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'Sick buildings' -a new environmental problem

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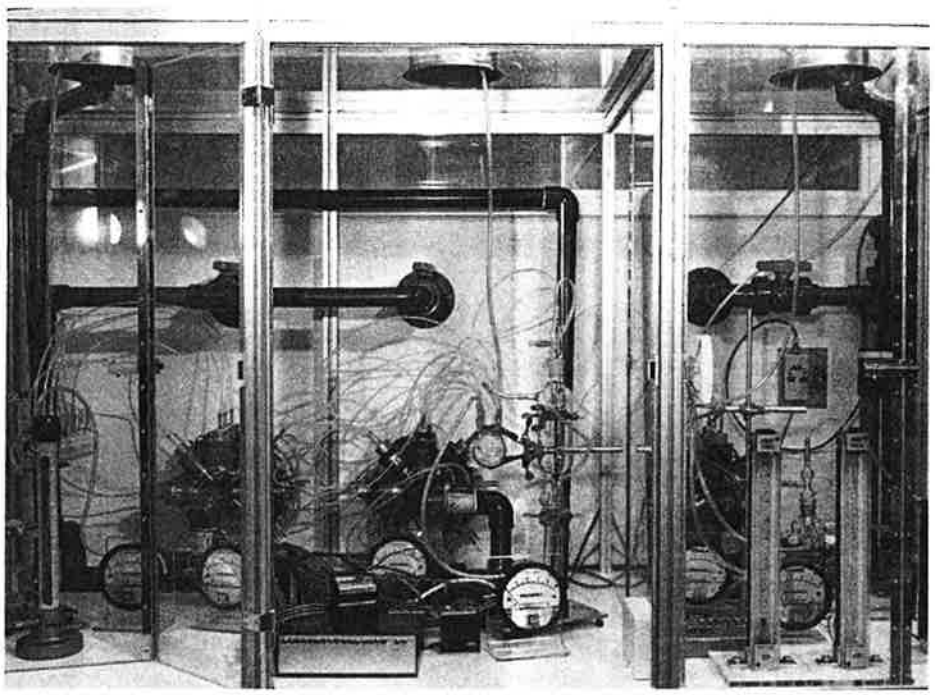
Excessive or incorrectly applied energy conservation in buildings can give rise to irritation of the mucous membranes and other discomfort. A considerable amount of research is being carried out into these problems. One group of workers, with financial funding from the Swedish Council for Building Research, is engaged on research into the quality of indoor air, and is led by Birgitta Berglund, of the University of Stockholm, Ulf Berglund of the Royal Institute of Technology and Thomas Lindvall, of the Karolinska Institute. This article describes their work.

An air quality field experiment in progress. The mobile environmental laboratory has been connected to a sick building. Photo: Ingegerd Johansson.

In many cases, energy conservation in buildings has been taken to excessive lengths or incorrectly implemented, resulting in problems of comfort hygiene in non-industrial environments such as child day-care centres, schools, offices and residential buildings. In recent years, a new concept has arisen, that of »sick buildings». Not only Sweden, but many other countries, have watched the growth of this new environmental problem with unease, as has also the World Health Organisation.

The term »sick buildings» is often applied to modern buildings in which the occupants experience discomfort of the mucous membranes in the same way as would result from exposure to formaldehyde, in spite of the fact that the actual formaldehyde levels lie below the threshold of sensitivity. The occupants of these buildings tend to complain about poor indoor air quality and over vague physiological symptoms which are often stated as being associated with the indoor climate. These problems seem to have started with the introduction of the 1975 Swedish Building Regulations.

On the other hand, however, an increasing number of chemicals and products have been introduced into the building sector at the same time. To this must be added, too, a deterioration in outdoor air quality in urban areas.



The picture shows a set of gas dosing equipment, known as an olfactometer, used for preparing exposures of known concentrations of a substance in air. Photo: Ingegerd Johansson.

Diffuse sensory symptoms

Reported diffuse symptoms have related to:

- ☐ eye, nose and throat irritation
- ☐ a feeling of dryness in the skin and membranes
- ☐ redenning of the skin
- ☐ mental tiredness, and
- ☐ faint but persistent odour.

Complaints have been received, for example, from around 100 of the 600 or so nursery schools that have been built in Stockholm since the middle of the 1970s. Over 20% of those built between 1977 and 1980 are regarded as problem buildings. The proportion of the occupants exhibiting symptoms in these buildings can vary from individual cases up to 50%.

Earlier research work has generally not succeeded in identifying any specific chemical or physical/biological factor as the cause of these problems. Symptoms encountered in sick buildings have also been investigated from the angle of possible psychological reasons. Many of the symptoms are similar to those encountered in connection with allergies. However, it is probable that the symptoms are not the result of immunilogical oversensitivity, but probably as the result of hyper-reactivity.

From this starting point, research concentrated on attempting to identify the mechanisms responsible for the symptoms reported by the occupants of sick buildings. The advantages and disadvantages of various air handling principles and methods of building with respect to air quality were considered. The results are felt, for example, to provide a basis for ventilation standards based on biological aspects of air quality and suited to modern energy conservation principles.

A trials subject carrying out odour tests on air. Photo: Ingegerd Johansson.

Field experiments

Research was carried out through both laboratory and field trials, using equipment intended specifically for investigation of air quality. This includes a mobile environment chamber, gas dosing equipment, an air analysis laboratory and computer systems.

The mobile environmental chamber consists of three units, each contained in a standard 20-ft. container. One of these containers forms an environmental chamber in which subjects are exposed to indoor air, e.g. from a building under investigation, or to pure air, provided by the unit ventilation system. The third container is an exposure unit, containing two different dynamic systems for the dilution of gases and mixtures of gases. This system has allowed formaldehyde concentrations, for example, around the maximum permissible level proposed for indoor exposure to be added to the air from the problem building in order to investigate the part played by formaldehyde in the development of certain symptoms.

The gas dosing equipment is used for the production of known concentrations of a substance in gaseous form, either for exposure of experimental subjects or for calibration of instruments. By linking a number of gas dosing systems together, it is also possible to mix known quantities of different gases in order to study their compound effects. Before subjects are exposed to low levels of various substances, their mucous membranes need to be conditioned to constant climatic conditions. This requires 15–30 minutes' acclimatization in an air-conditioned waiting room before each experiment.

Air samples, enriched on a porous polymer, are analysed in the air analysis laboratory. The concentration of volatile gaseous organic substances in the air is determined using a gas chromatograph and a mass spectrometer with associated computer systems. The substances separated in the gas chromatograph are detected in a flame ion detector. Data from the gas chromatograph and from the mass spectra (40–200 amu, boiling point 40–250°C) is stored in a data base together with sensory profile analyses from trials subjects who have sniffed the eluent after separation in the gas chromatograph. Sensory assessments are carried out using a specially developed master scale, from which calibrated subjective experience scales can be obtained.

The air sample data base has been assembled in a PRIME 350 computer, and software for pattern analysis of both chemical and sensory measured values has been developed. This system, which is used for such applications as testing various mathematical models and methods of recognising certain patterns (finger-

prints), is used here to distinguish between air in sick buildings and that in healthy buildings.

Ventilation and air quality

The safety margins for air quality which previously existed have now fallen to such a level that careful consideration is needed. In both office buildings and child day-care centres the quantities and concentrations of the majority of air pollutants tend to increase progressively as the air passes through the building in its passage from inlet to outlet. Altering the degree of recirculation alters the concentration of indoor air pollutants, but not necessarily by the same amount for different substances. It has been found, for instance, that greater quantities of carbon monoxide and organic substances are transferred to the return air than would be expected on the basis of data from flow measurements of carbon dioxide concentrations.

Only a few modern investigations intended to show the exact quantities of fresh air required by humans have been carried out, as such work requires field experiments performed on »living» buildings. Although such results are limited, experiments lead us to recommend fresh air flows of at least 5—6 l/s, person in areas where smoking is not permitted, determined primarily by the need to maintain the indoor odour level at a reasonably low value. Buildings ventilated by energy-saving mechanical systems have poorer »fresh» air qualities than the outdoor air, which means that higher outdoor air flows are needed than are normally encountered. Somewhat simplified, it can be said that the poorer the quality of the building and its interior fittings, the greater must be the flow of outdoor air in order to ensure a comfortable air standard indoors.

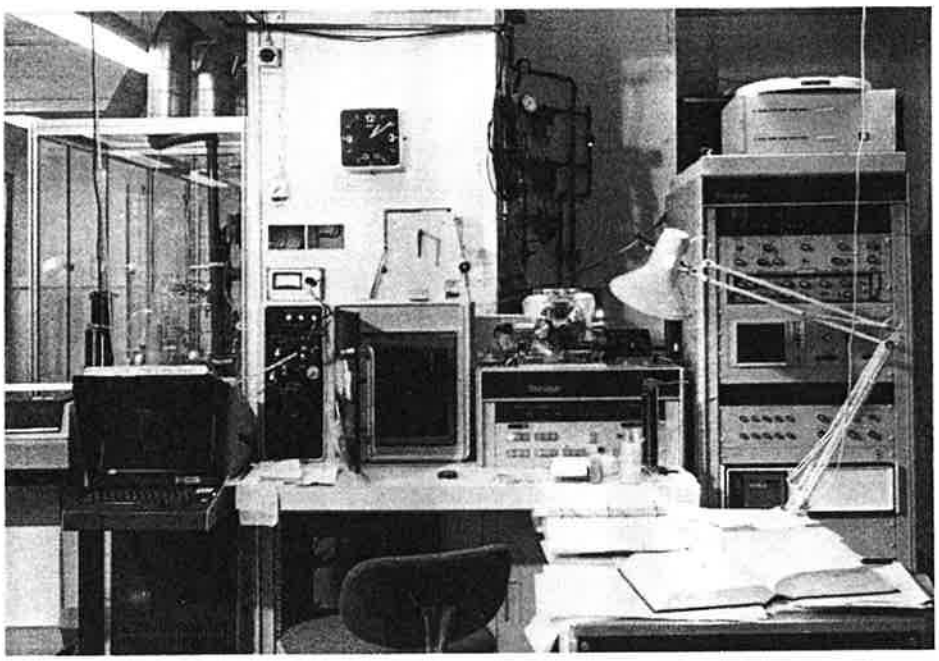
Pattern analysis of the field samples data base

Indoor air contains a complicated mixture of sensory stimuli, which means that we cannot expect to find any simple cause and effect relationship between sensory experience and stimulation patterns in sick buildings. Pattern analyses of indoor air samples tends to indicate that the inter-relationship between a large number of chemical substances and several different sensory perceptions is of considerable importance for the quality of the air as subjectively experienced. About 80% of the volatile organic substances in indoor air can be detected by the human sense of smell. Our chemical response senses presumably carry out a pattern analysis when exposed to mixtures of air pollutants. In this way, we recognise a scent or odour, and can relate the experience to a sick or healthy building, a process which is capable of triggering symptoms.

When considering the various possible explanations of symptoms reported by the occupants of sick buildings, we feel that mass hysteria is unlikely. Psychogenic factors, including non-specific stress reactions, can naturally play a modifying rôle in the symptoms, but the main causes are likely to be found in physical reasons.

It is very apparent that sensory perceptions dominate among the symptoms. It has also been shown that indoor air in modern buildings contains complicated pollutant patterns, in which many components are capable of irritating the senses. We cannot expect to find simple relationships between these pollutants and the reported symptoms.

The symptoms experienced by occupants of sick buildings could be caused by the additive effects of a large number of subthreshold sensory stimuli, in which no single substance lies above the stimulation threshold, or by a stimulus enhancement through the joint action of gases and particles, e.g. through simultaneous chemical and thermal stimulation.



The gas chromatograph/mass spectrometer/computer system used in the air analysis laboratory for chemical and sensory analysis of indoor air. Photo: Håkan Åström.

Current research

The work of the project group over the next three years is being supported by the Swedish Council for Building Research, and is expected to follow the following paths:

(1) Investigation of various sensory effects (odour, irritation of the mucous membranes, skin irritation) as possible air quality criteria for ventilation.

(2) Development and assembly of a data bank for pattern analysis of air samples from sick and healthy buildings and from buildings with different types of ventilation systems.

(3) Investigation of various exposure conditions to indoor air for persons exposed to a number of different environments, of which one is a sick building (individual subject dose).

(4) Investigation of outdoor air requirements in relation to the sensory criterion (occupant loading, pollutants from materials and activities).

(5) Hygienic assessments of buildings and building service systems (analysis of problem cases).

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Literature

Berglund, B, Berglund, U & Engen, T. *Do »sick buildings» affect performance? How should one assess them?* Rep. Dep. Psych., Univer. Stockholm, 1983, No. 609.

Berglund, B, Berglund, U & Lindvall, T. *Characterization of indoor air quality and »sick buildings».* ASHRAE Trans., 1984, 90, part 1.

Berglund, B, Berglund, U, Lindvall, T & Nicander-Bredberg, H. *Olfactory and chemical characterization of indoor air — Towards a psychophysical model for air quality.* Env. Int., 1983, 8, 327—332.

Berglund, B, Johansson, I & Lindvall, T. *A longitudinal study of air contaminants in a newly built preschool.* Env. Inte., 1982, 8, 111—115.

Berglund, B, Johansson, I & Lindvall, T. *The influence of ventilation on indoor/outdoor air contaminants in an office building.* Env. Int., 1982, 8, 395—399.

Berglund, B & Lindvall, T. *Olfactory evaluation of indoor air quality. In P.O. Fanger & O. Valbjörn (Eds.), Indoor Climate.* Copenhagen: Danish Build. Res. Inst., 1979, 141—157.

Berglund, B & Lindvall, T. *Sensory reactions to »sick buildings». In B. Berglund & C. Leve-Leboyer (Eds.), Application of Environmental Psychology: Recent Research on Environmental Hazards and Unfavorable Environments.* London: Sage Publ., 1983 (in press).