Towards Healthy Air in Dwellings in Europe

THADE Project

Report

OVERVIEW OF EUROPEAN DATA ON INDOOR AIR POLLUTION IN DWELLINGS AND RELATED HEALTH EFFECTS

Marzia Simoni, Antonio Scognamiglio, Giovanni Viegi
Pulmonary Environmental Epidemiology Unit,
CNR Institute of Clinical Physiology, Pisa, Italy.

This project received financial support from the European Commission.

ABSTRACT

This review summarizes published data on indoor pollution and related health effects in European dwellings. An overview on scientific literature since 1991 to 2003 was made.

Particulate matter (PM) concentrations were generally below the EPA standard of 65 $\mu g/m^3$. Furthermore, except for Italy, PM levels were lower than 40 $\mu g/m^3$, i.e. a threshold value for “good” Indoor Air Quality (IAQ) according to the guidelines of the Finnish Society of IAQ and Climate. Nitrogen dioxide (NO_2) levels were generally lower than 40 $\mu g/m^3$ (a value which should avoid health effects, as suggested by the World Health Organization). Few data on carbon monoxide (CO) and carbon dioxide (CO_2) levels at home were found. Volatile organic compounds (VOCs) levels were substantially low within several studies. Formaldehyde concentrations showed a pronounced variability among different surveys and were generally high. Visible dampness or mould and dust mites infestation were widespread inside European dwellings.

With regard to respiratory health, most studies described the effects of major sources of PM or NO_2 and few studies regarded direct effects of measured indoor PM or NO_2 exposures at home. However, PM and NO_2 showed harmful effects on respiratory health, even at low levels. With regard to VOCs and formaldehyde, some epidemiological studies indicated irritant effects on respiratory system. Dampness, mould and house dust mites resulted sensitizer for exposed subjects.

At present, there are inadequate scientific bases on which to establish limit values to produce guidelines for exposure in dwellings and to implement protective programs of public health. It is necessary to perform researches to analyse the health effects, taking into account both the time and the variability of exposure.

4.1 INTRODUCTION

It is well established that indoor environment contributes significantly to human exposure to pollutants (1, 2). Indoor air pollution increases the risk of respiratory symptoms/diseases, atopic sensitization, bronchial hyper-responsiveness, lung cancer, respiratory infections, irritations (3-13). Since people spend most of their time inside, especially at home, exposures from outdoor and indoor sources should be separately assessed, as suggested by the U.S. Environmental Protection Agency (14). Data mostly collected in European dwellings on particulate matter (PM), nitrogen dioxide (NO_2), carbon dioxide (CO_2), carbon monoxide (CO), volatile organic compounds (VOCs), formaldehyde, dampness/mould and dust mites at home and related health effects are summarized in this review, along with some unpublished results from two Italian indoor air studies.

4.2 METHODS

The MEDLINE database was searched from January 1991 to September 2003, along with the Proceedings of the 9th International Conference of Indoor Air (Monterey, California, USA, 2002). For each study, author name, source, year of data collection (range: 1983-2001), geographical area, type of sample, and main results were reported.

Home Monitoring: pollutants were reported as follows: mean of 24 or 48 hours monitoring, in μg/m3, for PM; mean along different sampling periods, in μg/m3 (if transformed, 1ppb=1.88μg/m3), for NO2; levels in mg/m3 for CO and CO2 (if transformed, 1ppm=1.25mg/m3 for CO; 1ppm=1.83mg/m3 for CO2); levels in μg/m3 for VOC and formaldehyde; levels in μg/g of dust for mite allergens concentration; as positive answers to questionnaire for dampness and mold.

Po Delta and Pisa Indoor Studies (15, 16) were performed during the period 1991-94 on sub-samples of stratified family cluster random samples of Italian general populations, previously enrolled in two cross-sectional epidemiological surveys (10, 17). Measurements of particles with aerodynamic diameter < 2.5μm ($PM_{2.5}$) and NO_2 were collected during one week, both in winter and summer, in 139 houses in Po Delta rural area and 282 in Pisa urban area and reported as 48h mean ($PM_{2.5}$) and weekly mean (NO_2). Levels of NO_2 in the immediate vicinity of the home were also measured (micro-outdoor). Information on house characteristics and family's habits were collected by questionnaire.

Health Effects: papers were included in this review according to report of relative risk for symptoms/diseases. Population Attributable Risk (PAR) % was computed (whenever possible) to estimate the amount of disease or condition abatable by eliminating the exposure or risk factor: PAR=100*p(RR-1)/p(RR-1)+1, where p= proportion of total population exposed and RR= relative risk for exposed vs nonexposed (18). In *Po Delta and Pisa Indoor Studies*, information on daily activity pattern and presence of acute respiratory illness/symptoms during the monitored weeks were collected by questionnaire. Each subject performed peak expiratory flow measurements four times daily using a mini-Wright peak flow meter. NO_2 and $PM_{2.5}$ exposure indices as product of pollutant concentration and exposure time were computed (12).

4.3 RESULTS ON INDOOR AIR POLLUTION IN DWELLINGS

4.3.1 Indoor Levels

Particulate Matter (PM): levels are reported in table 1 and in figure 1. The lowest level (9.5 μg/m^3) in Finland (19) and the highest values in Italy (mean about 50μg/m^3) (11, 20) were measured. Other European dwellings concentrations (19, 21-23) were below 40μg/m^3, similarly to the USA (5) and Mexico (24). The EPA air quality guideline is 65μg/m^3 (48h mean) (25), whilst the Finnish Society of Indoor Air Quality (FSIAQ) sets maximum values of 20, 40, 50μg/m^3 for a "very good", "good" and "satisfactory" indoor quality, respectively (26). Tobacco smoking, combustion of fuel for heating or cooking, and outdoor environment were the main determinants for elevated PM levels.

Nitrogen Dioxide (NO_2): levels are reported in table 2 (part I, II) and in figure 2. The lowest values in Scandinavia (range: 10-15μg/m^3) (30, 31), and the highest in Poland (65μg/m^3) (30) were measured. Levels of 8-35μg/m^3 in Switzerland (32) and Germany (33), of 20-40μg/m^3 in other European countries (i.e. Italy, France, England, Germany, Croatia) (11, 22, 23, 34-36, 30) were detected. They were lower than those measured in Asia (range: 43-81μg/m^3) (30, 37, 38), New Mexico (USA) (39), Mexico (30), and similar to those of Canada and the USA (30). The Air Quality Guidelines in Europe (40) suggest for NO_2 a daily maximum concentration of 200μg/m^3 (1 h), while the World Health Organization recommends, for long-term exposure, a limit of 40μg/m^3 (annual average) (41). Main determinants of NO_2 levels were the use of gas appliances and outdoor environment.

Carbon Monoxide/Dioxide (CO/CO_2): Concentrations of CO are reported in table 3. High CO levels were mainly determined by wood burning for cooking/heating, especially in developing countries. In England (43) CO levels were 0.43mg/m^3 (geometric mean). In other European countries (Expolis Study) (20), a mean of 1.39mg/m^3 for houses and workplaces was found, similarly to Costa Rica (44), Canada (45), and Korea (46). EPA standard value is 10 mg/m^3 (25), while FSIAQ suggests 2, 3, 8 mg/m^3 for "very good", "good", and "satisfactory" IAQ, respectively (26). Only two studies, performed in Sweden and Latvia (47) and in Korea (46), reported CO_2 levels at home: 1556/1665 vs 1031 μg/m^3. FSIAQ suggests 1300 for "very good", 1650 for "good", and 2200 mg/m^3 for "satisfactory" IAQ (26). Unvented heaters, gas cooking, tobacco smoke and outdoor environment were the major sources of indoor CO_2.

Volatile Organic Compounds (VOCs): concentrations are shown in table 4-Part I. Acceptable levels of toluene (26), the most studied compound within this group (49-51), ranged from 15.1 in England (49) to 37.3 μg/m^3 in Germany (50), similarly to those measured in Italy (51). Sources of common indoor VOCs were adhesives, foam insulation, tobacco smoke, cleaners, inks, floor/wall coverings, and paints.

Formaldehyde: concentrations are shown in table 4-Part II. Indoor levels varied substantially among different countries and were generally very high according to standard values suggested by FSIAQ (26). For example, in United States formaldehyde levels ranged between non detectable values (12.5 μg/m^3) to very high concentrations (575 μg/m^3) (54). High levels were detected also in Japan (55). However, in UK the geometric level was 22.2 μg/m^3 (56). Indoor sources of formaldehyde were adhesives, carpets, particleboard, wall coverings, paints, and tobacco smoke.

Dust Mites: mites proliferate in warm and humid environments. Data on presence of dust mites are shown in table 5. European studies indicated that mites were present inside more than 50% of the observed dwellings (59-61). Mite allergens concentrations were generally about 2 μg/g of dust and could sensitize exposed subjects (59, 62). The highest levels were found in Sweden (60).

Dampness/Mould: data on presence of dampness and mould are reported in table 6. Visible dampness and mould were present inside 15% of Finnish homes (64), 25% of Dutch homes (65), and 35% of Italian dwellings (15).

Po Delta and Pisa Indoor Studies: $PM_{2.5}$ and NO_2 (66) concentrations were significantly higher in winter than in summer. Levels of $PM_{2.5}$ in winter and of NO_2 in both seasons were significantly higher in Po Delta than in Pisa. The highest levels of NO_2 were found in the kitchen. ETS was the main determinant for $PM_{2.5}$ in both seasons and areas. In winter, air exchange in both areas and presence of airtight windows in Pisa were protective factors for $PM_{2.5}$ levels. Determinants of NO_2 were gas-furnace heating inside home in Po Delta, while ETS and NO_2 micro-outdoor in Pisa. In summer, larger concentrations of NO_2 were related to increase of air-exchange in Po Delta and to NO_2 micro-outdoor in Pisa. In Pisa, larger levels of $PM_{2.5}$ were related to the presence of gas-furnace inside home (11, 13, 66).

4.3.2 Health Effects

Few studies (especially in Europe) reported the effects of measured indoor PM, NO_2 and CO exposure as relative risk. Most studies regarded outdoor/occupational exposure or effects by pollution sources.

Particulate Matter (PM): effects of PM and major sources of PM are shown in table 7. In Poland (67) and in Switzerland (68) a significant relation between respiratory symptoms/disease and ETS exposure was found in adults. PAR% values, especially for wheezes and shortness of breath with wheezes ranged from 22 to 52%.

Nitrogen Dioxide (NO_2): table 8 shows the effects of NO_2 or major sources of NO_2 on respiratory health in people of all ages and both sexes. In a Polish study on elderly women, asthma and dyspnea were related to high exposure to gas cooking (67). In England, gas cooking was a risk for reduced lung function (72).

Carbon Monoxide/Dioxide (CO/CO_2): for an increment of 10ppm (12.5mg/m^3), an increased risk for wheezing attacks (O.R.=1.12, CI95% 1.02-1.28) was found in Korean asthmatic children (46). A Chinese study (27) reported harmful effects of CO level on pulmonary function. With regard to CO_2 levels, a study in Sweden and Latvia did not find differences between the houses of asthmatic and non asthmatic children (47), whereas another Swedish study on adults (20-45yrs) showed a significant relation of nocturnal breathlessness with indoor concentration of CO_2 (O.R.=20.0; 95% CI 2.7-146.0) for an increase of 1000 ppm (1830mg)/m^3 (76).

Volatile Organic Compounds (VOCs): effects of VOCs and formaldehyde are reported in table 9. A German study showed a significant association of VOCs exposure with irritation symptoms of the upper respiratory tract (53). In Sweden, asthma was related to newly painted surfaces (OR 1.5; CI 95% 1.0-2.4) (77). Formaldehyde resulted an irritant agent for the respiratory tract, and could cause sensitization in exposed children (OR 1.40; CI 95% 0.98-2.00) (57). Furthermore, an Australian survey indicated that every 10μg/m^3 increase in formaldehyde concentrations was associated with an enhanced risk of having asthma (OR 1.003; 95% CI 1.002-1.004) (78).

Dust Mites: effects of mites are reported in table 10. In studies carried out in Germany (80) and Australia (81) exposure to high mite allergen levels was associated with bronchial hyper-responsiveness (OR 2.30; 95% CI 1.03-5.12) and current asthma (OR 21.3; 95% CI 10.5-43.2), respectively.

Dampness/Mould: effects of dampness and mould are reported in table 11. In a large Finnish survey exposure to visible mould was associated with a risk of asthma (OR 2.21; 95% CI 1.48-3.28). For this study PAR was estimated at about 15% (64). Swedish subjects exposed to dampness inside their homes had a higher risk of asthma (OR 1.8; 95% CI 1.1-3.0) with a PAR estimated at 16% (83). Exposure to dampness was a risk factor for bronchial hyper-responsiveness (OR 5.77; 95% CI 1.17-28.44), with a PAR estimated at 38% in Germany (80). In The Netherlands, exposure to dampness/mould was associated with an augmented risk of having lower respiratory symptoms in males (OR 1.70; 95% CI 1.38-2.09) and females (OR 1.55; 95% CI 1.27-1.89). Considering the whole sample, PAR value was 9.5% (65).

Po Delta and Pisa Indoor Studies: almost all groups of acute respiratory conditions were more frequent in presence of high exposure to both $PM_{2.5}$ and NO_2 (tables 7, 8) and in presence of ETS. High exposure to $PM_{2.5}$, but not NO_2, was a risk factor for reduced lung function (11, 66).

4.3.3 Main Outcomes

There is a wide variability of indoor pollutants levels across European dwellings. Indoor exposures can include peak levels and be longer than outdoors. Health effects, mainly on the respiratory system, are related to indoor pollutants in European houses. However, most studies did not perform direct measures of concentrations but examined presence of pollution sources.

4.4 Research Needs

More recent studies have investigated the influence of household environment on respiratory health of infants and adolescents (84, 85). Nevertheless, there is insufficient scientific evidence on which to establish safe limit values to produce guidelines for indoor exposure, especially in dwellings. Furthermore, there is the urgent need of assessing the effects of both short and long term exposure at home. Studies should be performed in general population samples on the relationship of health and measured indoor levels, taking into account the exposure time and the exposure variability (e.g. exposure peak). European Union should devote research funds to these issues. A strengthened collaboration of research institutions and patients organizations of member countries is necessary to carry out updated epidemiological surveys.

Acknowledgement

The authors wish to thank Mrs. Patrizia Silvi for her precious assistance provided to collect and collate statistical and epidemiological data about air pollution in dwellings and related health effects.

REFERENCES

1. Rojas-Bracho L, Suh HH, Koutrakis P. Relationship among personal, indoor, and outdoor fine and coarse particle concentrations for individuals with COPD. J Expo Anal Environ Epidemiol 2000;10:294-306.
2. Sarnat JA, Koutrakis P, Suh HH. Assessing the relationship between personal particulate and gaseous exposures of senior citizen living in Baltimore, MD. J Air Waste Manag Assoc 2000; 50:1184-98.
3. Jaakkola MS. Environmental tobacco smoke and health in the elderly. Eur Respir J 2002; 19:172-81.
4. Bruce N, Perez-Padilla R, Albalak R. Indoor air pollution in developing countries: a major environmental and public health challenge. Bull World Health Organ 2000;78:1078-92.
5. Neas LM , Dockery DW, Ware JH, Spengler JD, Ferris BG, Speizer FE. Concentration of indoor particulate matter as a determinant of respiratory health in children. Am J Epidemiol 1994;139:1088-99.
6. Naftstad P, Oie L, Mehl R, Gaarder PI, Lodrup-Carlsen KC, Botten G, Magnus P, Jaakkola JJ. Residential dampness problems and symptoms and signs of bronchial obstruction in young Norwegian children. Am J Respir Crit Care Med 1998;157:410-4.
7. Jaakkola MS. Environmental tobacco smoke and respiratory diseases. In: Annesi-Maesano I, Gulsvik A, Viegi G (eds). Respiratory epidemiology in Europe. European Respiratory Monograph 2000;15(5):322-83.
8. Jaakkola JJK, Nafstad P, Magnus P. Environmental tobacco smoke, parental atopy, and childhood asthma. Environ Health Perspect 2001;109:579-82.
9. Viegi G, Carrozzi L, Paoletti P, Vellutini M, Ballerin L, Biavati P, Di Pede F, Pedreschi M, Modena P, Baldacci S, Diviggiano E, Sapigni T, Giuntini C. Effects of some indoor environmental factors on respiratory symptoms and lung function in a sample of young non smokers in North Italy. Aerobiologia 1991;7:152-9.
10. Viegi. G, Carrozzi L, Paoletti P, Vellutini M, Diviggiano E, Baldacci S, Modena P, Pedreschi M, Mammini U, Di Pede C, Giuntini C. Effects of the home environment on respiratory symptoms of a general population sample in Middle Italy. Arch of Environ Health 1992;47:64-70.
11. Simoni M, Carrozzi L, Baldacci S, Scognamiglio A, Angino A, Pistelli F, Di Pede F, Viegi G. Acute Respiratory Effects of Indoor Pollutants in two General Population Samples living in a Rural and in an Urban Area of Italy. Proceedings of Indoor Air 2002;1:119-24.
12. Simoni M, Carrozzi L, Baldacci S. Angino A, Scognamiglio A, Di Pede F, Sapigni T, Viegi G. The Po river delta (North Italy) epidemiological study: effect of pollutant exposure on acute respiratory symptoms and respiratory function in adults. Arch of Environ Health 2002;57:130-6.
13. Simoni M, Jaakkola MS, Carrozzi L, Baldacci S, Di Pede F, Viegi G. Indoor air pollution and respiratory health in the elderly. Eur Respir J 2003; 21: Suppl. 40:15s-20s.
14. U.S. Environmental Protection Agency. Respiratory health effects of passive smoking: lung cancer and other disorders. U.S. Environmental Protection Agency, Office of Health

and Environmental Assessment, Office of Research and Development. Washington DC, 1992. EPA/600/6-90/006F.
15. Simoni M, Biavati P, Carrozzi L, Viegi G, Paoletti P, Matteucci G, Ziliani GL, Ioannilli E, Sapigni T. The Po river Delta (North Italy) Indoor Epidemiological Study: home characteristics, indoor pollutants, and subjects' daily activity pattern. Indoor Air 1998;8:70-9.
16. Baldacci S, Carrozzi L, Viegi G, Giuntini C. Assessment of respiratory effect of air pollution: study design on general population samples. JEPTO 1997;16:77-83.
17. Carrozzi L, Giuliano G, Viegi G, Paoletti P, Di Pede F, Mammini U, Carmignani G, Saracci R, Giuntini C, Lebowitz MD. The Po river delta epidemiological study of obstructive lung disease: sampling methods, environmental and population characteristics. Eur J Epidemiol 1990;6:191-200.
18. Balmes J, Becklake M, Blanc P, Henneberger P, Kreiss K, Mapp C, Milton D, Schwartz D, Toren K, Viegi G. American Thoracic Society Statement. Occupational contribution to the burden of airway disease. Am J Respir Crit Care Med 2003;167:787-97.
19. Gotschi T, Oglesby L, Mathys P, Monn C, Manalis N, Koistinen K, Jantunen M, Hanninen O, Polanska L, Kunzli N. Comparison of black smoke and PM2.5 levels in indoor and outdoor environments of four European cities. Environ Sci Technol 2002;36:1191-7.
20. Maroni M, Carrer P, Cavallo D, Jantunen M, Katsouyanni K, Kuenzli N, Sram R, Zmirou D, Della Torre M. Air Pollution exposure of adult population in Milan (Expolis Study). Proceedings Indoor Air 2002;4:455-60.
21. Janssen NA, de Hartog JJ, Hoek G, Brunekreef B, Lanki T, Timonen KL, Pekkanen J. Personal exposure to fine particulate matter in elderly subjects: relation between personal, indoor, and outdoor concentrations. J Air Waste Manag Assoc 2000;50:1133-43.
22. Gee IL, Stewart L, Waston AFR, Fletcher G, Niven R. Indoor air quality in smoking and non-smoking households. Proceedings Indoor Air 2002;2:512-7.
23. Zmirou D, Gauvin S, Pin I, Momas I, Just J, Sahraoui F, Le Moullec Y, Bremont F, Cassadou S, Albertini M, Lauvergne N, Chiron M, Labbe A; VESTA Investigators. Five epidemiological studies on transport and asthma: objectives, design and descriptive results. J Expo Anal Environ Epidemiol 2002;12:186-96.
24. Cortez-Lugo M, Holguin Molina F, Hernandez Avila M, Palazuelos Rendon E, Santibanez Ruelas R. Relationship among personal, indoor and outdoor fine particle concentrations for individuals with chronic obstructive pulmonary disease living in three areas of Mexico City. Proceedings of Indoor Air 2002;4:578-83.
25. United States Environmental Protection Agency. Revision to the National Ambient Air Quality Standards for Particles Matter. Federal Register 1997;62:38651-701.
26. Säteri J. Finnish Classification of indoor Climate 2000: revised target values. Proceedings Indoor Air 2002;3:512-7.
27. Pan XC, Dong Z, Wang L, Yue W. An evaluation of the indoor/outdoor air pollution and respiratory health of farmers living in rural areas of Anhui Province, China. Proceedings of Indoor Air 2002;4:982-7.
28. Caceres D, Adonis M, Retamal C, Ancic P, Valencia M, Ramos X, Olivares N, Gil L. Indoor air pollution in a zone of extreme poverty of La Pintana, Santiago-Chile. Rev Med Chil 2001;129:33-42.
29. Evans GF, Highsmith RV, Sheldon LS, Suggs JC, Williams RW, Zweidinger RB, Creason JP, Walsh D, Rodes CE, Lawless PA. The 1999 Fresno particulate matter exposure studies: comparison of community, outdoor, and residential PM mass measurements. J Air Waste Manag Assoc 2000;50:1887-96.

30. Levy JI, Lee K, Spengler JD, Yanagisawa Y. Impact of residential nitrogen dioxide exposure on personal exposure: an international study. J Waste Manag Assoc 1998;48:553-60.
31. Hagenbjork-Gustafsson A, Forsberg B, Hestvik G, Karlsson D, Wahlberg S, Sandstrom T. Measurements of indoor and outdoor nitrogen dioxide concentrations using a diffusive sampler. Analyst 1996;121:1261-4.
32. Monn C, Brandli O, Schindler C, Ackermann-Liebrich U, Leuenberger P. Personal exposure to nitrogen dioxide in Switzerland. SAPALDIA team. Swiss Study on Air Pollution and Lung Diseases in Adults. Sci Total Environ 1998;215:243-51.
33. Cyrys J, Heinrich J, Richter K, Wolke G, Wichmann HE. Sources and concentrations of indoor nitrogen dioxide in Hamburg (west Germany) and Erfurt (east Germany). Sci Total Environ 2000;250:51-62.
34. Gallelli G, Orlando P, Perdelli F, Panatto D. Factors affecting individual exposure to NO2 in Genoa (northern Italy). Sci Total Environ 2002;287:31-6
35. Coward SK, Raw GJ, Llewellyn, Ross DI. Indoor air quality in English homes – Nitrogen Dioxide. Proceedings of Indoor Air 2002;4:467-72.
36. Saintot M, Bernard N, Astre C, Galan P, Hercberg S, Gerber M. Nitrogen dioxide and ozone exposures in a population sample from Ile-de-France. Rev Epidemiol Sante Publique 2000;48 Suppl 2:254-61.
37. Shima M Adachi M. Effect of outdoor and indoor nitrogen dioxide on respiratory symptoms in schoolchildren. Int J Epidemiol 2000;29:862-70.
38. Leung R, Lam CW, Chan A, Lee M, Chan IH, Pang SW, Lai CK. Indoor environment of residential homes in Hong Kong--relevance to asthma and allergic disease. Clin Exp Allergy 1998;28:585-90.
39. Lambert WE, Samet JM, Hunt WC, Skipper BJ, Schwab M, Spengler JD. Nitrogen dioxide and respiratory illness in children. Part II: Assessment of exposure to nitrogen dioxide. Res Rep Health Eff Inst 1993;58:33-50.
40. Air Quality Guidelines for Europe, Copenhagen, World Health Organisation Regional Office for Europe 2000.
41. World Health Organisation. Nitrogen Oxide. Environmental Health Criteria, n° 188; Geneve, 1997.
42. Garrett MH, Hooper MA, Hooper BM. Nitrogen dioxide in Australian homes: levels and sources. J Air Waste Manag Assoc 1999;49:76-81.
43. Raw GJ, Coward SKD, Llewellin JW, Brown DR, Crump DR, Ross DI. Indoor air quality in English homes – Introduction and carbon monoxide findings. Proceedings of Indoor Air 2002;4:461-6.
44. Lee K, Park E. Residential air quality in wood burning houses in Costa Rica. Proceedings of Indoor Air 2002;4:612-7.
45. Levesque B, Allaire S, Gauvin D, Koutrakis P, Gingras S, Rhainds M, Prud'Homme H, Duchesne JF. Wood-burning appliances and indoor air quality. Sci Total Environ 2001;281:46-62.
46. Kim CS, Lim YW, Yang JY, Hong CS, Shin DC. Effects of indoor CO_2 concentrations on wheezing attacks in children. Proceedings of Indoor Air 2002;1:492-7.
47. Frisk M, Raukas-Kivioja A, Andersson H, Loit HM, Meren M, Stridh G. Are there any difference in indoor environment of asthmatics and non-asthmatics persons? A case-control study performed in Sweden and Estonia. Proceedings of Indoor Air 2002;1:97-102.
48. Naher LP, Smith KR, Laeder BP, Grajeda R. Indoor and outdoor PM2.5 and CO in high- and low-density Guatemala Villages. J Expo Anal Environ Epidemiol 2000;10:544-51.
49. Brown VM, Coward SKD, Crump DR, Llewellyn JW, Mann HS, Raw GJ. Indoor air quality in English homes-VOCs. Proceedings of Indoor Air 2002;4:477-82.

50. Schneider P, Gebefugi I, Richter K, Wolke GW, Schneille J, Wichmann HE, Heinrich J; INGA Study Group. Indoor exposure and Genetics in Asthma. Indoor and outdoor BTX levels in German Cities. Sci Total Environ 2001;267:41-51.
51. Carrer P, Maroni M, Alcini D, Cavallo D, Fustinoni S, Lovato L, Visigalli F. Assessment through environmental and biological measurements of total daily exposure to volatile organic compounds of office workers in Milan, Italy. Indoor Air 2000;10:258-68.
52. Cox SS, Little JC, Hodgson AT. Measuring concentrations of volatile organic compounds in vinyl flooring. J Air Waste Manag Assoc 2001;51:1195-201.
53. Pitten FA, Bremer J, Kramer A. Air pollution by volatile organic compounds (VOC) and health complaints. Dtsch Med Wochenschr 2000;125:545-50.
54. Liu KS, Huang FY, Hayward SB, Wesolowski J, Sexton K. Irritant effects of formaldehyde exposure in mobile homes. Environ Health Perspect 1991;94:91-4.
55. Minami T, Matsumoto H, Kondo F, Yamada S, Matsumura T, Ando M, Miyakazi Y. Variation in indoor air pollutant concentrations with time in a newly constructed private house. Nippon Koshu Eisei Zasshi 2002;49:211-21.
56. Brown VM, Coward SKD, Crump DR, Llewellyn JW, Mann HS, Raw GJ. Indoor air quality in English homes-Formaldehyde. Proceedings of Indoor Air 2002;4:473-6.
57. Garrett MH, Hooper MA, Hooper BM, Rayment PR, Abramson MJ. Increased risk of allergy in children due to formaldehyde exposure in homes. Allergy 1999;54:330-7.
58. Lemus R, Abdelghani AA, Akers TG, Horner WE. Potential health risks from exposure to indoor formaldehyde. Rev Environ Health 1998;13:91-8.
59. Oppermann H, Doering C, Sobottka A, Kramer U, Thriene B. Exposure status of East and West German households with house dust mites and fungi. Gesundheitswesen 2001;63:85-9.
60. Munir AK, Bjornsten B, Einarsson R, Ekstrand-Tobin A, Moller C, Warner A, Kjellman NI. Mite allergens in relation to home conditions and sensitization of asthmatic children from three climatic regions. Allergy 1995;50:55-64.
61. Harving H, Korsgaard J, Dahl R. House-dust mites and associated environmental conditons in Danish homes. Allergy 1993;48:106-9.
62. Hirsch T, Range U, Walther KU, Hederer B, Lassig S, Frey G, Leupold W. Prevalence and determinants of house dust mite allergen in East German homes. Clin Exp Allergy 1998;28: 956-964.
63. Solarz K. Risk of exposure to house dust pyroglyphid mites in Poland. Ann Agric Environ Med 2001;8:11-24.
64. Kilpelainen M, Terho EO, Helenius H, Koskenvuo M. Home dampness, current allergic diseases, and respiratory infections among young adults. Thorax 2001;56:462-7.
65. Brunekreef B. Damp housing and adult respiratory symptoms. Allergy 1992;47:498-502.
66. Simoni M, Scognamiglio A, Carrozzi L, Baldacci S, Angino A, Pistelli F, Di Pede F, Viegi G. Home characteristics and acute respiratory effects of indoor pollutants in two general population samples living in a rural and in an urban area of Italy. J Expo Anal Env Epid, 2003; submitted.
67. Jedrychowski W, Maugeri U, Gomola K, Tobiasz-Adamczyk B, Bianchi I. Effects of domestic gas cooking and passive smoking on chronic respiratory symptoms and asthma in elderly women. Int J Occup Environ Health 1995; 1:16-20.
68. Leuenberger P, Schwartz J, Ackerman-Liebrich U, Blaser K, Bolognini G, Bongard JP, Brandli O, Bron C, Brutsche M. Passive smoking exposure in adults and chronic respiratory sumptoms (SAPALDIA Study). Swiss Study on air pollution and lung diseases in adults, SAPALDIA Team. Am J Respir Crit Care Med 1994; 150:1222-8.
69. Qian Z, Zhang J, Wei F, Chapman RS. Impact of cooking coal smoke and heating coal smoke on respiratory health of children in four Chinese cities. Proceedings of Indoor Air 2002;4:1030-5.

70. Wang TN, Ko YC, Chao YY, Huang CC, Lin RS. Association between indoor and outdoor air pollution and adolescent asthma from 1995 to 1996 in Taiwan. Environ Res 1999;81:239-47.
71. Xu X, Wang L. Association of indoor and outdoor particulate level with chronic respiratory illness. Am Rev Respir Dis 1993;148:1516-22.
72. Moran SE, Strachan DP, Johnston ID, Anderson HR. Effects of exposure to gas cooking in childhood and adulthood on respiratory symptoms, allergic sensitization and lung function in young British adults. Clin Exp Allergy 1999;29:1009-13.
73. Garret MH, Hooper MA, Hooper DM, Abramson MJ. Respiratory symptoms in children and indoor exposure to nitrogen dioxide and gas stoves. Am J Respir Crit Care Med 1998;158:891-5.
74. Neas LM, Dockery DW, Ware JH, Spengler JD, Speizer FE, Ferris BG Jr. Association of indoor nitrogen dioxide with respiratory symptoms and pulmonary function in children. Am J Epidemiol 1991;134:204-19.
75. Pilotto LS, Smith BJ, Nitschke M, Ruffin RE, Mitchell R. Industry, air quality, cigarette smoke and rates of respiratory illness in Porto Adelaide. Aust N Z J Public Health 1999;23:657-60.
76. Norback D, Bjornsson E, Janson C, Boman G. Asthmatic symptoms and volatile organic compounds, formaldehyde and carbon dioxide in dwellings. Occup Environ Med 1995;52:388-95.
77. Wieslander G, Norback D, Bjornsson E, Janson C, Boman G. Asthma and the indoor environment: the significance of emission of formaldehyde and volatile organic compounds from newly painted indoor surfaces. Int Arch Occup Environ Health 1997;69:115-24.
78. Rumchev KB, Spickett JT, Bulsara MK, Phillips MR, Stick SM. Domestic exposure to formaldehyde significantly increases the risk of asthma in young children. Eur Respir J 2002; 20:403-8.
79. Diez U, Kroessner T, Rehwagen M, Richter M, Wetzig H, Schulz R, Borte M, Metzner G, Krumbiegel P, Herbarth O. Effects of indoor painting and smoking on airway symptoms in atopy risk children in the first year of life: results of the LARS-study. Leipzig Allergy High-Risk Children Study. Int J Hyg Environ Health 2000;203:23-8.
80. Nicolai T, Illi S, von Mutius E. Effect of dampness at home in childhood on bronchial hyperreactivity in adolescence. Thorax 1998;53:1035-40.
81. Peat JK, Tovey E, Mellis CM, Leeder SR, Woolcock AJ. Importance of house dust mite and Alternaria allergens in childhood asthma: an epidemiological study in two climatic regions of Australia. Clin Exp Allergy 1993;23:812-20.
82. Huss K, Adkinson NF Jr, Eggleston PA, Dawson C, Van Natta ML, Hamilton RG. House dust mite and cockroach exposure are strong risk factors for positive allergy skin tests responses in the Childhood Asthma Management Program. J Allergy Clin Immunol 2001;107:48-54.
83. Norback D, Bjornsson E, Janson C, Palmgren U, Boman G. Current asthma and biochemical signs of inflammation in relation to building dampness in dwellings. Int J Tuberc Lung Dis 1999;3:368-76.
84. Berlanger K, Beckett W, Triche E, Bracken MB, Holford T, Ren P, McSharry JE, Gold DR, Platts-Mills TAE, Leaderer BP. Symptoms of wheeze and persistent cough in the first year of life: associations with indoor allergens, air contaminants, and maternal history of asthma. Am J Epidemiol 2003;158:195-202.
85. Chapman RS, Hadden WC, Perlin SA. Influences of asthma and household environment on lung function in children and adolescents. The Third National Health and Nutrition Examination Survey. Am J Epidemiol 2003;158:175-89.