatic hydrocarbons (PAHs)	Benzo[a]pyrene (BaP)	Condensation of combustion gases, incomplete combustion or organic material	Specific species varies with composition of biomass

Table 2
Summary of epidemiological studies on occupational exposure of wildland firefighters

Study design	Endpoints measured	Results	Reference
Longitudinal	Symptoms, lung function	Decreased cross-shift and cross-season lung function	32
Prevalence	Symptoms	High prevalence of headaches, lightheadedness, cough, shortness of breath, wheeze	33
Longitudinal	Symptoms, lung function	Slightly decreased cross-season lung function. No increase in symptoms	34
Longitudinal	Symptoms, lung function	Increase in cross-season symptoms. Slight decrease in cross-season lung function. Increased symptoms associated with increased recent firefighting.	35
Longitudinal	Lung function, airways responsiveness	Cross-season increase in airways responsiveness and decreased lung function	36
Cross-sectional	Lung function	Decreased lung function in firefighters measured 11 months post-exposure relative to unexposed control group. No association between years of firefighting and lung function.	37

Table 3
Summary of epidemiological studies on indoor exposure (high level)

Population	Study design	Endpoints measured	Results	Reference
Children in Papua New Guinea	Cross-sectional	Symptoms	Increased cough and rhinitis in high exposure group. Increased wheeze in low exposure group.	122
Children in Papua New Guinea	Prospective	Symptoms	No difference in symptoms between the two exposure groups	122
Adult women in Papua New Guinea	Cross-sectional	Lung function	10 per cent of women >45 years had FEV_1/FVC <60 per cent. No control group	123
Children in South Africa	Cross-sectional	Respiratory illness	Increased serious lower respiratory illness in exposed group	124
Adults in Nepal	Cross-sectional	Respiratory illness	Increased chronic bronchitis prevalence with increasing hours of exposure	79
Children in Nepal	Cross-sectional	Respiratory illness	Increased severe respiratory illness with increased hours of exposure	125
Children in Malaysia	Cross-sectional	Lung function	Decreased lung function with home wood stove	126
Children in Malaysia	Cross-sectional	Symptoms	Slight increase in cough and phlegm prevalence in exposed group	127
Children in Kenya	Cross-sectional	Respiratory illness	No increase in illness rates for exposed children	19
Children in Gambia	Cross-sectional	Respiratory illness	Increased acute respiratory infection risk in girls exposed while carried on mothers' back. No effect in boys.	20
Children in Zimbabwe	Cross-sectional	Respiratory illness	Increased lower respiratory illness with wood smoke exposure (blood COHb)	39
Adult, non-smoking women in India	Cross-sectional	Lung function	Reduced FEVI/FVC with increased exposure (expired CO)	128

Table 3 (continued)
Summary of epidemiological studies on indoor exposure (high level)

Population	Study design	Endpoints measured	Results	Reference
Adult women in Mexico	Case series	COPD	COPD in non-smoking women	43
Adults in China	Cross-sectional	Lung function	Increased lung function in adults with vented stoves. Decreased lung function with time spent cooking. County-wide COPD mortality highest in countries with lowest lung function	44
Adult women in Mexico	Case-control	COPD	COPD in non-smoking women	17
Adult women in Mexico	Cross-sectional	Symptoms, lung function	Slightly reduced lung function and increased cough and phlegm in women with highest PM_{10} exposure	41
Adult women in Mozambique	Cross-sectional	Symptoms	Increased cough symptoms in wood smoke exposed group (relative to charcoal, gas, electric). No increase in other respiratory symptoms (wheeze, difficulty breathing, etc.)	40
Adult women in Colombia	Case-control	COPD	COPD in non-smoking women	42

Table 4
Combined effect estimates of daily mean PM_{10} (46)

	per cent change per each 10 $\mu g/m^3$ increase in PM_{10}
INCREASE IN DAILY MORTALITY	
Total deaths	1.0
Respiratory deaths	3.4
Cardiovascular deaths	1.4
INCREASE IN HOSPITAL USAGE **(all respiratory)**	
Admissions	.8
Emergency department visits	1.0
EXACERBATION OF ASTHMA	
Asthmatic attacks	3.0
Bronchodilator	2.9
Emergency department visits	3.4
Hospital admissions	1.9
INCREASE IN RESPIRATORY **Symptoms reports**	
Lower respiratory	3.0
Upper respiratory	0 7
Cough	1.2
DECREASE IN LUNG FUNCTION	
Forced expiratory volume	0.15
Peak expiratory flow	0.08

Source: Dockery and Pope (46).

Table 5
Summary of epidemiological studies on indoor exposure (low level)

Population	Study design	Endpoints measured	Results	Reference
Children	Cross-sectional	Symptoms	No association between respiratory illness and home wood burning	81
Children	Cross-sectional	Symptoms	Increased cough, wheeze, allergic symptoms with home wood burning	77
Children	Cross-sectional	Symptoms, respiratory illness	Increased history of chest illness in past year with home wood burning; no effect on symptoms	76
Children	Longitudinal	Symptoms	Increased frequency of wheeze and cough with increased hours of wood stove use	82
Children <2 years	Longitudinal	Respiratory illness	Increased risk of lower respiratory illness with wood burning	84
Children	Cross-sectional	Symptoms, respiratory illness, lung function	No increased symptoms or illness and no decreased lung function with home wood burning	2
Children	Case-control	Hospitalisation for respiratory illness	Increased hospitalisation with home wood burning - results dependent upon control group	2
Adult asthmatics	Longitudinal	Symptoms	Increased cough, shortness of breath on days with home wood burning	86
Children <2 years	Case-control	Respiratory illness	Increased acute respiratory illness in wood burning homes with PM_{10} >65 $\mu g/m^3$	85

Table 6
Summary of epidemiological studies on ambient exposure

Population	Study design	Endpoints measured	Results	Reference
All ages > 1	Cross-sectional	Symptoms, respiratory illness	No significant effects. Trend for children 1-5	88
Children	Longitudinal	Lung function	Decreased lung function during and after wood burning season is exposed community but not in control community.	30
Children	Longitudinal	Lung function	Decreased winter lung function in exposed community but not in control community	87
Children	Longitudinal	Spirometry	Decreased lung function and fine particles in asthmatics	89
All ages	Longitudinal	Emergency room visits	Increased asthma visits with fine particles in areas where wood smoke accounts for 80 per cent of $PM_{2.5}$	66
All ages	Longitudinal	Emergency room visits	Increased asthma visits with PM_{10} in area where wood smoke accounts for 45 per cent of winter PM_{10}	91
All ages	Longitudinal	Mortality	Increased daily mortality with PM_{10} in areas where wood smoke accounts for 45 per cent of winter PM_{10}	90
All ages	Longitudinal	Emergency room visits	Increased respiratory visits in community exposed to fire smoke	97
Adult asthmatics	Experimental	Lung function	Decreased lung function following exposure to burning leaves in asthmatics, but not in non-asthmatics	92
Adults with airways obstruction	Prevalence	Symptoms	42 per cent of population reported increased or worsened symptoms during episode of exposure to agricultural burning emissions. 20 per cent reported breathing trouble	93
All ages	Longitudinal	Emergency room visits	Increased asthma visits with PM_{10} during episode of exposure to biomass burning emissions in Singapore	94
All ages	Longitudinal	Emergency room visits	No increase in asthma visits with PM_{10} during episode of exposure to bushfire emissions in Australia	95
All ages	Longitudinal	Emergency room visits	No increase in asthma visits with PM_{10} during episode of exposure to bushfire emissions in Australia	96

Table 7
Estimated Percentage of Particle Removal for Portable Units by CADR and by Room Size

Room Size	CADR	Percentage of Particles Removed: Smoke (20 min.) AC	Smoke (20 min.) T	Dust (20 min.) AC	Dust (20 min.) T	Pollen (10 min.) AC	Pollen (10 min.) T
5 x 6	10	49%	68%	49%	70%	-	-
	40	89%	97%	88%	98%	57%	93%
	80	95%	100%	95%	100%	75%	99%
9 x 12	40	53%	71%	52%	72%	24%	78%
	80	76%	89%	75%	89%	40%	86%
	150	89%	98%	89%	98%	58%	94%
12 x 18	80	53%	71%	52%	72%	24%	78%
	150	74%	87%	73%	88%	38%	85%
	300	89%	97%	-	-	-	-
	350	-	-	91%	99%	-	-
	450	-	-	-	-	69%	97%
18 x 24	150	51%	70%	50%	71%	23%	78%
	300	73%	87%	-	-	-	-
	350	-	-	77%	91%	-	-
	450	-	-	-	-	50%	91%
20 x 30	300	63%	79%	-	-	-	-
	350	-	-	67%	84%	-	-
	450	-	-	-	-	40%	86%

AC=Removal by the air-cleaning device
T= Removal by the air-cleaning device plus natural settling
Note: Estimates ignore the effect of incoming air. For smoke and, to a lesser extent, dust, the more drafty the room, the smaller the CADR required. For pollen, which enters from outdoors, a higher CADR is needed in a drafty room.
Source· Reference 26.

Figure 1
Adverse health effects associated with air pollution. The size of each level of the pyramid represents the proportion of the population affected.