

EU forum

Working towards healthy air in dwellings in Europe

Poor indoor air quality has been implicated in the increase in allergic and respiratory diseases seen in industrialized countries in recent decades. Although air pollution in the workplace is well studied, much less is known about the consequences of poor air quality in homes. In an attempt to halt or slow down the increase in allergic and respiratory diseases, the European Federation of Allergy and Airways Diseases Patients Associations (EFA) carried out the EU-funded project entitled 'Towards Healthy Air in Dwellings in Europe' (THADE). The aims were to: compile an overview of evidence-based data about exposure to indoor air pollution and its health effects, particularly in relation to allergies, asthma and other respiratory diseases such as chronic obstructive pulmonary disease; review cost-effective measures and technology to improve indoor air quality; review legislation and guidelines on indoor air pollution; produce maps of pollutants in dwellings; and recommend an integrated strategy that defines appropriate indoor air quality policies for implementation in Europe. This paper summarizes the information about air quality in dwellings and indoor environment-related diseases collected by expert consultants within the framework of THADE and terminates with recommendations for actions aimed at improving air quality in homes. The results of this project confirmed that air pollution in dwellings is a relevant health problem. It is a complex problem that must be addressed at European and international levels, and it involves the medical profession, scientific societies, patients' organizations, lawmakers, architects and the building industry. The complete THADE report is available at <http://www.efanet.org/activities/documents/THADEReport.pdf>.

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Allergic and respiratory diseases have become a major health problem. These conditions have increased over the last half of the 20th century, and the trend is accelerating. In fact, cases of allergic and respiratory diseases have almost doubled in the past 15 years (1–3). Allergy and respiratory diseases are the most common chronic illnesses among children and are responsible for a high level of mortality in the whole population (4). Indoor air pollution may cause or aggravate illnesses, increase mortality, and have a major economic and social impact (5–8).

The right to breathe healthy air in dwellings was recognized as a fundamental right by the World Health Organisation in 2000 consequent to scientific evidence of the health risks related to poor air quality (9). Unfortunately, this right and the adverse effects of indoor air pollution are largely ignored. The public and authorities need to be made aware that each day people are exposed to potentially harmful substances in their homes.

Although people with allergy, asthma or chronic obstructive pulmonary disease (COPD), children and the elderly are particularly susceptible to indoor air pollution and are aware of the hazards, we should all be concerned about the quality of air we breathe in our homes.

Most studies of indoor air quality have been carried out in the workplace and concern occupation-associated diseases and conditions. Few data are available about air quality in dwellings, and the effect of exposure in the home to airborne pollutants. In 2000, the European Federation of Allergy and Airways Diseases Patients Associations (EFA) published the results of an EU-funded project devoted to indoor air pollution in schools (10). More recently, the findings of the EU-funded INDEX project, which concerns indoor exposure limits in the EU, have become available (11).

It was against this background that EFA was awarded an EU grant, within the Pollution-Related Diseases

programme, to address two basic issues: what is the impact of poor air quality at home on health and what measures can be taken to improve. To this aim, a project, designated 'Towards Healthy Air in Dwellings in Europe' (THADE) was designed to collect data about air-borne pollutants in homes and to draw up recommendations that could serve as a basis for a European strategy to improve the quality of air in dwellings (12). In particular, the data and evidence-based information related to exposure and to the health effects of air pollution in dwellings particularly in relation to allergies, asthma and other respiratory diseases were collected and discussed.

This study was endorsed by the European Academy of Allergology and Clinical Immunology (EAACI), European Respiratory Society (ERS), European Federation of Building Services Engineers (REHVA), Global Initiative on Asthma (GINA), International Society on Indoor Air Quality and Climate (ISAIQ). Sixteen associations affiliated to the EFA network took part in the project.

This article summarizes the salient features of the THADE project. The complete report is available at the EFA website, <http://www.efanet.org/activities/documents/THADEReport.pdf>, and is largely cited in a recent review on the effects of indoor air pollution (13).

Methods

The consulting experts surveyed the evidence-based literature, authoritative publications and Internet sources to identify the main health determinants indoors, their effects on allergies and the respiratory system, possible control methods, legislation and guidelines, and actions aimed at preventing or attenuating the adverse effects of indoor air pollution.

Air pollution in dwellings and related health effects

Data about the health effects of particulate matter (PM), nitrogen dioxide (NO₂), carbon dioxide (CO₂), carbon monoxide (CO), volatile organic compounds (VOCs), formaldehyde, damp/mould and dust mites in European dwellings were collected from the Medline database (January 1991–September 2003), and the Proceedings of the 9th International Conference of Indoor Air Quality and Climate (14).

Legislation and guidelines

Data on legislation and guidelines on air pollution and air quality in dwellings in Europe and outside Europe were obtained from various sources. The proceedings of the most authoritative indoor air quality congresses (the *Indoor Air and Healthy Buildings* series) were consulted. The Internet was scanned for relevant documents, policies and actions aimed at providing healthy indoor air in dwellings. A questionnaire was designed to collect information from reports, research programmes and policies on indoor air quality in dwellings, and distributed to European countries through the EFA network.

Control methods and recommendations

For each health determinant, an extensive literature survey was conducted to identify methods to eliminate or reduce the harm caused by poor air quality. The recommendations to improve indoor air in dwellings in Europe are based on information collected from numerous sources, including experts of European scientific societies and representatives of patients' associations.

Indoor air quality: the extent of the problem and maps of pollutants in dwellings

People living in urban areas spend most of their time (85–90%) indoors, where concentrations of many air-borne pollutants are higher than outdoors (15). Concentrations of priority air pollutants, e.g. aromatic compounds and carbonyls, in homes, offices, shopping malls and schools are often 2–5 times those found outdoors, and can occasionally reach 100 times outdoor levels. Indoor environments changed enormously with the introduction of soft furnishings, fitted carpets and mechanical air ventilation systems. The rate at which indoor air is changed for fresh air is now lower than it was 30 years ago, with a consequent increase in humidity and in levels of indoor pollutants and air-borne allergens.

Most people are not aware of the risks resulting from poor air quality in their own home. In this context, it was thought that graphic representations could be useful in increasing both awareness and understanding of the risks of poor quality indoor air and possible solutions. Therefore, a pollution mapping programme was devised whereby the user can simulate individual indoor spaces within their home and evaluate the level of pollution in each space. This interactive tool is available on a CD that is contained in the printed version of the complete THADE report.

Sources of indoor air pollutants

Many factors affect indoor air quality. Outdoor pollutants (e.g. pollen, and traffic and industrial emissions) enter buildings through open windows, ventilation system air intakes and building leaks. These pollutants, together with pollutants that arise inside the building concentrate in tightly sealed, inadequately ventilated buildings. Ventilation systems meant to bring in clean or filtered outdoor air and to flush out 'used' indoor air do not always function properly because of poor design or poor maintenance (16).

The major sources of indoor pollutants are (17):

- Tobacco smoking indoors
- Water and moisture damage
- Microbial growth

- Unvented combustion indoors (gas heaters, cookers, etc.)
- Emissions from building materials and furnishings
- Household activities (cooking; cleaning chemicals and procedures, use of deodorizers and fragrances, sweeping and vacuuming)
- Heating, ventilation and air conditioning (HVAC), dust or dirt in the ductwork or other components, microbiological growth in drip pans, humidifiers, ductwork and coils, improper use of biocides, sealants and/or cleaning products
- Contaminated outdoor air (pollen, dust, fungal spores; industrial pollutants; general vehicle exhaust)
- Soil gas (radon, contaminants from previous uses of the site)
- Redecorating/remodelling/repair activities (paint, caulk, adhesives and other products)
- Pesticides
- Pets
- Unsanitary conditions and water damage
- Supplies (solvents, toners, ammonia)
- Individuals (body odour; cosmetic odours)
- Accidental events

Health determinants in dwellings and their effects

The major health determinants in dwellings were found to be tobacco smoke, dust mites, pet allergens, cockroaches, mould, pollen, nitrogen oxide, formaldehyde, VOCs, indoor-generated particulate matter, man-made mineral fibres, radon, CO and CO₂. For each indoor pollutant, the evidence-based information related to exposure and to the health effects of air pollution in dwellings, particularly as regards allergies, asthma and other respiratory diseases have been collected.

Four main conditions have been related to indoor air quality.

- 1 Building-related illnesses are conditions that are directly attributable to environmental agents present in the air of a building. Legionnaire's disease and CO intoxication are examples of building-related diseases that can have serious consequences.
- 2 Several allergic diseases have been associated with indoor air pollution, namely rhinitis with 'hay fever' symptoms, asthma with wheezing, tightness of the chest and shortness of breath. In addition, extrinsic allergic alveolitis with acute pneumonia-like bouts of fever, cough and lung infiltration can result from poor air quality.
- 3 Sick building syndrome refers to buildings in which most of the building occupants experience acute health and comfort effects that seem to be linked to the time they spend in the building, but in which no specific illness or cause can be identified (18).

- 4 Lastly, a small percentage of the population may be sensitive to chemicals in indoor air – a condition known as 'multiple chemical sensitivity'.

In particular, indoor pollutants can affect the respiratory system in various ways. In fact, they can cause or exacerbate acute and chronic respiratory diseases and they can also cause a decline in respiratory functions and sensitization to common aeroallergens. Exacerbation of asthma and allergic illnesses is strongly linked to exposure to allergens such as house dust mite, cat, dog, cockroach, fungi and mould, to certain chemical compounds (e.g. formaldehyde, NO₂ and oxidants) and to environmental tobacco smoke. The relevant public health burden of mould/dampness exposure at home has recently been demonstrated in a large epidemiological study (20 016 children, mean age 7 years; and 13 266 adolescents, mean age 13 years) in Italy (19). It was found that avoidance of early exposure would abate wheeze by 6%, asthma or cough/phlegm by 7%, rhinoconjunctivitis by 4% in children, asthma by 6% and wheeze by 4% in adolescents.

Indoor air pollutants act at three levels: (i) By activating the immune system to react unfavourably to a factor in the environment (initial sensitization). (ii) By triggering symptoms (exacerbation of asthma) in subjects already sensitized. (iii) By maintaining a sustained inflammatory state in the mucous of the respiratory passages which results from a heightened sensitivity to allergens and other irritants or provocative conditions, such as oxidants or corrosive air pollutants, cold air or physical exertion. The concentration of these indoor air contaminants and, therefore, exposure levels, can increase if ventilation is not sufficient.

Subjects particularly susceptible to indoor air contaminants include people with allergy or asthma; people with chronic respiratory disease; people with a suppressed immune system; and contact lens wearers. Other subjects may be vulnerable to certain pollutants. For example, people with heart disease may be more affected by exposure to lower levels of CO than healthy individuals.

Recommendations for preventive actions on indoor air quality in dwellings

There is a large body of scientific information on healthy buildings, but very little has been translated into practice. Unless policies are developed and put to work nationally and internationally, advances made in the indoor air sciences will not be exploited in real life and will have a limited impact on the community. Based on the data collected within the THADE project, a series of actions to prevent, reduce or eliminate the adverse effects of poor air quality are recommended for each of the health determinants identified.

These actions fall into five main categories: (i) improve ventilation and heating; (ii) moisture control

to microbial growth; (iii) improve cleaning methods and housing hygiene; (iv) avoid wall-to-wall carpeting; and (v) control of the sources of pollution, e.g. tobacco smoke and emissions from building and consumer products.

To implement the actions identified, the THADE consultants recommend the following measures: (i) prohibition and avoidance of smoking indoors; (ii) labelling systems to control emissions from building and consumer products; (iii) better building codes and guidelines for ventilation and moisture control; and (iv) education and information campaigns. Most of these measures are independent of cultural and climate differences. The exceptions are measures related to moisture control and ventilation, and even in these cases, European guidelines should be developed (see Recommendations for a European programme on indoor air quality in dwellings). The measures suggested will improve indoor air quality, and alleviate, but not necessarily prevent, the symptoms of allergy, asthma and COPD, as well as improving living conditions for the healthy.

Recommendations for a European programme on indoor air quality in dwellings

Guidelines, actions and programmes related to indoor air quality in dwellings are already in place in many European countries. The main implementation strategies are legislation, codes and norms, research projects and general public information. However, these actions are usually targeted to a specific topic or issue rather than aiming for an overall national strategy.

The measures, including new directives and European standards, that could be taken at EU level are: initiatives to prohibit smoking in public buildings and the workplace; campaigns against smoking at homes; better building codes for the new constructions especially as regards ventilation and moisture control; measures to improve the indoor environment in the existing building stock; development of testing and labelling procedures for air cleaners; restrict pet exhibitions in public places (schools, etc.); development of product control and labelling systems for building materials, furniture and household products as regards harmful emissions; development of performance criteria for vacuum cleaners; development of testing methods for fibre release from mineral wools; development of inspection methods and control of small heating appliances; and promote research on indoor air quality in dwellings as regards health effects and prevention.

Guidelines for a healthier indoor environment should be developed at European and national levels in collaboration with professional societies. These guidelines should include but not be limited to:

- Ventilation guidelines for residential and nonresidential buildings to control pollutants generated indoors.
- How to control moisture in buildings so as to avoid problems related to mould and dust mites.
- Guidelines and procedures to measure emissions from building materials and consumer products including criteria for low polluting materials and products, and labelling systems.
- Criteria for buildings to ensure a healthy indoor environment, including the limit values of known pollutants.
- Guidelines for the public on how to check and control the indoor environment of their home to ensure it is 'healthy'.
- Guidelines for the operation and maintenance of buildings as regards health.
- Guidelines for heating and cooking to avoid indoor pollution and moisture problems.

Future research

It clearly emerged from this investigation that there is a shortage of evidence-based information about health indoor determinants and measures to prevent/counteract adverse health determinants. More research is required to determine the effects and costs of preventive and remedial measures related to indoor air quality. Technical information about the building stock should be taken into consideration when developing guidelines for remedial action. This information should include data on heating and ventilation systems, cooking appliances, ventilation rates and moisture conditions. In addition, we need to know more about the prevalence of health determinants and the number of people sensitive to each specific determinant.

Concluding remarks

There is clearly an urgent need for a strategy to improve the quality of air in dwellings in Europe, and despite the gaps in our knowledge in this field, a strategy can be developed with the data now available. To be effective, the actions proposed to control the health determinants identified must be co-ordinated and implemented at international level (WHO, International Council for Research and Innovation in Building and Construction, International Standardization Organization, etc.), European Union level (European Parliament for new directives, and the European Committee for Standardization), national level (lawmakers as regards national building codes and standards, etc.), professional society level (doctors, investigators, and engineers, architects, building owners and facility managers), and at the level of patients'

organizations. The recent launch of the Global Alliance Against chronic Respiratory Diseases (GARD) (20), a joint venture of WHO and international and national scientific societies (allergological and respiratory) might constitute an opportunity to advocate for better air quality in homes.

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References

1. WHO World health report 222 [WWW document]. Geneva: World Health Organization, 2002. URL <http://www.who.int/whr/2002>. (Accessed 9 September 2004).
2. Janson C, Anto J, Burney P, Chinn S, de Marco R, Heinrich J et al. The European Community Respiratory Health Survey: what are the main results so far? *Eur Respir J* 2001;**18**:598–611.
3. World health report [WWW document]. Geneva: World Health Organization, 2000. URL <http://www.who.int/whr/2000/en/statistics.htm>. (Accessed 12 September 2004).
4. Strachan D, Sibbald B, Weiland S, Ait-Khaled N, Anabwani G, Anderson HR et al. Worldwide variations in prevalence of symptoms of allergic rhinoconjunctivitis in children; the International Study of Asthma and Allergies in Childhood (ISAAC). *Pediatr Allergy Immunol* 1997;**8**:161–174.
5. Bousquet J. Global initiative for asthma (GINA) and its objectives. *Clin Exp Allergy* 2000;**30**(Suppl. 1):2–5.
6. National Institute of Health, National Heart Lung and Blood Institute (NHLBI). Global strategy for the diagnosis, management, and prevention of chronic obstructive pulmonary disease. Based on April 1998 NHLBI/WHO Workshop, Bethesda, MD, USA; April 2001 (updated 2003).
7. European Respiratory Society. European Lung White Book. The first comprehensive survey on respiratory health in Europe. Huddersfield, UK: European Respiratory Society, 2003:1–182.
8. Franchi M, Carrer P. Indoor air quality in schools: the EFA project. *Monaldi Arch Chest Dis* 2002;**57**:120–122.
9. World Health Organisation. The right to healthy indoor air [WWW document]. Report of a WHO meeting, Copenhagen, Denmark; 2000. URL http://www.euro.who.int/air/activities/20030528_9. (Accessed 12 September 2004).
10. European Federation of Allergy and Airways Diseases Patients Associations (EFA). Indoor air pollution in schools, 2002.
11. Kotzias D, Koistinen K, Kephelopoulou S, Schlitt C, Carrer P, Maroni M et al. The INDEX project. Critical appraisal of the setting and implementation of indoor exposure limits in the EU. *EUR Report No. 21590 EN*; 2005. <http://www.jrc.cec.eu.int/pce/>.
12. Franchi M, Carrer P, Kotzias D, Rameckers EMAL, Seppänen O, van Bronswijk JEMH et al. Towards healthy air in dwellings in Europe. The THADE Report. <http://www.efanet.org/activities/documents/THADEReport.pdf> (Accessed 4 January 2006).
13. Viegi G, Simoni M, Scognamiglio A, Baldacci S, Pistelli F, Carrozzi L et al. Indoor air pollution and airway disease. *Int J Tuberc Lung Dis* 2004;**8**:1401–1415.
14. Levin H, editor. Proceedings of the 9th International Conference of Indoor Air Quality and Climate. Monterey, CA, June 30–July 5, 2002.
15. Carrer P, Maroni M, Alcini D, Cavallo D, Fustinoni S, Lovato L et al. Assessment through environmental and biological measurements of total daily exposure to volatile organic compounds of office workers in Milan, Italy. *Indoor Air* 2000;**10**:258–268.
16. Seppänen O, Fisk J. Summary of human responses to ventilation. *Indoor Air* 2004; **14**(Suppl. 7):102–118.
17. Etkin DS, Vogt C. Indoor air quality in schools. Arlington, MA: Cutter Information Corporation, 1996.
18. Maroni M, Seifert B, Lindvall T, editors. Indoor air quality. A comprehensive reference book. Amsterdam: Elsevier, 1995.
19. Simoni M, Lombardi E, Berti G, Rusconi F, La Grutta S, Piffer S et al. Mould/dampness exposure at home is associated with respiratory disorders in Italian children and adolescents: the SIDRIA-2 Study. *Occup Environ Med* 2005;**62**:616–622.
20. Prevention and control of chronic respiratory diseases at country level: towards a global alliance against chronic respiratory diseases. Geneva: June 17–19, 2004. WHO/NMH/CRA/05.1, 2005.