The Danish Centre for Indoor Air and Health in Dwellings – CISBO

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SUMMARY
The CISBO centre is a cross-disciplinary research consortium with a goal to improve quality of life throughout the built environment, with a special focus on private housing. The aim of the centre is to develop a scientific basis for decision making, improving the knowledge base and implementation of knowledge into the building with the overall objectives to promote "healthy" buildings
This is, in other words, to develop knowledge about buildings and health and to bring this new knowledge as well as established knowledge in use for the benefit of the occupants of the housing stock. To reach the goals we will work in studies describing the exposure occurring in homes in Denmark, we will perform intervention studies on particles and allergens, we will use the existing Danish cohorts, to study effects of indoor air on health, and finally we will perform a series of experiments from indoor chemistry to human exposures. All these studies will be coordinated by the centre, in order to get the most synergy from the research projects initiated under the umbrella of the CISBO centre.

KEYWORDS
Private Housing, Multidisciplinary Research Centre, Transition of knowledge, IAQ & Health.

BACKGROUND AND THE SCOPE OF CISBO

National and international field studies have documented that indoor air quality is not optimal in many buildings (Bluyssen et al. 1996, Skov et al. 1987, Sundell 1994). Since we spend almost 90% of our time indoor, the overall hypothesis of the project is that improving the indoor environment in the dwellings can improve health and reduce development and suffering from major public diseases such as allergies and asthma (Mitchell, 2007) that have shown a marked increase in incidence in Denmark during recent decades (Linneberg 2007) as well as chronic obstructive pulmonary and cardiovascular diseases.

CISBO has a goal to improve quality of life throughout the built environment. In this field there is a substantial potential for improvement, but there is a lack of knowledge on a number of issues necessary for prioritization of efforts and development of operational solutions. Some improvements can be achieved by implementation of current knowledge in design, construction, maintenance and use of buildings. Other potential interventions still need a scientific input in order to be evidence based, and others even need to be found through research.

To develop a basis for decision making and improving the knowledge base as well as implementation of knowledge into the building process REALDANIA has decided to provide funds for a research centre with the overall objectives:

- To advance our knowledge base about the relationship between buildings and health on strategically important areas.
- To facilitate the transition of knowledge about buildings and health into building design and operation.
- To contribute to knowledge about buildings and health is applied in practice in the decisions of building design and properties.

The important target groups are the decision-makers on operational and constructional issues. Examples of such actors are: Building developers, building owners (construction operation), construction businesses and their employees (e.g. architects, engineers, builders) and users of buildings (e.g. tenants, owners). Through this initiative these target groups will get access to scientifically based knowledge in their daily practices.

FOCUS OF CISBO

The existing knowledge is based on the current understanding of the indoor environment, including chemical and microbiological indoor contaminants, indoor physical conditions related to thermal environment, lighting and acoustical issues, as well as modifying factors e.g. air exchange rates in the case of air pollutants. In the following we are highlighting the areas where we find there is the greatest need for more research, in order to facilitate the improvement of public health in homes. We focus on indoor air, although we, for example, are not considering the carcinogen effects of radon, because we find that the existing knowledge is sufficient to recommend sound engineering measures to mitigate the exposure for these parameters.

A number of choices which are made during the design, construction, maintenance and operation of buildings have implications for users' health, wellbeing and performance. These choices affect a number of factors in indoor air including ventilation, humidity, particle concentration and the concentration of chemical compounds in indoor air. Therefore, there are various explanations for the poor indoor air quality including low air exchange rates due to the sealing of housing stock in the attempt to save energy and introduction of numerous new pollution sources indoors in the form of building products, furniture, electronic equipment etc. There is no comprehensive, research-knowledge base that makes it possible to predict how these constructions and maintenance decisions affect the indoor environment. Hence, there is a need for new knowledge.

In addition to asthma and allergies indoor environment also can have impacts on chronic obstructive and cardiovascular diseases (Jousilathi et al., 2002; Barnoya & Glantz, 2005; Brauner, 2008) and cancer (Darby, 2005). These prevalent diseases share a range of common features in their pathogenesis in the form of the inflammatory response and oxidative stress, caused by free oxygen species. The knowledge on relationship between indoor environment and residents' health problems is limited. This is largely attributed to the existence of complex causal chains in which a large number of risk factors may act alone or in combination in small unit families of 2-6 people.

While the impact of indoor environment on public health is substantial, the scientific literature is probably only revealing a limited part of the total problem. Internationally, indoor environment research has had a surprisingly low political attention, taking into account the enormous impact of the indoor environment on the total exposure of the population. Research

has so far focused on conditions in offices, schools and institutions despite the fact that we spend 16 hours in our own home every day (Keiding et al. 2003).

A residence building differs from office buildings in many ways. In homes, people of all ages including children and the elderly are living. The indoor environment of a residence is determined by a complex mixture of construction techniques and materials, and residents' behaviour in the dwelling. The indoor conditions are related to air exchange rate, heating, area of windows and the like. Choice of material, including type of coating is essential, partly for the emission of indoor air pollutants from the materials and partly for their cleaning-friendliness. Residents' behaviour can have a marked influence on the indoor environment. Behaviour includes e.g. frequency of forced ventilation through opening of windows, the frequency of cleaning, lighting candles, use of exhaust hood when cooking, indoor drying of laundry, keeping of pets, etc., see Figure 1.

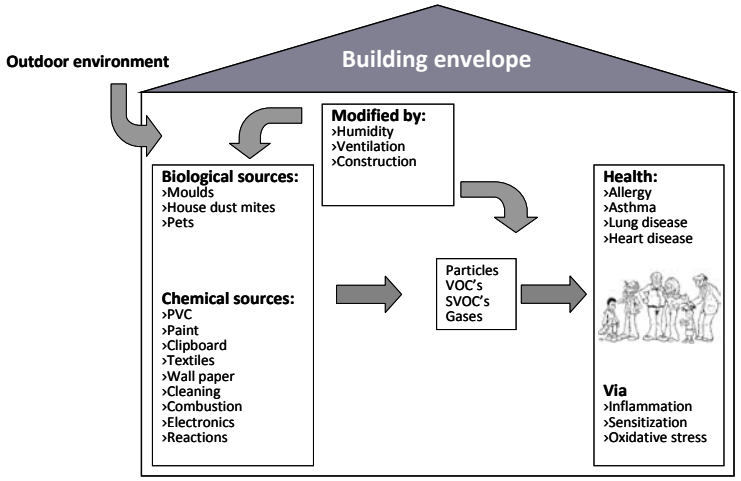

Figure 1. Associations between construction techniques, indoor climate and health.

OBJECTIVE

The goal of the interdisciplinary research centre CISBO is to provide knowledge on the indoor environment and its impact on humans. There is a need for knowledge building and dissemination in order to ensure optimal housing for all people so that we - as shown in Fig. 2 - can go from RISK-factors to FRISK-factors (i.e. in Danish “Frisk” relates to factors beneficial to health).

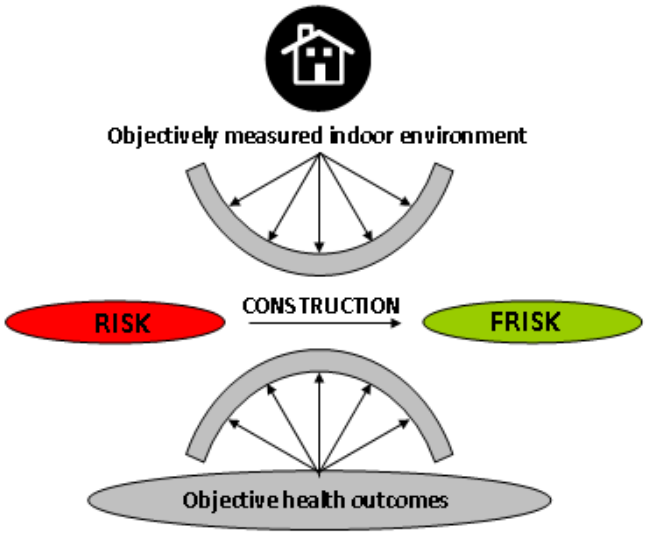

Figure 2. From ’RISK’ to ’FRISK’ in the indoor environment

The necessary knowledge building involves systematic reviews of the indoor environment, including the range of exposure in the Danish housing, population studies on the relationship between exposure and health, intervention studies of health effects of engineering interventions, and controlled laboratory experiments in which more specific correlations between specific exposure and health effects are examined.

This will be studied in the general population and in vulnerable groups, which should be considered when constructing new or renovated homes in the current housing stock. Children, persons suffering from allergy or asthma, people with chronic pulmonary disease and cardiovascular disease are examples of such vulnerable groups, which will constitute an increasing proportion of the population in the coming years.

The research in CISBO is aimed at providing recommendations on construction and operation of dwellings to benefit the entire population. Actions that benefit the most vulnerable groups will also have a positive influence on the general population.

The overall hypothesis of the project is that improving the indoor environment can improve the health of the residents, who have different susceptibility.

This overall hypothesis entails a number of hypotheses to be tested in the research centre:

- There are gradients in exposure to chemical, physical and biological parameters in Danish housing, which can explain important health outcomes of the inhabitants.
- Factors related to indoor exposures can explain a significant proportion of chronic health outcomes (asthma, allergy, chronic obstructive pulmonary disease and cardiovascular diseases) in population studies.
- By changing the indoor climate in homes it will be possible to obtain measurable improvements in health among people with asthma, chronic pulmonary disease and cardiovascular disease.
- In controlled studies in climate chambers, it will be possible to establish dose response association between exposure to contaminants in indoor air and health effects in the general population and among susceptible persons with e.g. asthma, allergies, chronic pulmonary disease and cardiovascular disease.

The program is divided into four focus areas, which are mutually dependent and supporting the overall aim of the project.

I. ***Exposure in Danish dwellings:*** There is a need for considerably more detailed description of the main building-related risk factors in the indoor environment. In addition, it is also important to know the residents' behaviour in the period in order to explain the possible variation in the measured risk factors that are not caused by the building, and to describe how the building modifies the effect of residents' behaviour on the indoor environment. For the sake of consistency with later health outcomes, it

is also important to have information on residents' behaviour on a daily basis. It is natural to embed the detailed mapping of the building-related risk factors for indoor air quality in population studies at two levels: A questionnaire-based mapping with e.g. simple measurements used for all; and a more thorough mapping of selected residences representing structural variation to be used for the validation of the simple measurements. This allows information to be disseminated to all participants in population studies if the data set is representative of Danish dwellings in general.

II. ***Population Studies:*** Denmark has one of the world's best platforms for population studies due to comprehensive registers on e.g. census, address, hospitalisation, socioeconomic status, education, dwelling characteristics and mortality linked together by a unique personal identification-numbers and covering the entire population (Frank, 2000). A number of cohorts suitable for studies of the association between building characteristics and health have already been established. These cohorts represent all age groups, geographical areas and possible relevant health outcomes within allergy, lung and heart ailments. Geographical information systems and exposure models further allow adjustment for outdoor air pollution with high temporal resolution from 1990 at any given address (Hertel, 2007; Hertel, 2008).

III. ***Intervention Studies*:** In intervention studies, the actual exposures in the target group are examined by the effect, determined as improvements in the state of health after alteration of certain factors by e.g. filtration of particles or dehumidification. Demonstration of improved health at decreased exposures provides strong evidence for causal relationships, which can be difficult to achieve even in the best cohort studies. Moreover, this approach is also well suited for test of technical solutions that can be immediately implemented in housing.

IV. ***Controlled exposures*:** Evidence of direct causal relationships is achieved by detecting the dose response relation of a specific health effect under controlled exposure in randomized controlled double-blind cross over trials. Human exposure studies are resource demanding but suitable for documentation the effects of single components or the interactions between them. These studies are complemented by laboratory exposure experiments in bioassays to supplement our understanding of the underlying mechanisms. Further laboratory experiments will study a number of transformation and transport mechanisms of selected chemicals and microorganisms.

CONCLUSION

By the creation of a multidisciplinary scientific consortium with the focus on indoor air, it is the intention of the CISBO to advance science as well as the transition of knowledge about indoor air and health into building design and operation.

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REFERENCES

Barnoya J, Glantz SA. Cardiovascular effects of secondhand smoke: nearly as large as smoking. Circulation. 2005 May 24;111(20):2684-98.

Bluyssen, P. H., Fernandes, E. de Oliveira , Groes, L., Clausen, G., Fanger, P.O., Valbjørn O., Bernhard C.A., Roulet C.A., 1996: European audit study in 56 office buildings. Indoor Air, Vol 6, No. 4, 221-238.

Brauner EV, Moller P, Forchhammer L, Barregard L, Gunnarsen L, Afshari A, Wahlin P, Glasius M, Dragsted LO, Basu S, Raaschou-Nielsen O, Loft S. 2008. Indoor Particles Affect Vascular Function in the Aged: An Air Filtration-based Intervention Study. American Journal of Respiratory and Critical Care Medicine 177, page 419-425.

Darby S, D Hill , A Auvinen , J M Barros-Dios , H Baysson , F Bochicchio , H Deo , R Falk , F Forastiere , M Hakama , I Heid , L Kreienbrock , M Kreuzer , F Lagarde , I Mäkeläinen , C Muirhead , W Oberaigner , G Pershagen , A Ruano-Ravina , E Ruosteenoja , A Schaffrath Rosario , M Tirmarche , L Tomácek , E Whitley , H-E Wichmann , R Doll (2005) Radon in homes and risk of lung cancer: collaborative analysis of individual data from 13 European case-control studies. BMJ; 330: 223

Frank L. Epidemiology. When an entire country is a cohort. Science 2000 Mar 31; 287(5462):2398-9.

Hertel O, Ellermann T, Palmgren F, Berkowicz R, Lofstrom P, Frohn LM, et al. Integrated air-quality monitoring - combined use of measurements and models in monitoring programmes. Environmental Chemistry 2007; 4(2):65-74.

Hertel O, Hvidberg M, Ketzel M, Storm L, Stausgaard L. A proper choice of route significantly reduces air pollution exposure - A study on bicycle and bus trips in urban streets. Sci Total Environ 2008 Jan 15; 389(1):58-70.

Jousilahti P, Helakorpi S. (2002) Prevalence of exposure to environmental tobacco smoke at work and at home--15-year trends in Finland. Scand J Work Environ Health. 2002;28 Suppl 2:16-20

Keiding, L., Gunnarsen, L., Rosdahl N., Machon M., Møller, R., Valbjørn, O. (2003) Miljøfaktorer i danskernes hverdag - med særligt fokus på boligmiljø. Statens Institut for Folkesundhed i samarbejde med Statens Byggeforskningsinstitut.

Linneberg A, Gislum M, Johansen N, Husemoen LL, Jørgensen T. 2007. Temporal trends of aeroallergen sensitization over twenty-five years. Clin Exp Allergy. 37:1137-42

Mitchell CS, Zhang J, Sigsgaard T, Jantunen M, Lioy PJ, Samson R, and Karol MH. 2007. Current State of the Science: Health Effects and Indoor Environmental Quality. Environmental Health Perspectives. 115 (6) 958-964.

Skov P., Valbjørn O., DISG, 1987: The "sick" building syndrome in the office environment: The Danish town hall study. Envir. Int., Vol. 13, 339-34

Sundell J., 1994: On the association between building ventilation characteristics, some indoor environmental exposures, some allergic manifestations and subjective symptom reports. Indoor Air, Supplement No2/94.