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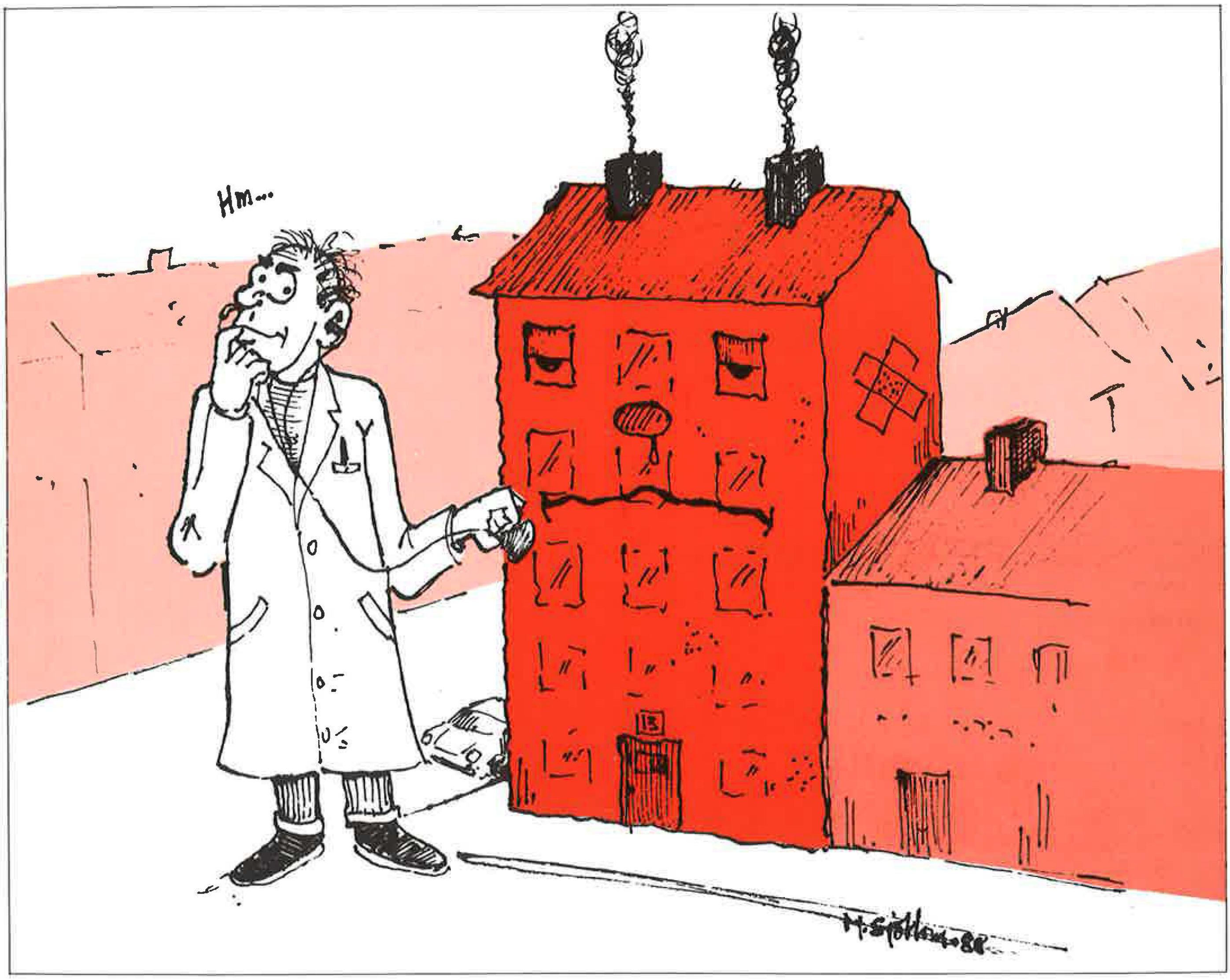
How do we get healthy buildings?



Swedish Council for Building Research

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Translation reprints of articles from
the magazine BYGGFORSKNING (BUILDING RESEARCH)
No 3:1988.

Cover: Sketch by Mikael Sjöblom.

G18:1988
Swedish Council for Building Research,
Stockholm, Sweden

Concerted R&D commitment to the indoor environment

By Nina Dawidowicz and Bertil Pettersson, the Swedish Council for Building Research

The importance of the climate to general health and wellbeing has long been understood. The ultimate goal for planning, building, renovation and administration of the housing stock is to satisfy people's needs. When this goal is not attained, the results will be human sacrifices, social problems and losses to the national economy. This, of course, also applies to the issues of climate and the environment. Research and development work on these questions is nothing new for the Swedish Council for Building Research (BFR). In recent years, considerable emphasis in the activities of the Council has been placed on health protection in buildings. The commitments within this sector are one part of a concerted R&D commitment to the indoor environment which, in our view, should be a cardinal subject for the R&D community at large in the coming years.

During the last decade, interest in the questions relating to building hygiene has grown after having long laid dormant. The fundamental reasons for this growing interest are first the number of health problems which have arisen and secondly the evolution of the so-called sick building syndrome. The rapid pace of development in the fields of construction and interior decorating materials, as well as incorrectly executed energy conservation measures, are often seen as the causes of the problems which have arisen. The public debate and the media have highlighted such concepts as radon, formaldehyde, fungus and rot, asbestos, air ions, dry air, day-nursery illness, office illness, self-copying paper, work at VDU terminals etc. The major emphasis in research in this area has been placed on investigations, plotting of the problem building, and on specific problems linked to individual factors such as radon, formaldehyde emission from building materials, damp and mould damage or self-levelling screeds.

The above problems are not specifically Swedish. According to the estimations of the World Health Organization WHO, almost 30 per cent of all newly built or renovated buildings are unhealthy. There is no overall picture available for the Swedish building stock in this respect. However, various studies have given a clear picture of the nature of the problems. The health aspects which have come into prominence relate to such matters as hypersensitivity.

The "groups at risk" (people suffering from allergies or other medical hypersensitivity) who make up a considerable proportion of the population of Sweden and may

"We who are engaged in planning had no idea of much of the knowledge you are talking about here", exclaimed a planner invited to a research seminar on measurement methods in sick buildings. It was generally agreed that many questions remain for science to answer, but there is already a corpus of knowledge about sick houses. Knowledge which is based on scientifically conducted experiments, not only within the sector of construction engineering, but also in chemistry, medicine and psychology.

However, the planner hit the nail right on the head. "As long as the knowledge possessed by research workers remains in the background or is not tapped by the people who order, plan, project, build, use and administer buildings, we are going to continue to have sick buildings."

In this issue of Building Research, we would like to provide a review of the knowledge available in this sector today and how researchers and practitioners aim to make progress in finding methods for healthy buildings. So much seems clear: simply ventilating these problems is not a happy solution. The dissemination of smells, fibres and other impurities from building materials, as well as their sensitivity to moisture, must be highlighted. Attention should also be focused on the pollutants which ventilation systems themselves are responsible for. Maintenance and cleaning are sectors which require studying. Radon emissions from the ground into buildings can be avoided by employing the right constructional technology. There is a wealth of knowledge on how to avoid or combat fungus and rot.

There are sick buildings throughout the entire industrialized world. In September, the Swedish Council for Building Research will be hosting a "Healthy buildings" conference within the framwork of the activities of the International Building Research Organization CIB. At the conference, further knowledge will be presented and demands for continued research and development will be formulated.

be estimated at between 1.5 and 2.0 million individuals must, naturally, be taken into account in designing the indoor climate.

Different requirements in different buildings

Those factors which primarily influence human climate perception indoors are shown in Fig. 1.

If complaints and critical viewpoints on the indoor climate are followed up, it can be ascertained that there are different climatic factors which dominate the "complaint profile" in respect of different types of activities. On the basis of complaint frequencies and assessments of how seriously shortcomings in a certain climatic factor affect the activity in question, it is possible to formulate a kind of "problem potential" which gives a picture of the relative importance of different climatic factors. Fig. 2 shows examples of this.

The large potential for temperature problems in the second and fourth columns are, of course, related to the fact that the room temperature in these premises often tends to be excessively high. Sensitivity to disturbing noise is fundamentally high in dwellings. However, there is seldom any appreciable risk of really disturbing noise from installations in dwellings which are not provided with fan-controlled supply air.

Draughts in buildings normally derive from untight windows etc. Draught in other premises may more readily be related to the function of the supply air equipment.

Sweden well to the forefront

The awareness of climatic and environmental factors as a growing problem area has increased in recent years. Sweden is well to the forefront in certain of these areas at study. This relates, for example, to air quality research where WHO (partly on the basis of Swedish research results) has now

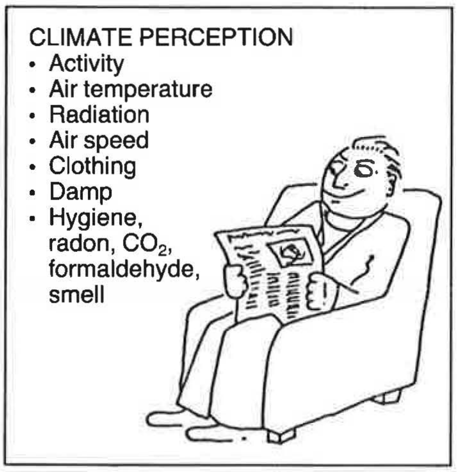


Fig. 1. Different parameters which influence human climate perception.

accepted the human nose as a criterion for judging air quality indoors. The research carried out by the Swedish Institute for Building Research (SIB) into people's temperature requirements and the insulation capacity of clothing is also of a high international standard. Today, we possess dependable knowledge about radon and how radon-affected buildings can be treated. The growth of fungus in buildings – and particularly in such sites as bathrooms, showers etc. – constitutes a serious hygienic and economic problem. Research aimed at evolving methods for exposure (mycological and chemical diagnosis criteria) and registration of health effects has commenced. The purpose is to establish a documentary basis for assessing the effects which different measures for treating and renovating fungus-damaged buildings will have.

Energy conservation measures have resulted in tighter buildings and reduced ventilation flows. Mites, which need an RH of more than 40 per cent, thrive in certain buildings where the ventilation is insufficient. Studies have shown that these tiny creatures are often the culprit in cases of asthma and dust allergy.

Over the last decade, a new and rapidly expanding problem has been visited on us, the so-called sick buildings. The investigations which have hitherto been carried out have not been able to pinpoint any individual factor as the cause of this phenomenon, but rather a series of factors which affect and together bring about this problem.

How are healthy buildings to be constructed?

Research and discussion into how to build and administer with a view to creating "sound" or "healthy" buildings are still in their infancy. But sporadic attempts have so far been carried out to test ideas in this field on full scale. Nor has sufficient time elapsed to allow for an evaluation of such experiments to a requisite degree. It is easy to arrive at the conclusion that we quite simply do not know how to build a healthy building other than in blindingly obvious terms. In particular, it may appear difficult to reach a consensus of opinion on those technical approaches which give healthy or unhealthy buildings. The vast majority of technical solutions may, in the right context, correctly executed and correctly employed, give a fully satisfactory end result. But some of these solutions are more sensitive to the commonest faults which may be committed in conjunction with planning, construction, running and use. When such "risk solutions" are employed, the inspections carried out at different stages of the project must be more exhaustive. If these inspections cannot in all probability be expected to be adequate, such "risk solutions" should be avoided. Experience from the large number of problem buildings which have been examined in recent years shows that these problems have often been brought about simply because "proven experience" had been disregarded.

One example of a BFR project in which different solutions are studied is a "user-healthy" day nursery in Skarpaby which has been planned and constructed in such a manner as to minimize the risk of climatic problems. Evaluation of this project is planned to last for a four-year period starting in April 1987. In this project, the hygienic and thermal climate will be thoroughly evaluated.

Continued R&D vital

Despite the relatively large backing from both the Swedish Council for Building Research and other research financers, improved knowledge is required to determine the limits for indoor temperature, air movement, air humidity and air pollutants. Of particular importance is continued research into simultaneous exposure to different physical environmental factors. But research into individual environmental factors such as formaldehyde, tobacco smoke, smells and noise is also necessary. Specific research efforts are also necessary to shed some light on how climatic and environmental knowledge is handled in the planning and projecting process.

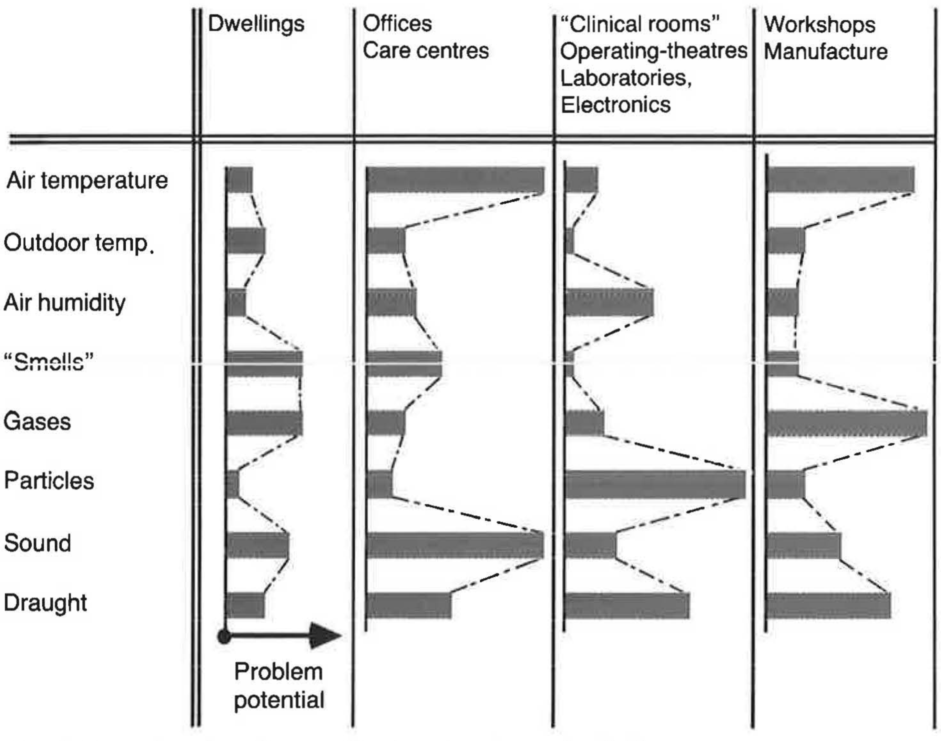


Fig. 2. Examples of problem profiles for a few types of activities.

Children's games are often noisy; sound-damping wall panels and suspended ceilings give a better environment. Here, the reverberation time in a playroom is measured using a starting pistol. Photo: Johnny Andersson.

The goals of the R&D activities of the Swedish Council for Building Research in the field of the indoor climate are to:

☐ achieve an interdisciplinary long-term build-up of knowledge in which medicine, chemistry, behavioural science, architecture, onstruction and installation engineering etc. make their own contributions.

☐ clarify how exposure to individual environmental factors and combinations of environmental factors influence people's health and well-being.

☐ develop methods to eradicate harmful environmental factors and their effects on people and buildings.

☐ create, in cooperation with the other participants in the construction process and building administration and with researchers, a data bank for purposeful energy utilization in Sweden's buildings.

Healthy buildings – opportunities and obstacles in energy conservation measures

The Government and the Parliament have established that measures to limit energy consumption and dependence on finite energy sources in buildings may not normally lead to a deterioration in the living situation of the users. Consequently, it is a vital necessity to attempt to map out the social, medical and behavioural-dependent consequences of energy conservation measures and the introduction of new energy technology. Extensive knowledge is required of the nature and level of the users' demands in order that conservation measures do not become hedged in by unnecessarily strict safety margins or misfire because of a lack of knowledge about the users' value judgements and behaviour.

The Swedish Council for Building Research strongly feels that the requirement for healthy buildings need not conflict with the requirement for efficient energy savings. However, a fundamental condition is that the requirements for qualified planning, careful building and competent running and maintenance always be met. "Risk solutions", as well as insufficiently tested materials, should be given special attention. Of course, it is crucial that greater prominence be given to health aspects than hitherto in the continued energy conservation debate.

International conference on healthy buildings in Sweden

This autumn, 5–8 September, Sweden will be hosting a world-wide CIB conference on "Healthy Buildings". At the conference – arranged by the Swedish Council for Building Research in cooperation with the National Institute of Environmental Medicine (SML), a large number of medical and technical experts from all over the world will gather to discuss how healthy buildings are to be constructed.

By way of preparation for the CIB conference, a Nordic seminar on "The Healthy Building" was held in March 1987. At the seminar, attended by both research workers and practitioners, some of the questions dealt with were:

☐ What demands may be placed on the indoor environment?
☐ What technical solutions may be recommended to obtain "healthy buildings"?
☐ What technical solutions increase the risk of obtaining "unhealthy buildings"?

Documentation from the seminar in the form of written contributions, conclusions and recommendations arrived at by the delegates is available in the BFR publication *The Healthy Building, G20:1987, in Swedish. A summary report is available in English and in French.*

Literature:

Johansson C and Pettersson Bertil. *Takvärme – energiförbrukning och inomhusklimat* (Roof heating – energy consumption and the indoor climate), the Swedish Council for Building Research, R12:1984

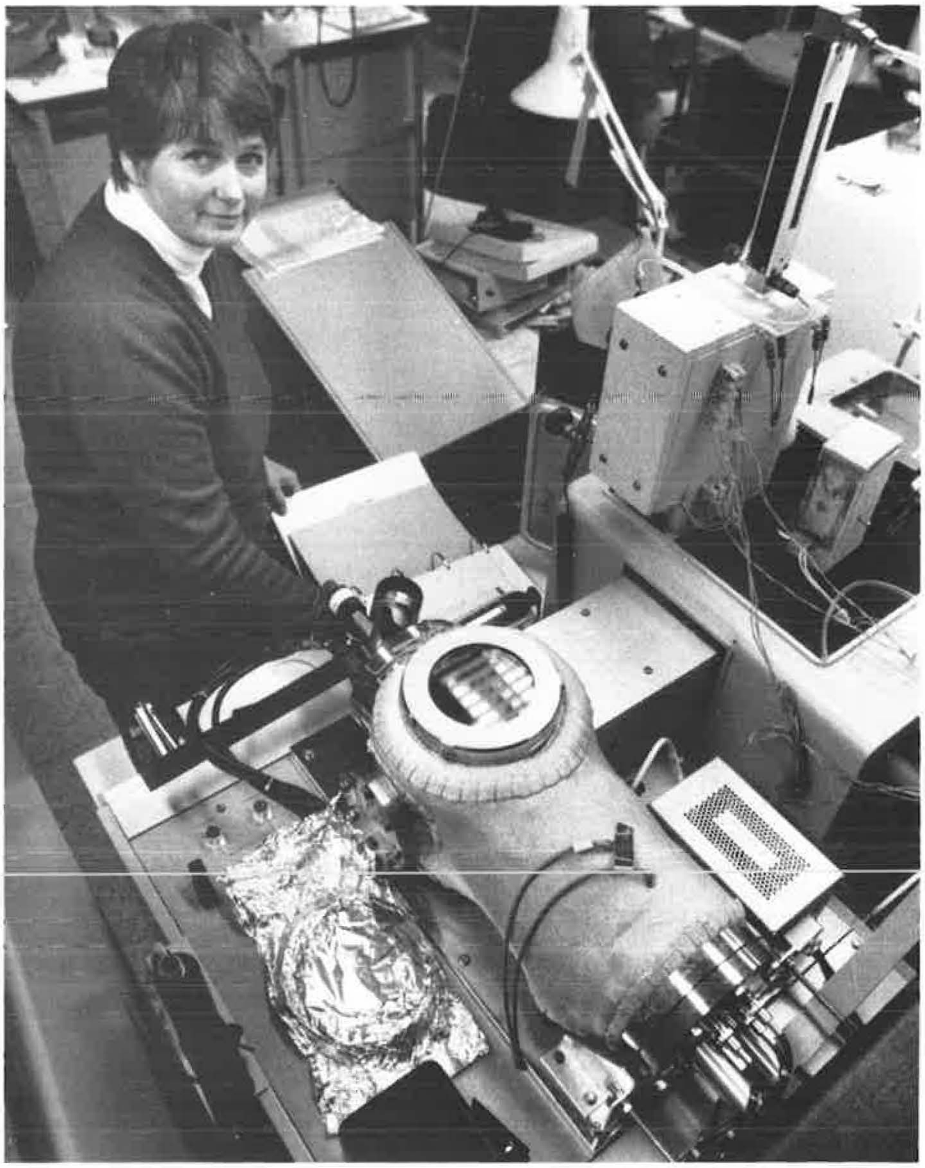
Hult M. *Miljövänlig barnstuga* (User-healthy day nursery), the Swedish Council for Building Research, R94:1986

Dawidowicz N, T Lindvall, J Sundell. *Det sunda huset* (The healthy building), the Swedish Council for Building Research, G20:1987. A summary report of this publication is available in English, The Healthy Building, and in French, Les Constructions Saines, both published by the Swedish Council for Building Research in the Document series.

Energi i byggd miljö – 90-talets möjligheter (Energy in the built environment – the possibilities of the nineties), the Swedish Council for Building Research, G16:1987. Also published in English by the Swedish Council for Building Research, G16:1988.

Time for functional demands on healthy buildings

The time would now seem to be ripe to move on from discussing and diagnosing incorrect functions in buildings towards systematizing and developing functional demands for healthy buildings. To create an acceptable indoor climate in both thermal and air-quality terms, hygienic demands must be placed on building materials, building technology, ventilation function etc. A self-evident evaluation for acceptable building quality should be followed by a new hygienism in which a hollistic view is taken of the results. Since 1975, the Swedish Council for Building Research has backed a research program into air quality and ventilation which is being conducted within an informal group led by the authors and linked by an inter-disciplinary composition to three institutes of a vast education system, Stockholm University, the Caroline Institute and Stockholm Institute of Technology, as well as to the National Institute of Environmental Medicine.



Professor Birgitta Berglund in the air analysis laboratory in front of the GC/MS/DS system for analysis of air samples relating to volatile organic substances (GC = gas chromatograph; MS = mass spectrometer; DS = data system). Photo: Svensk pressfoto, Ingvar Svensson.

A number of odorous and irritating air pollutants are characterized by the fact that they can be sensed in concentrations which are lower than those at which toxic effects can be demonstrated (for example formaldehyde, styrene, toluene). Indoors, these pollutants are emitted from a large number of different materials and processes. Indoor smell is a common cause of complaint in buildings. While it is unclear what importance to health such smell discomfort may have, considerable emphasis has, in practice, been placed on such discomfort in climate inspections, for example by smell criteria for ventilation requirements. It may also be pointed out that the sense of smell can be used as a model organ for how people are influenced by chemical pollutants in the environment. In short, smell is a warning signal for chemical overload.

Methods for measuring smell

A speciality among the research team is to develop methods the better to be able to measure smell in complex gas mixtures. Smell measurement is one method, by so-called biological dosimetry, of obtaining measurement values of the air as a whole instead of measurement values of individual substances in air. Together with the World Health Organization, discussions have also been held as to the possibility of employing subjective assessment scales as a measurement basis for limits to be applied in the indoor environment.

The need of quality assurance in so-called sensoric air analyses is now often put forward at conferences and in specialist articles in various magazines. At present, the group is engaged in attempting to concretize the theoretical measurement requirements on practical measurement procedures for air quality control.

Passive smoking can give acute irritation and discomfort effects. For example, it is calculated that between 25 and 40 per cent of the employees in office buildings are disturbed by tobacco smoke and approximately 25 per cent suffer from eye irritation. An important question is whether the disturbing effects of passive smoking are to be related to any particularly sensitive groups. In experiments, we have demonstrated that smokers may suffer from a reduced sense of smell for substances which are included in tobacco smoke, while passive smokers show a slightly modified sensitivity. The effects are slight but are most manifest at the low concentrations which occur indoors. In other experiments, we have shown that nitrogen dioxide in concentrations formed in the home from gas cookers and poor ventilation may increase the sensitivity in the respitory system of asthma-sufferers. Consequently, attention should be paid to reduction of both the sense of smell and pulmonary function in setting limits for odorous and irritating substances which occur indoors.

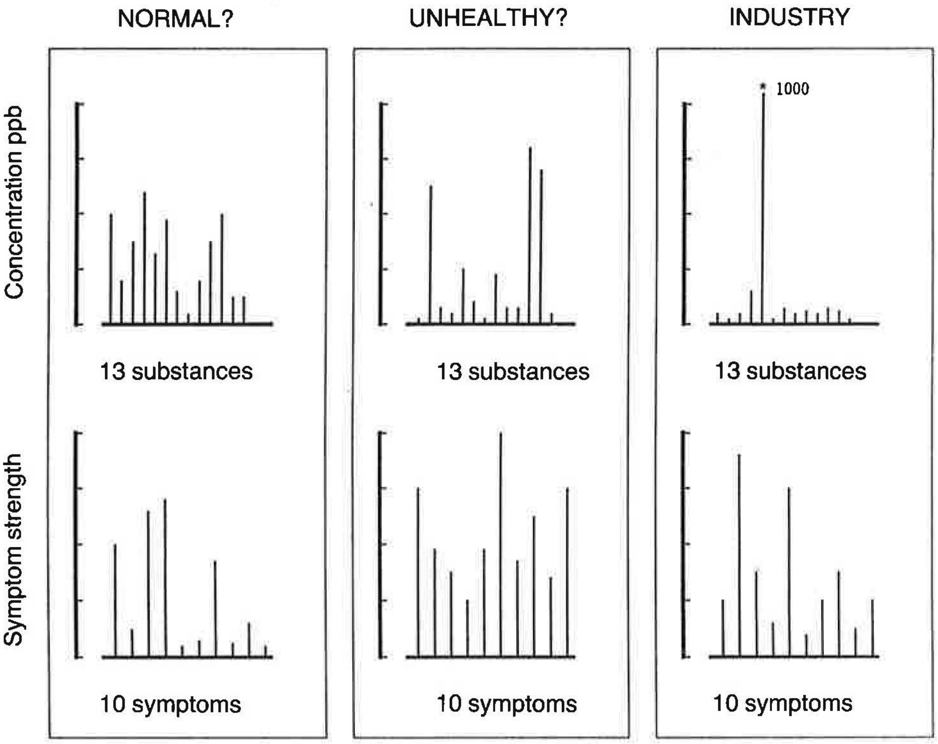
Formaldehyde is another powerful sensory irritant. It is a common air pollutant indoors and is emitted from a large number of building materials and consumer products. The sensory effects include irritation of the membranes in the eyes, nose and throat, as well as smell. We have demonstrated that the smell thresholds for formaldehyde vary by a factor of more than 100 and that most people react to very low concentrations, 10–100 ppb. Only at concentrations above 300 ppb can it be certain that a given change in the concentration results in a clear change in the irritation experience. The results of the group have been used not least by the World Health Organization which recently set up guidelines for the presence of formaldehyde in indoor air.

Not uncomfortable air for 80 per cent

Research has shown that many complex sensory processes are involved in the human perception of air quality. On occasions, some people fail totally to sense quite high contents of irritant substances, while others already show manifest sense reactions at concentrations close to the sensible threshold. Normally, indoor air is perceived as a whole and the users cannot normally distinguish between different components in the air quality. At the same time, research has shown that the indoor air contains a complex pattern of sensory stimuli. The interplay between smell components indoors is a damping process. The practical consequence is that the force in experiencing smells and irritant substances cannot be expected to reduce simply by removing a few of the components in the complex indoor air.

In offices, discomfort has a critical effect. The current philosophy of the American Society of Heating, Refrigerating and Air-Conditioning Engineers expresses this in that the air in an office must always be not discomforting for at least 80 per cent of the users. In offices with densely situated conditioning screens, the function of the mechanical ventilation system must be carefully monitored. Reuse of exhaust air from rooms where other than sporadic smoking is permitted, from storage premises, from copying rooms etc. should not be allowed. We know that sensory warning signals carry a major emotional rate for many people. This may result in exaggerated reactions even against buildings which suffer from minor or insignificant climatic problems. Increased sensory irritation, discomfort and the fear of serious and permanent effects on health may easily be compounded to form a health problem, with the result that preventive measures will be extremely cost-effective.

Data from a number of problem buildings gives reason to suspect an interplay between chemical and physical sense stimulations. For example, a number of the irritation effects are linked to the employment of radiation heat. Research has developed models which describe the interaction processes. In particular the low concentrations of irritant substances have proved to be of importance for such interaction.



Multifactorial psychophysical relationships between a chemical pattern (the upper diagrams) and a symptom pattern (the lower diagrams) illustrated for a normal building, an unhealthy building and an industrial building. The fictive patterns contain different numbers of substances and symptoms.

A recurring question is whether the quality of indoor air can affect human performance. This has been illuminated in a comparative study of two day nurseries, one classified as unhealthy and the other as not. No difference in psychological performance tests (including reaction time, problem resolution, memory) could be shown. It is obvious that if such effects occur at all, they cannot be discovered by conventional psychological testing methods for performance measurement. It would still appear that the critical and measurable effects of air quality are reported experiences.

The importance of also taking into account subtle sensory experiences in the indoor environment is illustrated in one of our field experiments which studied the effects of interaction between formaldehyde and the indoor air in an unhealthy building which was, however, free of formaldehyde. The results show that when formaldehyde is mixed with the indoor air from the unhealthy building, a relative increase of the strength of the smell occurs at low concentrations, while the strength of the smell remains largely unchanged at higher concentrations.

Building materials and ventilation

Building materials give off volatile organic substances into the indoor air. A key question is whether these materials also absorb corresponding pollutants so that a state of equilibrium occurs in the indoor air. In a degasing experiment in a chamber of material samples from floor, walls and ceiling in a seven-year old building, roughly 60 pollutants were identified. The concentrations of the greater part of these pollutants decreased progressively over 40 days to zero, but with different degradation times. After one month, roughly 15 substances remained in constant concentration without any further degradation being notable. The results show that building materials "infect" one another in a building which has been in use for some time. It is, therefore, probable that a relatively long time will be necessary – perhaps a month – after the implementation of countermeasures to eradicate a source of pollution before a real improvement in the air quality can be observed.

The design of the ventilation system, for example return air supply, influences the concentration of indoor air pollutants in different manners for different substances. Consequently, it is of major importance that air quality analyses of buildings suffering from a long case history of uneradicated climatic problems be subject to a qualified analysis which shows the air quality variations with time, and with varying external climatic conditions. During a measurement period of a length of 16 weeks, the concentrations of approximately 90 measured pollutants in the exhaust air varied widely by a factor of between 10 and 30 times. Toluene appeared to be the sole component which had the same variation pattern with time as the smell strength. Consequently, toluene might be a conceivable index substance for the experienced air quality in buildings. A negative relationship was also demonstrated between the relative humidity (RH) and the concentration of a small group of typical indoor air pollutants. This is an interesting result which is subject to further examination.

Pattern analysis of good and bad indoor air

The group has built up a data bank for air samples consisting of chemical subtances and concentrations for individual air samples taken in different buildings and outdoors in immediate association with the building. Material from a score of buildings has been stored so far. For 8 of these, a large number of samples have been stored in the database, approximately 80 samples per building. In addition, for 10 or so of the objects the database includes smell reports for individual substances in the samples at the low concentrations at which they occur in the air. The database is being gradually expanded as new field studies are carried out on both unhealthy and healthy buildings.

Because of the multiplicity of pollutants in the indoor air in low concentrations, together with the absence of any clear causal relationship between individual substances and the experienced equality of the indoor air, it is necessary to utilize methods for measuring the total effect of several substances in interaction. Development work is in progress by technicians for analyzing both chemical and sensory patterns. The aim is to attempt to find the critical pattern in the chemical pollutant picture which may explain the sensory reactions (symptom pattern) in the so-called unhealthy buildings. This research has so far identified different patterns in the chemical composition of the air in one healthy and one unhealthy building. Roughly 30 volatile organic substances define the air quality and distinguish the unhealthy from the healthy building.

Indoor air contains a complex pattern of sense stimuli. As a result, we cannot expect, in unhealthy buildings, a clear cause and effect relationship between sense experiences and stimulus patterns. Nevertheless, research into pattern analysis and the relationship between different environmental factors has shown that these are of considerable importance to the quality of the air, not only as regards the unhealthy buildings, but also – in a positive direction – as regards an acceptable and comfortable air quality.

Birgitta Berglund, Ulf Berglund and Thomas Lindvall

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A pointer towards the healthy buildings of the future

Building location and local climate

☐ Select a site which has favourable basic conditions (look out for soggy ground, risk of radon and of land subsidence).
☐ Place the external air intake of the building so that the quality of the air is not affected by such factors as roads, parking lots, industries etc.
☐ Orient the building in relation to sunshine, wind, the external environment and the need for contact with the immediate surroundings.

Constructional physics and constructional engineering

☐ Take steps to keep the building dry.
☐ Water must be led off wherever it may occur: foundations, bathrooms, window openings, outer walls.
☐ Ventilate those parts of the structure that are exposed to damp.
☐ Avoid risk solutions: horizontal roofs, slabs on ground with overlying insulation, joisted floor on slabs on ground, floating floor on slab on ground.

Climate engineering

☐ Ventilation must have a certain excess capacity to allow for "human" errors.

Make *sure* that:

☐ pollutants are taken care of at source (encapsulation, spot extraction etc.)
☐ the technology is simple and flexible to allow for changes of use of premises, to be individually controllable and to be comprehensible to the user
☐ windows are openable
☐ it is simple to inspect (fixed measurement points), finely adjust, clean and replace components
☐ the systems are decentralized and symmetrically constructed and with a high air exchange and ventilation efficiency
☐ the systems are silent and without low frequency noise
☐ balanced ventilation systems with heat recovery do not recycle pollutants.

Avoid *risky* solutions such as

☐ recirculated air systems
☐ natural ventilation systems (insufficient capacity, no channelling to individual rooms, draughts)
☐ exhaust air systems
☐ air humidification
☐ hot-air systems (spreading pollutants)
☐ rotary heat exchangers (recycling pollutants)
☐ heat exchangers which cannot be turned off in the summer
☐ unsensitive or hypersensitive control and regulation components
☐ poorly maintained or adjusted and uncleanable installations
☐ ventilation ducts in flooring structures.

System make-up and design aspects

☐ Satisfy quantified and controllable climate function requirements.
☐ Make the systems easy to clean, maintain and run.
☐ Make the systems simple, controllable, comprehensible, permanent, flexible and "forgiving".
☐ Never let the systems conceal problems (addition of substances to make "clean" air).
☐ Make sure the end user is able individually to regulate the climate and external air flow.

Building materials

☐ Use known and low-emitting materials.
☐ Ask for a statement on pollutant emission.
☐ Make sure materials are stable, permanent and durable for the prevailing conditions.
☐ Make sure materials do not contain heavy metals, asbestos or biocides.
☐ Avoid large-surface materials such as wall-to-wall carpeting in public premises (high "fluff factor").
☐ Avoid materials which may be suspected of containing toxic substances in adverse concentrations.
☐ Avoid plastic wallpaper and painted glass-fibre fabric in wet rooms.
☐ Avoid flooring materials which entail a personal static charge of more than 1,000 V at 22°C and 25%RH.
☐ Avoid agents which protect against biological degradation – design the building so that these agents are unnecessary.

Maintenance and administration, building process

☐ Take into account maintenance and administration aspects in the building process.
☐ Plan for careful execution, including time for drying out, fine adjustment, functional inspection and trouble shooting (quality assurance).
☐ Provide for functional and responsible cooperation throughout the entire building process from planning to occupancy and follow-up.
☐ Do not restrict the building to dependence upon sensitive technology with all of the fault risks involved.
☐ Include maintenance routines in the project planning.
☐ Contract for a long guarantee time as protection against concealed faults.
☐ Compete on a qualitative rather than a monetary basis in the building process.
☐ Ensure a high standard of cleaning without "harmful" cleaning agents.
☐ Give priority to climate and hygiene aspects over energy aspects. A key lesson for operational and maintenance personnel.
☐ Carry out regular functional inspections.

Literature:

The healthy Building Report from a Nordic Seminar, March 1987. Published by the Swedish Council for Building Research. Also available in French: Les Constructions Saines.

We get what we plan for

Today's building industry is overheated. Architects' offices, national and local government, and everybody else involved in planning the built-up environment can offer plentiful confirmation of this statement. Apologies are muttered for the time pressure involved in producing drawings and documents. This is a situation which repeats itself. What will the consequences be for the planning process and the very appearance of the environment? How can planning preparedness be improved?

When we buy an article in the shops, we weigh the pros and cons of function, quality, cost, service life etc. The production apparatus has been adapted to such consideration principles. Material qualities, composition and assembly principles, strengths - and, in many cases, the working life of the product are all determined when the product itself is created. The result is a good, fair or bad product. The design and manufacturing process primarily determines the success or failure of the product.

Do we apply the same consideration principles when we plan and build our houses? Is the quality and service life of the building primarily determined by the programming and projecting process?

Compared with normal consumer articles, a building is a product which possesses quite different dignities. Together with other elements, it constitutes a vital part of our dwelling, free-time and working environment. It either opens the way or gets in the way of all of our activities. It influences our perception of our surroundings and our physical and mental health. It has a working life which far exceeds normal depreciation principles and constitutes a historical and social/cultural monument for the future. Unlike mass-produced goods, every building is unique, just like the process of its creation.

How is the built-up environment evaluated?

What value do we place on the creation and production process of our buildings? Do we really devote the necessary care to programming, project planning and building? In far too many cases, the answer can only be no. Motivation, knowledge and experience there are. Sectorization, short-term economic thinking and unrealistic time schedules there are also.

One of the consequences in an overheating of the planning and building sector is an almost superhuman pressure applied to the planning sector, a pressure which is often accepted without open criticism. The buyer has eyes only for the product and not for the quality in the manner of creating it. There are examples of good and bad planning processes, just as there are examples of "healthy" and "unhealthy" buildings! Despite building research results which clearly demonstrate the relationship between process and product, which emphasize the importance of careful program study and project documentation, and despite the fact that we who are directly engaged in the process are aware of the seriousness and scope of the problem, we sometimes fail to take into account results and to take heed of advice.

The relationship between process and product

Prompted by personal experience of planning and construction project work which clearly demonstrate that the planning intentions were not always in tune with the requirements raised by activity and climate, I took an interest in the relationship between "process and result". Consequently, my research studies have touched upon the planning process and the working environments which are thereby created. The general questions which I have attempted to answer were:

- ☐ The discrepancy between planning intentions and results.
- ☐ The relationship and intercommunication between purchaser, consultant, building contractor and user and their effect upon the process.
- ☐ The influence on the process of different purchasing methods – for services and processes.
- ☐ The continuity in the planning process and feedback of results.
- ☐ Negative experiences of the indoor climate of various buildings – air, heating, light and sound.

Experience from a number of studies

I view one building which we studied as a classic example of the effects of the process on the product. The building suffered from activity and functional shortcomings, serious acoustic, heating, ventilation and lighting problems which were the cause of operational difficulties and problems on the personnel level.

All of these functional and climatic problems could be traced back to: a) faulty or

PLANNING	ASSUMPTION	USE
Program work:	**Under preparation:**	**Operation:**
Localization Activity information Rererence group participation Projecting Time schedules Economics	Development of competence Transfer of intentions Contact between purchaser, reference group and architect	Planning function Climate and installations Interior decoration and equipment Flexibility Operational responsibility and organization
Norms:	**Inspections:**	**Activities:**
Application Purchase Contractual form Services, work and materials	Final inspection Guarantee inspection Norms – controls	Organization Rule systems Management patterns Decision-making process Problem resolution
Rôle situation:	**Rôle situation:**	**Rôle situation:**
Purchaser Staff Consultants Planners (purchasers) Builders	Purchaser Staff Consultants Planners (purchasers) Builders	Purchaser Staff Operating personnel Planners (purchasers)
Final evaluation:	Final evaluation:	Final evaluation:
Feedback:	Feedback:	Feedback

A model of "active mutual relationship" between different parties, phases and decisions. Note that the consultants, and especially the architect, are seldom active in the take-over and use phases.

unsupported decision-making documentary basis in the various stages of the planning process, b) lack of communication between parties, not least between the purchaser and the user on assumption of tenancy, as well as between those responsible for planning and operation, c) lack of understanding of different parties' competence and experience, d) replacement of materials, air conditioning systems and technical solutions during the construction phase without sufficient-making basis, e) the lack of adaptability in the design of the building and difficulties for the purchaser and the user to analyze, isolate and process these problems.

The complexity of such problems depends upon an active "mutual relationship" between different parties, phases and decisions as intimated in the figure. Among the general conclusions which could be drawn from the study were:

☐ The importance of a blanket program and project planning basis.
☐ The necessity that the planning process should not end on completion of the building but must include the operational and administrational phases.
☐ The understanding that channels must be open and knowledge available for problem analysis and resolution on the local level.
☐ The realization that information feedback to all those involved in planning and design errors was conspicuous by its absence.
☐ The need for increased quality inspection during the construction phase and at the final and guarantee inspection.

The need for better analysis methods

To conclude: the quality of buildings depends upon care in the planning processes, which is intimately related to experience feedback. Anyone engrossed in complex functional and climatic problems in buildings may find it difficult despite a wealth of knowledge about the activities and operations involved – to gain sufficient perspective and distance from the situation to be able to carry out an effective analysis and identify basic problems and their solutions.

Building contractors and users need help in such situations. In one project financed by the Swedish Council for Building Research which is now in progress, we are studying methods which, expressed in simple terms, are applicable in carrying out a qualified "building analysis". Why problems arise when they should have been dealt with during programming, project planning and administration, and how are these necessary modifications to be introduced into the process? The search for methods of impartial quality evaluation has been greatly advanced by the National Board of Public Building and the ER committee – which was swallowed up in the new organization formed by the fusion of BSAB and Svensk Byggtjänst (Swedish Building Service). Today's discussions concerning quality assurance in building emphasize the need of such methods.

Such analysis methods may not only improve the handling of general and climatological knowledge in the building process, but may also help to evolve a more structured feedback of information and provide a greater level of preparedness in overheated planning situations.

Ronald Colven

Ronald Colven, architect, member of the National Association of Swedish Architects. Research worker/lecturer at the Royal Institute of Technology, Architecture, Stockholm.

Literature:
1. Colven, R, Bengtsson. Planering och projektering av anpassbara byggnader (Planning and projecting of adaptable buildings). The Swedish Council for Building Research R10:1982. Distributed by: Svensk Byggtjänst.
2. Colven, R, William-Olsson I. Kontinuitet i planering (Continuity in planning), 1986. Distributed by: the Royal Institute of Technology, Formlära, Stockholm.
3. Colven, R. Akustik i förskolor (Acoustics in preschools), 1986. Distributed by: the Royal Institute of Technology, Formlära, Stockholm.
4. Colven, R, Skantze, A. Skolpersonalens arbetsmiljö (The working environment of school staff), the Royal Institute of Technology, Architecture, the Department of Education at Stockholm University, 1983. Distributed by: the Royal Institute of Technology, Formlära, Stockholm.

CIB conference in Stockholm, 5–8 September:

Healthy Buildings '88

The Swedish Council for Building Research and the National Institute of Environmental Medicine will be hosting an international conference, within the framework of CIB, on healthy buildings. The conference is also supported by the World Health Organization (WHO).

The theme of the conference will be technical solutions and functional requirements which make for healthy buildings in which to live and work. The program includes lectures, joint symposia with invited speakers, group discussions, poster presentations and exhibitions of scientific, educational and technical material. The major areas to be dealt with in lectures and seminars are:

☐ Localization and planning of buildings
☐ Constructional physics
☐ Requirements for satisfactory technical solutions for the indoor climate
☐ System and design solutions
☐ Selection and inspection of materials
☐ Trouble-shooting in air treatment systems
☐ Maintenance and inspection of buildings and installations
☐ Rules and policy for product control, quality standards etc.

The main purpose of the conference is to adopt recommendations on the selection of systems and products and on how materials and systems should be combined. These recommendations are intended as guidelines for architects, consultants, property owners and material manufacturers.

Considerable international interest has been shown in the conference and it is expected that some 500 delegates from all over the world will be taking part. The Chairman of the Organising Committee of the conference is Bertil Pettersson from the Council for building Research, and Chairman of the Scientific Committee is Thomas Lindvall from the National Institute of Environmental Medicine. The extensive planning required for a conference of this nature is coordinated in a conference secreteriat under the direction of Göran Hellsten.

CIB Conference
in Stockholm, Sweden
September 5–8, 1988

HEALTHY
BUILDINGS '88

For further details contact:
The Swedish Council for Building Research, Sankt Göransgatan 66, S-112 33 Stockholm, tel. int. +46 8 54 05 40. Göran Hellsten (coordinator), Gabrielle Waldén (information) and Anita Svahn (assistant).

The conference secretariat: Stockholm Convention Bureau (SCB), Box 6911, S-102 39 Stockholm, tel. int. +46 8 230 990. Contact person: Inger Ahl

Hidden olfs the cause of unhealthy buildings

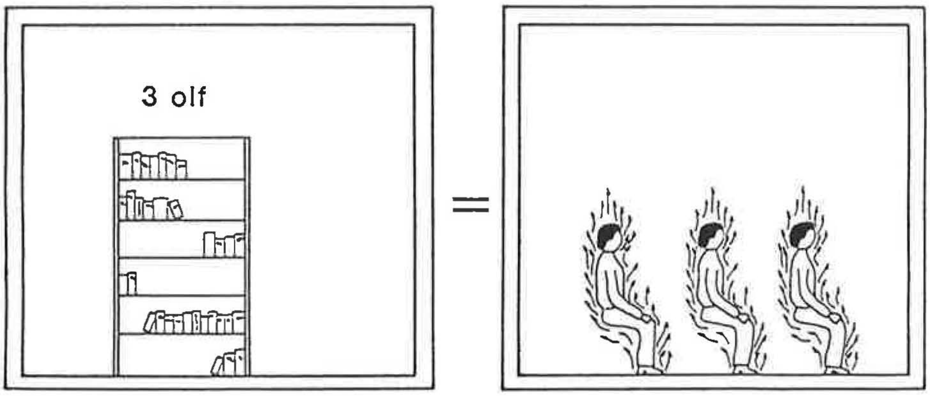
Why do people suffer discomfort in indoor environments where the ventilation operates according to standard criteria calculated on the number of people normally present in the premises? And where chemical measurements have shown that carbon dioxide, carbon monoxide, organic gases and particles occur in concentrations which cannot theoretically give rise to an unhealthy indoor climate? These are mysteries about which many wise heads have been scratched, but the answer seems to be just around the corner. The answer is: ***the hidden olfs****. And this answer comes from Ole Fanger, Professor at the Heat and Climate Laboratory at the Danish Institute of Technology in Lyngby. He has coined a new unit for measuring pollutant sources, the olf, and for air quality, the decipol, in analogy with the lumen and the lux for light and the watt and the decibel for sound.*

"It's about time to launch a systematic olf hunt," says Ole Fanger. In an investigation into 15 mechanically ventilated offices with, on average, 230 m^2 of floor space and 17 people using the premises, he has found an average total of 138 olf per premises. Since an olf is a unit which designates the air pollution emitted by one standard person, this implies that only a minor fraction of the poor indoor air comes from the people in the premises. Ole Fanger is firmly convinced that it is not sufficient to dimension the ventilation system according to the number of people present in any given building. However, this has been the rule for the last century. And this rule has always presupposed that the ventilation systems are clean.

Chemical measurement methods not sufficient

Ole Fanger also contests the view that chemical measurement methods are sufficient when it comes to obtaining a measure of how the indoor climate is perceived by people. People often complain about poor indoor air while the chemical measurements show that all is well. This was also the case in Ole Fanger's investigation. Chemical measurement values could not predict those premises which were to be classed as high olf centres.

The explanation could be that the air in any given premises may contain several thousand gaseous pollutants in minute concentrations which almost defy measurement, and that their synergistic effect is unknown.



A pollutant source has a strength of 3 olf if the pollutant from three standard persons causes the same discomfort as the source, which, here, is a bookcase.

Man the most sensitive instrument

How, then, is an olf measured? Well, Ole Fanger – who emphasizes that olf is an abbreviation of olfaction which means sense of smell – has produced the olf by using the most sensitive of all instruments, namely man.

He engaged 168 assessors (equally divided among the sexes) to judge 1,000 test subjects in order to establish the amount a "standard person" emits in terms of air pollutants. When once the olf unit had been established as the amount of air pollutant caused by a standard person, any other pollutant source whatever could be quantified by the number of standard people who entail the same discomfort as in the perceived pollutant concentration.

Ole Fanger is of the opinion that the olf is analogous with the lumen for light sources and the watt for noise sources. The olf is a unit of measurement of the pollutant source and the unit of measurement of the concentration of air pollutant perceived by people is called decipol by Ole Fanger. A decipol is the pollutant emitted by a standard person in a room which is ventilated at a rate of 10l/s of clean air. Hence, the decipol is analogous with the lux and the decibel.

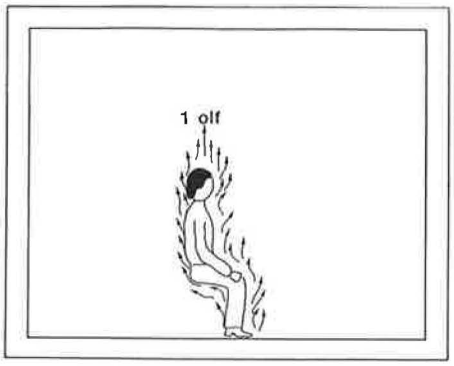
Originally, people were actually used to measure light and sound. Later, instruments were developed with built-in information as to the perceptions of the eye and the ear of wavelengths. Now we use people to measure olfs and decipols, but it is, of course, quite a challenge to develop instruments that could measure the perceived air pollution – a decipolmeter, suggests Ole Fanger. He points out that the olf and the decipol say nothing about actual health hazards. For example, radon cannot be discovered using these units. In just the same way as ultraviolet light cannot be perceived by the human eye. Ole Fanger has not yet got round to investigating whether common symptoms suffered by people in unhealthy buildings, such as headaches, irritated mucous membranes etc. have any relationship with the experienced indoor air. Nevertheless, it is a characteristic feature of unhealthy buildings that the users' symptoms disappear when people get out into the fresh air. It is, therefore, probable that these symptoms would also disappear if the indoor air were perceived and experienced as fresh and stimulating.

In a further study, those premises which were classed as high olf centres are to be examined with a view to establishing how the people working there feel.

The first impression from 15 offices

Ole Fanger's investigation into the indoor air in 15 offices was conducted with the help of a panel of 58 assessors. The investigation was carried out according to the picknick method. The panel members were transported by bus from building to building and were asked to make their assessments after their first impression is the fairest, because people soon get used to their indoor environment.

The members of the panel were asked to rate their smell experiences on a 6-point scale ranging from no smell to overpoweringly bad air. The panel members were also asked to state if they would perceive this smell as unacceptable if working in it every day. A 5-point scale was used to indicate how the air was perceived, ranging from extremely fresh and healthy to dusty.

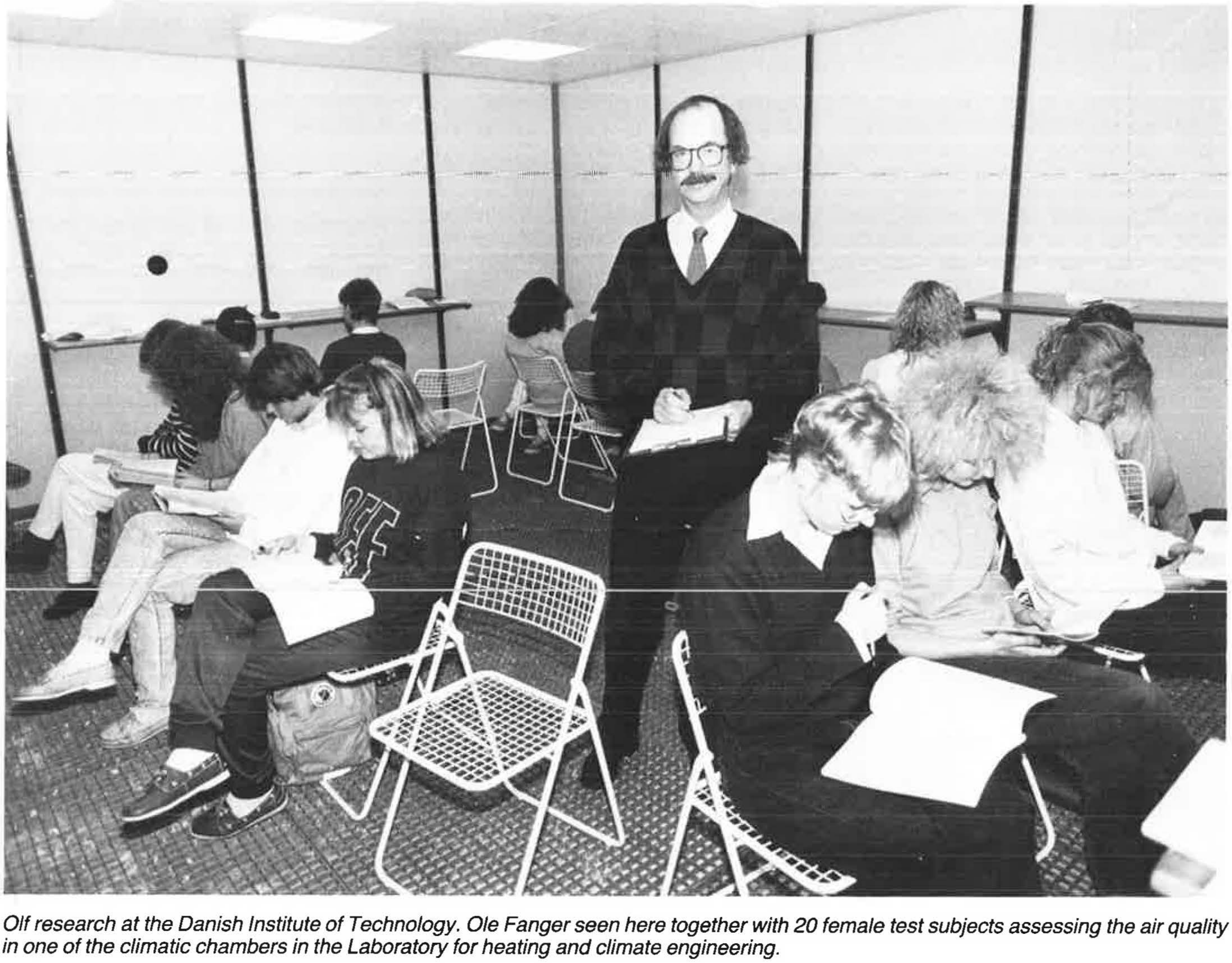


An olf is the amount of air pollutant emitted by a standard person. A standard person is defined as an adult working in an office or the like, is sedentary and in thermal comfort with a hygienic standard corresponding to 0.7 baths a day.

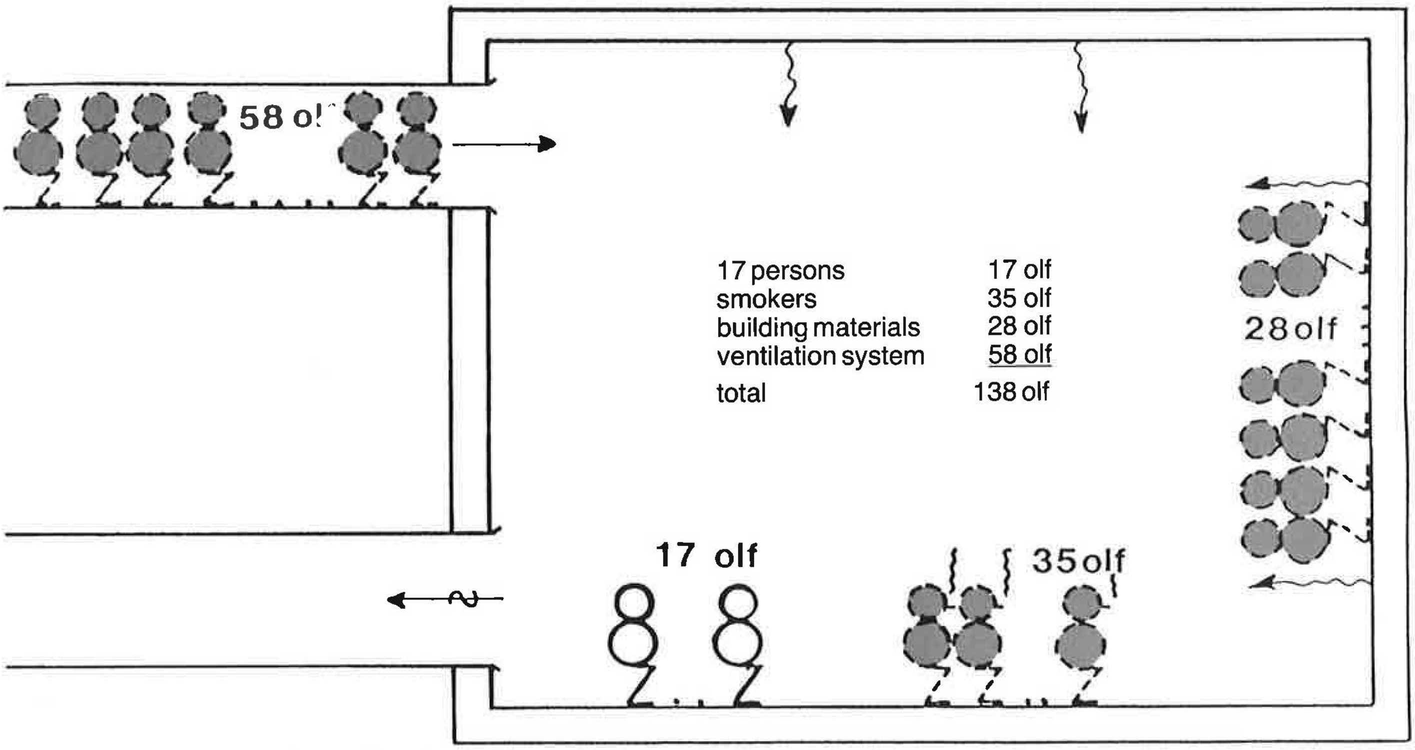
The premises studied had not previously been classed as unhealthy buildings. They were ventilated mechanically, many with a more powerful air flow than that prescribed in the ventilation standards.

The panel visited these premises on three occasions. On the first occasion, the ventilation had been turned off and no employees had been in the premises for 24 hours. On the second occasion the ventilation system was running, but still no employees were present. On the last occasion the employees were at their desks and the ventilation system was running. In this manner olf values were arrived at for the different sources of pollutant: building and interior decorating materials, the ventilation system and the employees.

On average, 58 olf were found in the ventilation systems and 28 olf in the building materials. Ole Fanger is entirely convinced that these hidden olfs are the explanation of why people suffered discomfort in well ventilated premises with low concentrations of measured chemical pollutants.



Olf research at the Danish Institute of Technology. Ole Fanger seen here together with 20 female test subjects assessing the air quality in one of the climatic chambers in the Laboratory for heating and climate engineering.



Average pollutant sources in 15 offices in Copenhagen. The average workforce was 17 people per office. The many hidden olfs (grey) in rooms and ventilation systems are the probable solution to the mystery of the sick buildings.

Eradicate the causes of bad air

"If we want to have healthy buildings, we must eradicate the causes of the poor indoor climate, both in the ventilation systems and in the building materials," asserts Ole Fanger.

"Existing ventilation systems must be thoroughly checked. All sorts of things have been built into today's ventilation systems, a lot of which we know very little about at present," says Ole Fanger. "We have just launched a project in which we are studying potential pollutant sources such as solder absorption, electric materials, plastic fittings, filters and many other materials used in air conditioning units without a thought given to the fact that they may pollute the air."

"Tomorrow's ventilation systems must be completely olf-free," says Ole Fanger firmly. "It is vital to evolve methods for systematic cleaning and maintenance of ventilation systems," he adds.

List of low-olf materials

As far as olfs from building materials and internal fixtures and fittings in existing buildings are concerned, there is only one method of approach, in Ole Fanger's opinion. And that is quite simply the laborious process of removing piece by piece everything out of a room to determine where the pollutant comes from. First the books, then the carpets and so on. If everything has been removed leaving only the shell of the building and there are still a large number of olfs in the room, then the ultimate solution is to demolish the building, says Ole Fanger with an expansive gesture.

In the future, he would like to see tables of building materials and internal fixtures and fittings showing the number of olfs they emit. It would then be possible for architects to choose materials with low olf ratings.

"Of course, architects can already use their nose and smell material samples. If these samples smell bad don't use them," states Ole Fanger categorically. "In new buildings, new materials should not be introduced until it is absolutely certain that they will cause no discomfort."

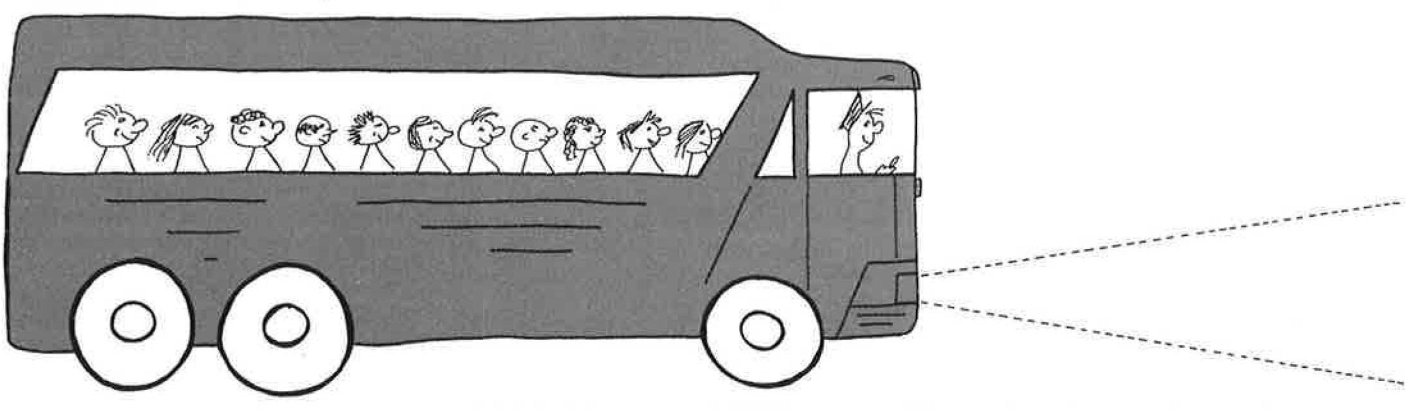
Ole Fanger is optimistic about the possibility of constructing healthy buildings in the future. "We can build with low olf ratings. Our investigation has demonstrated this. Some office premises enjoyed fresh and pleasing indoor air and clean ventilation ducts, as well as materials which did not emit any smell. Nor were they the cause of any discomfort," he concluded hopefully.

Birgitta Bruzelius

Literature:

Fanger, P.O. *Introduction of the olf and the decipol units to quantify air pollution perceived by humans indoors and outdoors.* Energy and Buildings, Vol. 12, 1988, No. 1, pp.1-6.

Fanger, P.O., Lauridsen, J., Bluyssen P., Clausen G. *Air pollution sources in offices and assembly halls, quantified by the olf unit.* Energy and Buildings, Vol. 12, 1988, No. 1, pp. 7-19.



The investigation of 15 offices was conducted with the help of a panel of 158 assessors. The panel members were transported according to the picknick method by bus from premises to premises where the panel members were asked to make their assessments of their first impression of the indoor air.

Buildings to live and work in

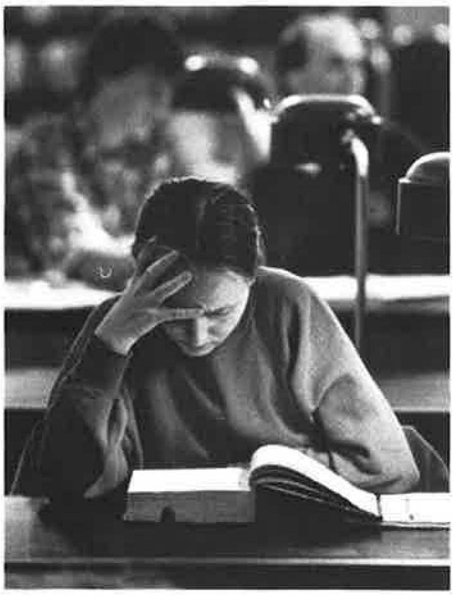
David Wyon, the Swedish National Institute for Building Research

Buildings are healthy if the people who use them can themselves control the climatic factors which determine whether their general state of health will be good or bad in the building. If it is possible to arrange and regulate the environment for living and working, people's health will be safeguarded. If such adaptation cannot be done by the individual residents or workers, responsibility for their health rests with the authorities. Unfortunately, such problems come to the knowledge of the authorities too late and are then difficult to remedy.

The indoor environment should facilitate and encourage those human activities for which it is designed. It should be easy and enjoyable to spend time in the living room, to wash in the bathroom, to sleep in the bedroom etc. Self-evident it may seem, but everything which impedes the human body or brain from functioning properly is a stress factor and may lead to symptoms of strain if the contemplated activities must be carried out despite the difficulties involved.

Wrongly designed furniture and equip-

Access to daylight is of major importance to human health. Photo: Svenne Nordlöf, Tiofoto AB.



Habitually working in poor light is injurious to the eyes and forces the worker unconsciously to assume an unsuitable working posture which, in the long term, may lead to ill health. Photo: Ulf Simonsson, Tiofoto AB.

ment force people to assume an incorrect body posture which strains muscles and skeleton and, in the long run, will lead to poor health in some people. Others are exposed to strenuous lighting conditions, disturbing noise, unsuitable temperatures and draught which, through uneven heat loss, cools down certain muscle groups excessively. This predisposes to poor health. Preventive health care must identify those factors in the indoor environment that make it more difficult for us to function.

This can be demonstrated physiologically or psychologically (subjectively). It is also possible to measure how well a manual or intellectual task is carried out under different indoor environmental conditions. All three types of study are elucidated below.

Windows, daylight and lighting

There should be daylight access in all rooms where people spend any length of time. Not only that, people should be able to see out. Some form of daylight is better than none at all. This also applies to the window view. If the duties performed are boring and monotonous, these features are of particular importance. Windows let in light but also provide information about the outside. Windows may also serve as emergency exits and provide access to fresh air in emergency situations. Consequently, it should be possible to open the window.

Windows help the blind to orientate themselves in a building and counteract the feeling of being shut in experienced by many sighted people. The vital rôle played by windows in reducing suppressed feelings of panic, anxiety, disorientation, boredom and listlessness demonstrates that windows are important to general health. In one American hospital, it proved that the time for recovery after operations and the need for pain-killers were reduced when the patients were given better possibilities of looking out from the wards.

Windows may function as a source of light but will usually have to be supplemented by artificial lighting. Poor working lighting is a health hazard not only to the eyes, but also to the rest of the body because it forces workers to assume unnatural postures. Most people do not need working lighting in excess of 300 lux. In precision work, several thousand lux may at times be desirable. But if such powerful lighting is not necessary, an intensity of as little as 1200 lux combined with but a moderate increase in room temperature will reduce working performance.

Sound

It may reliably be assumed that no building and no ventilation system in itself causes more than 85 dBA, at which level hearing may impaired, but it is known that low intensity noise affects sleep, digestion, thinking capacity and the ability to communicate.

It must be possible to sleep, eat, think and talk undisturbed in a dwelling, even if not at all workplaces. As the standards for sound insulation are today, this cannot always be achieved. Disturbing noise from neighbours may cause people to feel ill at ease - or may even lead to detestation of one's surroundings, to aggression, or perhaps to anxiety and depression if the sound is misinterpreted as coming from an intruder.

These are aspects which clearly require preventive health protection. Access to necessary silence is more important than a general reduction of the sound level in the environment, because people react very differently to noise.

More research is needed into the effects of constant background noise from, for example, fans, water in pipes, and traffic. Even if people do not consciously feel that they notice the noise, there is a general feeling of relief when the noise ceases. When, for example, time-regulated fans on shut off, the experience may be so manifest as to indicate a latent state of tension of the same type as, in other contexts, is suspected of having a long-term detrimental effect on health.

The thermal climate

It is easy to correct the thermal balance by an insignificant adjustment of the degree of heat generation when people are active. Heat problems are particularly pronounced in inactive, sedentary occupations. For such activities, which are the most common in buildings, the following recommendations apply:

The air temperature should be in the range of 20–24°C (20–22°C in the winter, 22–24°C in the summer) and in no case should it fall outside the limits of 16–30°C. If the temperature is lower than 16°C, the temperature of the fingers will be below 25°C. It then becomes difficult to write and work with them. It is also believed that there is a risk of injury to muscles and joints, although this remains to be proved. At temperatures above 30°C, apart from the negative effects on performance in people who are not used to spending any length of time in such warmth, individuals with a weak heart may be stricken by panic when they discover that the body is reacting insufficiently to heat stress.

The floor temperature should also be in the range of 20–24°C and in no case fall

It is more important to have access to necessary silence than to generally lower the sound level in the environment. Photo: Ulf Simonsson, Tiofoto AB.

People show different degrees of sensitivity to the temperature in the environment. If we can individually control our microclimate, we can avoid negative effects on our health. Photo: Lars Strandberg, Tiofoto AB.

outside the range of 16–26°C, since it then becomes difficult to protect the feet properly.

Directed Operative Temperature should preferably exceed 20°C, and should never be less than 18°C at any point where a part of the body may be present. This requirement implies that if the flat radiation temperature is lower, the air temperature must be correspondingly higher. This recommendation is based on experience and good practice and has recently been adopted by the National Board of Health and Welfare in its definition of sanitary inconvenience.

Relative humidity should most suitably 20–40%, and only in exceptional cases fall outside the limits of 10–60%. In most buildings, little can be done about this problem. Dry air with a relative humidity below 20% causes discomfort at temperatures above 21°C, in the form of dry eyes, lips, skin and nasal mucous membrane. This situation probably increases sensitivity to air pollution, since the cleansing function of the mucous membrane movements is impaired.

High humidity levels increase the risk of condensation and fungus formation. In addition, high humidity creates problems for the human thermal balance when people enter or leave the humid environment. The conversion effect in the form of moisture condensation or vaporization in clothing corresponds to a temperature change in the air of 5–10°C and may be as long 30–60 minutes.

Air draughts must be as little as 0.15 metres per second if people are to avoid a feeling of discomfort. This suffices for a requirement that the body's natural convection is not disturbed. Increased moisture emission from the surface of the eye can be measured within only 10 minutes at an air flow rate of 0.5 metres per second and will entail eye trouble if the draught continues for any length of time.

Individual control of the microclimate is the only solution for remedying individual differences in sensitivity to the temperature environment. It must be possible to regulate the thermal balance in order to avoid negative effects on health.

The only method available at present is to adapt people's clothing. But clothes have not been optimized for this purpose. If a garment is donned or doffed, the distribution of the heat flow throughout the entire bodily surface will always be changed. Some parts of the body become too hot or too cold in the attempt to correct the overall thermal balance.

To conduct detailed clothing research, use is made of laboratory dummies divided into sections for temperature measurement. Research is currently being concentrated on finding practical ways of improving the possibilities for people to control their microclimate. Studies are in hand on the microclimate in vehicles. Some of the techniques which have been developed there for climate and air conditioning control can be employed in buildings.

Inevitably, remote-controlled temperature regulation entails that some people will be troubled by heat whilst others sit and freeze. Individual control solves this interminable problem, saves energy by utilizing it properly and protects the health of all energy consumers. Many of the energy conservation methods currently in operation give rise to increased health problems.

Ventilation and air quality

In healthy buildings, the air is removed from "wet" rooms (kitchens, bathrooms, toilets, washrooms) and from rooms which may pollute the air (workshops, copying rooms, gymnasiums etc.) and fresh air flows in where it is needed to work rooms and living rooms during the day, to bedrooms during the night. The buildings which satisfy these requirements today are few and far between. Moreover, the quality of the air must be such as not to jeopardize health. If air pollutants come from a machine or a process, they may readily be identified and the problem often solved. On the other hand, the problem of pollutants emanating from the building shell or its interior furnishings and fittings has so far defied solution.

Roughly 10–30 per cent of modern buildings are considered as giving rise to SBS ("the sick building syndrome"). This manifests itself through symptoms in the eyes, nose, throat, lips, mucous membranes, skin, head and face – in the form of irritation, headache, fatigue, reduced concentration and feelings of disability.

It is only now that these symptoms are being studied quantitatively. But while research into chemicals and allergenes progresses, those afflicted must do something about their own situation in the meantime. They cannot throw out the material the building itself consists of. But they should be given every opportunity to influence such factors as temperature, air exchange rate, humidity, draughts, static electricity and so on to find the particular combination that minimizes these symptoms.

Ideally, buildings should consist solely of traditional, uncomplicated materials such as brick, masonry, clay or wood.

Less well tried and proven materials such as plastics, composites, glue compounds, synthetic surfacing materials and textiles should only be employed in interior fixtures and fittings and furniture, so that they can easily be removed if necessary. There is an urgent need for research aimed at developing empirical methods to solve SBS problems. In the meantime, a makeshift solution is to ventilate off the concentrations of harmful particles and gases.

All heat-exchange equipment which makes it economically viable to raise the air-exchange rate should, for health reasons, be given top priority. However, in the long run the only solution is to eradicate the pollutant sources that cause SBS. But first we must learn to understand the mechanisms involved.

David Wyon is a Ph.D. and head of the Human Laboratory at the National Institute for Building Research. At present, he is a visiting Research Fellow at the Laboratory for the Physiology and Psychology of the Environment in Strasbourg, France.

David Wyon's article has previously been published in full in the magazine WWS & Energi No. 7-8/1987. It includes a detailed list of the references from which the author has gathered source material for his article.

Hearing with builders, administrators and doctors

Sick buildings and how they affect people's health is one of the key questions addressed by the committee of inquiry into allergies ("the Allergy Inquiry"). During the autumn, the committee of inquiry held two hearings with builders, administrators and medical expertise. Perhaps the most surprising feature was that a large number of people in the building trade appeared not to have seen any major problems in their properties. Are builders blissfully unaware of these questions?

While the builders have not been aware of any major problems, the allergy inquiry has declared, on the other hand, that "what we find so surprising is that there are such close links between allergy and hypersensitivity and the environment".

When the users of workplaces and dwellings suspect that different medical symptoms may be caused by the building itself, they probably first approach their own company doctor or the environmental and health safety administration. This may explain why the flow of information between users and builders does not always function.

No overall picture

What problems and wishes do the builders and administrators have today, was the question put at the first hearing. After all, the future proprietors constitute a key group in the attempts to achieve healthy buildings. No clear answer was forthcoming.

Instead, Bertil Pettersson from the Swedish Council for Building Research took up a burning issue right from the outset, namely the relationship between energy conservation and questions of health. He strongly felt that these issues need not run counter to one another. However, a basic precondition is thorough project planning, careful construction and competent running and management of the property. It is important to take into account how different materials and systems work. Flexibility and system adaptation must be the hallmark of all technical solutions applied. The future proprietor must also possess sufficient knowledge to make the correct functional demands. In its work, the committee of inquiry has arrived at a somewhat different standpoint. The chairman of the committee, Gunnar Nilsson, pinpointed the "low energy society" as a quite special risk which must be viewed with some gravity. He emphasized that more than 2 million people in Sweden are hypersensitive or allergic. The primary goal must now be to preempt these problems.

No major problems were reported by HSB (the National Cooperative Housing Association), nor from any other of the major companies in the housing sector. Instead, the state of health was assessed as good in the properties. "A lot is sorted out at the local level."

The representative of SABO (the Swedish Public Utility Housing Enterprises) felt that the relationship between sick buildings and questions of public health have not been made sufficiently clear. However, SABO was only too willing to participate in such codification work and viewed these issues as vital. There are already a number of internal projects in progress which directly deal with or at least touch upon this sector.

"We don't know very much about the state of health in our buildings."

This remark was made by a representative of the Swedish Federation of Wood Product Manufacturers who soon got to grips with the question of standards and limits. "Chipboard which was acceptable ten years ago may not perhaps be good enough today or next year because of new standards and limits which come into force. As far as standards and limits are concerned, we producers are often at odds with politicians and public sector authorities. Any official raising of standards may cause difficulties. This is particularly so in the case of allergy sufferers. Must everyone go without a particular product simply because a few might suffer?"

One step behind

One distressing but unfortunately general truth was also put forward by the wood product manufacturers: "Generally speaking, the problem we are faced with is that we are always one step behind. When problems arise, we have already created them. We would like to be one step ahead. What is needed is an early warning system.

"It is quite clear that our product control does not make the grade."

"As a result, we must instead build using greater safety margins, for example as far as ventilation is concerned," asserted Thomas Lindvall from the National Institute of Environmental Medicine.

On the question of specifying clients' requirements, Lennart Holm from the National Board of Physical Planning and Building had a concrete proposal. On the one hand, he wanted to prohibit the use of "slabs laid straight on the ground" and, on the other hand, he was looking for a guarantee that the mechanical exhaust air systems actually work. Then he would feel much happier about the situation.

No maintenance

The systems are installed and there is nobody who can look after them. This would seem to be a kernel in the debate on unhealthy buildings and took up considerable time during the second hearing. The tenants themselves cannot regulate the system. Draughts, cooking smells and noise are unpleasant factors which the individual is powerless to remedy.

"We need simple systems, for example individual apartment ventilation systems. Systems which the tenant understands," SABO suggested.

Jan Sundell from Syntax AB expanded on the same theme:

"The inefficient function of many systems is not so much because of designers and manufacturers. The primary reasons are rather to be found in shortcomings in demand specifications, fine-tuning, operation and maintenance."

There was a consensus of agreement on this point:

"Ventilation and heating don't work. Why is this? The answer is that the users are unable to run the systems and have not been provided with instructions so that they can. It is surprising, isn't it, that products can be supplied without operating instructions," continued Wilhelm Tell, former head of the National Board of Physical Planning and Building.

"Why has ventilation become the whipping boy? What has happened to bring this about?" asked the representative of Fläkt. But he also arrived at the same answer as the earlier speakers:

"The technology is there, but the breakdown comes when the systems are to be utilized and physically applied."

A large number of the participants felt that competent buyers was a precondition to enable us to construct healthy buildings.

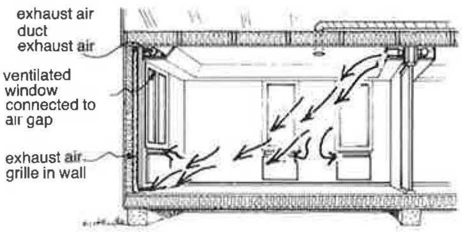
If we and the buyers can assume this joint rôle in the future, we might perhaps be able to start talking about healthy buildings instead of sick buildings.

Kerstin Fredholm

The user-healthy day nursery – one year on

The so-called user-healthy day nursery in Skarpaby was completed at the turn of 1986/1987. By March 1987, the toddlers began the acclimatization phase. In the meantime, measurements were taken of air pollutants in the indoor air. During this time, both heating and ventilation were fully operational, which gave a little extra time for the new building materials to "degas".

The day nursery, which has two sections, has been built with particular attention to a congenial indoor climate – both thermally and hygienically. The idea was also to combine a good indoor climate with good energy husbandry.



Airborne heating with fixed air flow rate. Heating: Heated supply air at a constant air flow rate equivalent to 5 air changes/hour. At this flow rate, the supply air temperature should not need to exceed the room temperature by more than about 4°C at the minimum design ambient temperature. Ventilation: Balanced ventilation, constant flow rate. Same air flow direction as illustration 1. Exhaust-air-ventilated windows are also in use. Varying degree of air recirculation will be tested (from 0 per cent giving 5 air changes/h of outdoor air to 90 per cent giving 0.5 air changes/h of outdoor air). With no or low recirculation, heat recovery will be provided, as in illustration 1, by an air/liquid/air system.

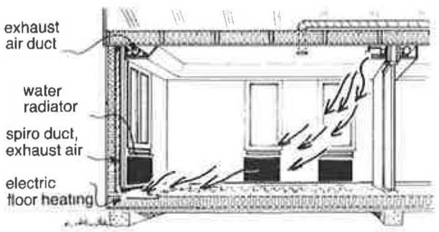
Design

The design of the building was generally in line with the Stockholm Metropolitan Council standard. However, the machine room is larger, since the building is equipped so that different combinations of heating and ventilation systems can be tested. The principles of these different installations are apparent from the figures.

The day nursery is built on a raised foundation with light beams of masonite instead of slabs placed straight on the ground as used in typical day nurseries for many years, with a large number of problems of damp in their wake.

The building materials were selected so as to give a minimum of volatile pollutants and particles in the indoor air. For example, one cardinal point in the planning was to employ as little glue and paint as possible inside the building. Most of the walls are clad with wooden panelling coated with a thin layer of water-based clear lacquer. In the "wet areas", high pressure laminate has been used on the walls. The floors are linoleum-covered, apart from in the wet rooms which have a plastic floor covering. The acoustic ceiling consists of perforated plasterboard panels nailed on battens. Chipboard in the floors is of class E1 which emits only a very slight amount of formaldehyde (class 1 is now Swedish standard).

The ceiling height is 270cm as opposed to the normal 250cm. As a result, the ventilation ducts could be placed internally without insulation. Heat recovery is effected using a battery heat exchanger in which supply and exhaust air never meet or pass the same surfaces. Both the supply and exhaust air ducts can be cleaned.



Waterborne heating with balanced ventilation with variable air flow rate. Heating: Radiators. The electric floor heating can be connected or disconnected for investigation of any link between the surface temperature of the floor and subjective comfort. Ventilation: Balanced ventilation. Supply air from the upper region of the interior walls, exhaust air extracted from the lower part of the interior walls. Supply air temperature can be adjusted for measurement of best ventilation performance. Air flow rate will be varied between 2–5 air changes/ hour during different periods. Heat exchange using an air/liquid/ air system.

Evaluation

The program of evaluation of the indoor climate of this day nursery and the different combinations of heat and ventilation will continue for more than three years, of which the first year has now passed. The evaluation is made by continuous measurement of room temperatures and relative air humidity, and by recurring measurements of air pollutants, air exchange efficiency, air flow rates, noise and energy consumption at different heat and ventilation settings.

With a view to creating a comfortable floor temperature, an electric heating loop has been laid in the floor along the outer walls. Comparative measurements of the surface temperature of the floor were made when the loop was switched on and switched off. In this context, the electromagnetic fields of force were also measured.

A particular evaluation is made of the basic construction. In the underfloor space, which is naturally ventilated, regular measurements are taken of the air exchange rate. A thermal hygrograph is also placed here which continually registers temperature and RH. Samples are taken from the lightweight beams for moisture quotient measurement and analysis of fungus and rot attack.

It goes without saying that the most important sensor of the indoor climate is the human being itself. The nature of the indoor climate as perceived by the nursery staff is monitored by recurring questionnaires which are to be individually completed every sixth week, and by a questionnaire which is to be completed by the supervisor at a staff meeting each week.

Check-ups of the staff health are made by the company doctor.

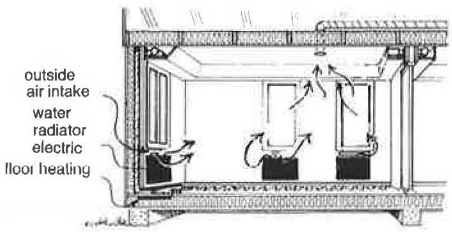
The parents have so far been asked to complete one questionnaire on their experiences of how their children feel physically at the day nursery.

Results of the first year's evaluation

So far, only setting 1 for heating and ventilation has been tested with air change rates varying from 2 to 5 changes per hour.

Broadly speaking, it can be said that the climate in the day nursery has so far come up to expectations. The staff are happy with the climate and perceive the air as being pleasant. At high change rates (4 and 5 changes per hour) some of the staff think, however, that the air feels dry. At these higher air change rates, floor draughts are also experienced during rest periods.

The sound level was perceived by the staff as being more comfortable and damped than normal in day nurseries. This



Waterborne heating, outdoor air inlets and variable air flow. Heating: As 1 above. Ventilation: Outdoor air inlets and exhaust air ventilation. The outdoor air inlets are fitted beneath the window frame/ window ledge, with their interior openings behind the radiators. Outdoor air is heated as it enters and flows past the back of the radiators. Exhaust air is extracted through a ceiling-mounted exhaust air grille on the opposite side of the room. Air flow rate will be varied within the range 0.5–2.0 air changes/h during different periods.

In the underfloor space of the day nursery, the air temperature and air humidity are registered using a thermohygrograph. Photo: Johnny Andersson.

may probably be attributed to the special wall construction with an air gap behind the wooden panelling. The reverberation time is between 0.3 and 0.5 seconds.

All of the parents thought that their children felt well in the building. Absence on account of illness among the children is low, even though all children were less than 2 years old when they began attending.

The results of the climate measurements are in the process of being compiled. An interim report is expected to be ready during the spring of 1988.

However, a few measurement values can already be reported:

☐ In playrooms not facing south, the room temperature during the heating season has been very uniform at about 21°C, with the exception of a few weeks last autumn when the radiator thermostats jammed after the summer break. In a playroom facing south, the temperature rose on sunny afternoons to about 23°C and occasionally higher during the heating season. This room has now been fitted with awnings.

☐ The floor temperature has remained quite even, at about 21°C. The results so far seem to indicate very little effect from the electric floor loop.

☐ The concentrations of volatile substances are low. For example, the formaldehyde concentration, during the actual building time, was 0.05 ppm indoors. In the completed but empty building, in February 1987, this content had fallen to 0.01 ppm. When the basic equipment had been installed and activities had begun, the concentration was between 0.01 and 0.02 ppm. In the requirement specification, the maximum permitted concentration had been set at 0.04 ppm.

☐ The radon daughter concentration indoors has been measured at 5 Bq/m3 indoors and 15 Bq/m3 in the underfloor space. The limit as set by Swedish Building Standards 80 for new buildings is 70 Bq/m3.

☐ The air change efficiency at different air change rates has varied between 90 per cent and 95 per cent once the ventilation system had been finely tuned.

A "full-scale project" of this type creates a favourable discussion climate between all of the parties involved in the expansion of day nurseries. It becomes a forum where discussions can be held on alternative solutions. Some of the solutions evolved during the work at the Skarpnäck day nursery have already been put into practice in standard type nursery production. This applies to such matters as demands for higher air change in the children's playrooms, raised foundations, higher ceiling heights and different types of heat exchanger.

Marie Hult

Marie Hult is an architect employed at the Stockholm Social Welfare Administration.

HIM report lays the foundation for healthier buildings

Our buildings have become steadily more complex products. The building costs for achieving the quality of health and hygiene which gives us comfortable and healthy buildings now exceeds 50 per cent of total building costs. Not only that, running costs for maintaining this quality throughout the service life of the building are also higher than 50 per cent of total running costs.

The result is that the hygienic standard of our buildings has been raised dramatically during the 20th century. However, with the arrival of new technology on the scene in the 1970s, new health problems have been highlighted which have been caused by substances such as formaldehyde, mould, self-levelling screeds, etc. Moreover, environmental medical research has demonstrated new health hazards related to, not least, asbestos and radon.

The effects of the external environment and the working environment on general health are under relatively close surveillance by politicians and the authorities involved the National Environment Protection Board and the National Board of Occupational Safety and Health. When it comes to the indoor environment – in which we spend between 70 and 100 per cent of our time – the National Board of Physical Planning and Building, the National Board of Health and Welfare and the National Board of Occupational Health and Safety have provided a concerted review of the health problems occasioned by buildings, together with proposals for short and long-term measures to limit them. This is presented in "Healthy and unhealthy buildings", report No. 77 from the National Board of Physical Planning and Building. It was drawn up by a joint committee on the health risks in the indoor environment, the so-called HIM Commission chaired by Ulf Thunberg (political appointment), Guldbrand Skjönberg (National Board of Health and Welfare) and Lennart Holm (National Board of Occupational Health and Safety), the author serving as principal secretary.

Some 21 special sectors have been dealt with - ranging from air quality and chemical substances to sewage, vibration and mites. More than 30 research workers and experts have presented background facts in 27 appendices. Almost half of the material made available is based on research supported by the Swedish Council for Building Research.

The proposed measures set out those bodies who should bear the major responsibility for each implemented measure. The proposals relate to:

1. Plotting of existing health problems, indoor exposure and shortcomings in buildings.
2. Follow-up of new health problems caused by buildings.
3. General recommendations on improvement measures in construction, maintenance and clearing of buildings.
4. Ventilation and air pollutants.
5. Building materials and chemical substances.
6. Studies of "sick building" problems.
7. Damp protection.
8. The noise climate.
9. Improved quality assurance of the health and hygiene qualities during both the construction process and throughout the entire administration phase (at least 50 years).
10. Cooperation between local inspection authorities.
11. Environmental medical and structural engineering research.
12. International cooperation.
13. Information and education on health protection in buildings to such targets as builders, property administrators and the general public (the users of the buildings).

This report has been submitted to the Government and embodied in a green paper distributed for comment to different bodies and individual experts in the health safety, building, the working environment, environmental medicine and property sectors.

This review has been welcomed and all proposed measures have been approved with the exception of a few individual points by a small number of bodies. The responses are in the process of being compiled and will be submitted to the Government.

Wilhelm Tell

Wilhelm Tell, M.Sc. (Eng.), formerly a Division Head at the National Board of Physical Planning and Building.

Allergy-free building in Denmark

A project in Århus, Denmark, has demonstrated that it is possible to build healthy dwellings - primarily for asthma- and allergy-sufferers. Now that this estate has been in existence for a few years, we know that those who suffered from allergies when they moved in enjoy considerably better health today.

At the end of 1984, the first tenants moved into the dwellings. These had been built in the first instance for asthma-allergics. Cooperation between the Department of Hygiene at Århus University, the National Building Research Institute and the Lejerbo Construction Company brought the project to fruition.

Exterior. The Skejby estate on the northern outskirts of Århus has been the centre of considerable interest, since the dwellings have been built to ensure asthma-allergics the optimum living environment. Selection of materials and ventilation were two areas to which considerable work was devoted.

Interior. The kitchen fittings are of solid wood. They are not large, but extremely well planned. A lot of work has been devoted to their design.

The dwellings are in the Skejby suburb in the northern outskirts of Århus. One primary cause of mould and allergies caused by mould is water-logged ground. In Skejby, the prime consideration was to avoid siting the project on such terrain.

One of the enthusiasts behind the project is Jens Korsgaard, physician with the Department of Lung Diseases at Århus Municipal Hospital who has worked with asthma allergies. He has been able to demonstrate that the dwelling is of vital importance for people to be able to avoid asthma-allergic reactions. Damp and dust are two factors which every attempt has been made to minimize.

The estate comprises 111 dwelling units of which 99 are from two rooms plus kitchen up to five rooms plus kitchen. Twelve of the units have been specially designed for young people. All of the dwelling units are two-storey, with the living zone on the ground floor and the bedroom(s) and bathroom on the upper floor.

The dwellings are built on a creep foundation or, in normal parlance, a raised foundation. Considerable thought has been devoted to choice of materials. By a process of analysis, attempts have been made to avoid hazardous building materials and surface layer treatments. Concrete and laminated timber are the main components in the structure. The kitchen fittings are of solid wood, beech. All painting work has been carried out using silicate-based paint. The floors are of beech with a surface layer of a two-component isocyanate lacquer. The wood has been industrially varnished.

Ventilation has assumed a central rôle in these dwellings. They are provided with a mechanical supply and exhaust air system. The air exchange rate is once per hour, which is twice as much as in normal dwellings. As a result of this system, electric power consumption will be approximately 2000 Danish kroner dearer than the normal annual bill for a dwelling consisting of four rooms plus kitchen. In addition, filters are changed at regular intervals in the ventilation system so as to avoid accumulation of dust particles, mites etc.

Such factors as the cleaning have also been taken into account. The radiators are installed with generous spacing from the wall. The kitchen cabinets have been designed so that moisture will not gather. A particularly good detail is the wall-mounted WC pan, not least from the point of view of cleaning. Elegant supply air units are among further details worthy of note.

The estate otherwise is extremely well planned, with such ancillaries as launderettes, club rooms and meeting hall.

There is a crying need for estates like this to be built. It is vital that the dwelling works properly for everybody, regardless of their handicap.

Ingela Grahn-Ahlbom

Ingela Grahn-Ahlbom is an architect, member of the Society of Swedish Architects and is currently taking her Ph.D. at the Royal Institute of Technology, Department of Architecture, Environmental Design and Basic Forms. Her field of research is into healthy and sick buildings seen from the point of view of the architect.

The municipal house doctor takes the temperature of sick buildings

Headaches, nausea, runny eyes, catarrh and rashes. These are just a few of the most unpleasant symptoms which, sadly, often manifest themselves in people who live or work in so-called sick buildings. In Malmö, this problem was not long in being discovered. The municipal housing department is currently engaged in a large-scale study to trace and remedy the causes of such complaints, which strike first at toddlers in day nurseries and at school children.

In the words of Sven Andersson, the Head of Malmö Municipal Real Estate Department and – thereby – the municipal "house doctor" – the major reasons for these problems are to be found in factors such as poor thermal climate, substandard ventilation systems, large-scale chemical emissions and electrostatic charges.

"I greatly suspect that it is the interaction between these factors that results in unhealthy buildings. But we are not absolutely sure today which of the factors is the main culprit."

Research into these problems is under way at several places in Sweden. In Malmö, this work has probably made the most progress. In any event, the authorities here were the pioneers. As long ago as 1984, a study was launched on the initiative of the Municipal Real Estate Department into the state of the 1,740 municipal buildings. The results of this study, which embraced all medical care and administration buildings, schools and day nurseries, was hair-raising: one building in five in municipal ownership could, on the basis of the symptoms shown by personnel and others, be classed as unhealthy. Only a tenth of all of the buildings passed through the eye of the needle of Sven Andersson & Co's measurement instruments.

"The worst hit were the day nurseries. This is where the indoor climate is at its absolute worst," Sven Andersson claims.

Find the common denominator

In the ongoing investigation (which is expected to be completed within about two years) an attempt is to be made to get to grips with all of the known causes of sick buildings and also to seek out a common denominator for this category of buildings.

As was mentioned earlier, one problem source is the thermal climate, which includes such factors as uneven temperatures, draught and incorrect air humidity.

"In simple terms, the whole issue is a matter of people's well-being in the zone where they dwell, breathe and spend their time," explains Sven Andersson, who goes on: "The air must not be too dry. There are also established standards for air flow rate (draught), and in addition the temperature difference from floor level and a few metres up in the building should not exceed 3 degrees."

In those buildings which have failed to meet the standard requirements, the Real Estate Department has actively worked to right these problems:

"We have adjusted and finely tuned the ventilation systems and have made every effort to create what we describe as a 'means tested' heating and ventilation system for the people who suffer from the effects of the thermal climate."

Fans not fiends

In this context, Sven Andersson is justified in his criticism of the ventilation industry: "Many installation firms seem to have forgotten that ventilation should primarily be employed where there are people! The ventilation plants often malfunction, sometimes don't function at all. The air flows will then be wrong, with the result that the supply air quite simply does not penetrate into the entire premises and remove the pollutants which are present."

This is what the experts call "a short circuit" which, combined with poor quality filters, may result in the formation of moisture, mould and micro-organisms which are then blown into the premises. But measures are in hand to remedy these problems in Malmö.

"We are currently engaged in a sweeping asbestos clearance program in our properties and, at the same time, are taking this opportunity to carry out thorough cleaning of the whole of the duct system and assembly components. We are also replacing poor quality filters and are fine-tuning the ventilation plants so that they will be worthy of the name."

Sven Andersson is convinced that chemical emissions are another contributory factor in unhealthy buildings. These emissions are chemical gases emanating from the building and interior decorating materials. And this may be a many-splendoured Molotov cocktail: at one measurement recently taken at a Stockholm day nursery, no less than 150 volatile organic substances were recorded!

The medical effects these different substances have on humans remain as yet to fully identified. For some of the substances,

The construction industry is not overly cooperative and turns something of a deaf ear to these problems, says Sven Andersson, the municipal house doctor in Malmö. Sketch by: Mikael Sjöblom.

the National Board of Occupational Safety and Health has set up hygienic limits, but these have been adapted according to what an adult may reasonably be assumed to withstand. And while such limits are on the low side, allergy physicians and other interested parties assert that no limits can be applied at all for small children, and the substance should quite simply be eradicated from the building.

"We take this for granted in our job. We will not, and shall not, have those materials which give off these emissions, and, consequently, we have now put pressure on manufacturers to oblige them to present statements of the chemical composition of their products. And, even if this is a sensitive area, we are sure that they will comply," Sven Andersson believes.

Charging up

Anyone who belts around on carpets and floors will gradually be charged with static electricity. Depending upon the relative humidity in the air, it is possible, within a few hours, to "attract" between 500 and 15,000 volts, positive or negative. If the polarity is negative, this will also mean that the person will simultaneously be attracting a large amount of pollutant particles and fibres – which normally are positively charged.

To be able to measure the amount of particles and analyse them, the Municipal Real Estate Department has now ordered simulation equipment from Kockum's laboratory. This equipment includes a plate which is charged to the theoretically acceptable levels of a human being. After, for example, a day or so, the pollutants which have become attached may be scraped off to make for a later in-depth analysis.

The final bill for this project in Malmö is expected to run to approximately SEK 2 million. As the project continues, a medical and a chemical expert are to be linked to the study to establish an interdisciplinary breadth. At the same time, Ingela Grahn-Ahlbom, architect and Ph.D. student, is engaged at the Royal Institute of Technology in Stockholm in studying system selections, design, building materials etc. In order to find the relationships between different parameters in the materials used in unhealthy buildings.

Almost like banging your head agains a wall

A spontaneous question to be posed is the degree to which the newly gained experiences which Sven Andersson & Co have made have influenced new constructions.

"The surprising answer is 'almost imperceptably'. Sadly, the building industry is not particularly prone to cooperation and shows a tendency to turn a deaf ear to these problems."

"But it transgresses the balance of sanity and naivety to incorporate the same faults as before into new buildings, in the face of the knowledge we have to hand," says Sven Andersson.

As far as day nurseries are concerned, secretary Bengt Lindqvist has announced a construction program for a total of SEK 4 billion over the next four years. But it is already statistically predictable that approximately a third of this program, and at a cost of more than SEK 1 billion, will be classified as "sick" even before the first pencil line has been drawn on a plank.

"Nor can these problems have passed those in positions of senior responsibility unnoticed. They have been presented at a number of conferences and seminars and have also been highlighted in the media," Sven Andersson concludes.

Lasse Sjöblom

Declare the performance and emission levels of material

Offices with a maximum of four people in each room. The rooms must be easy to clean. The heating plant must be clearly separated from the ventilation system. Preferably manual ventilation and a minimum of carpets and textiles which attract particles. Curtains of course, but they must be washed often. Building materials without formaldehyde must be used, like well-wrapped mineral wool if acoustic ceilings are necessary. It is important that the indoor temperature is below 23°C. – This is the answer given by Ole Valbjörn, indoor climate research worker at the Danish Institute of Building Research, SBI, to the question as to how he would construct a healthy building. He bases his answer on, not least, a comprehensive study of the indoor air in offices in Copenhagen.

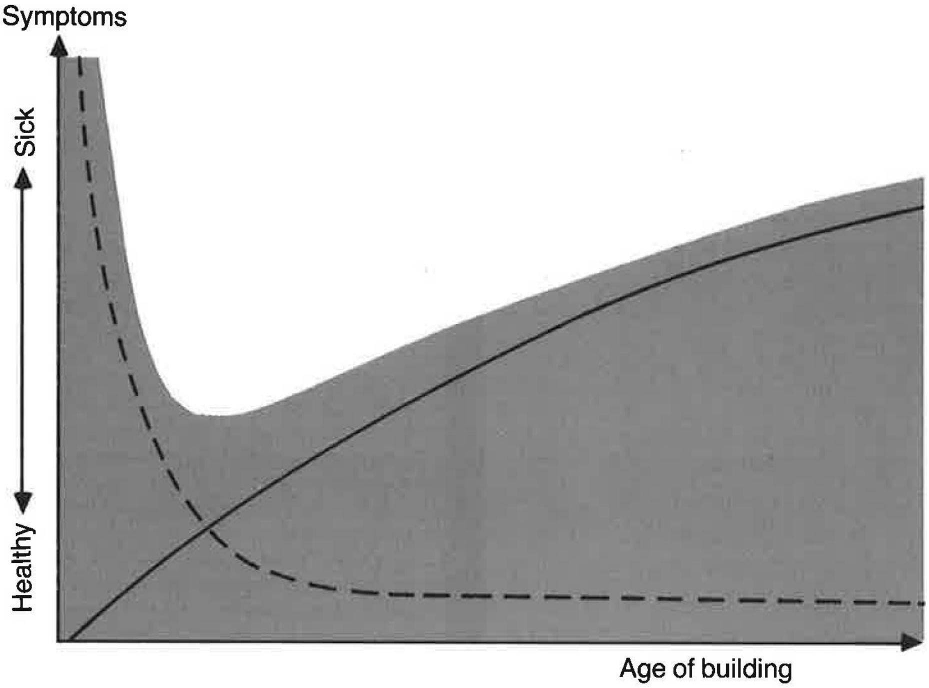
"The physical conditions prevailing in a building are of decisive importance for those symptoms which the users manifest," says Ole Valbjörn. The Danish Building Research Institute has, together with the Danish Indoor Climate Research Institute, conducted a survey among the employees in 28 office buildings in Copenhagen, and have measured the indoor climate in 14 of these buildings. Some 3,500 office employees answered the questionnaire.

The results show that temperature, the amount of fluff on textiles, the number of open bookcases, organic dust on the floor, and the number of people in the room play a decisive rôle in the occurrence of such symptoms suffered by the employees as headaches and mucous membrane irritation in the eyes, nose and throat.

These measurements, which were carried out at the same time as the questionnaire survey, registered the presence of formaldehyde, microspores, bacteria, mineral fibres, organic gases, particles and carbon dioxide, to name only few. The measurements also showed that even if the carbon dioxide concentration in the air indicated a satisfactory level of ventilation according to applicable standards, a large number of the employees in many of the buildings complained of stale air. This means that other sources of pollutants than people are of importance for how the quality of air is experienced, as Ole Valbjörn explains. "We must focus on the building materials in the room and do something about them. Instead of simply ventilating off the pollutants, we must attack the problem at source. This is why we should make every effort to determine what different materials emit so that it may, in future, become a requirement of the building materials producers to set out such information."

Let new buildings "degas"

Ole Valbjörn wants to divide up pollutants from building materials into three groups. One group consists of the free and unbonded pollutants which comprise the excess formaldehyde from adhesives in chipboard, loose fibres in mineral wool ceilings, or disinfectants and solvents in paints. A



– – – Symptoms because of "degasing" from the building material.

——— Symptoms because of accumulated or released "bonded" pollutants, reduced ventilation.

■ Total symptoms.

A building may be "sick" for its first six months – become healthy – and then become "sick" again. One of the reasons for this is that pollutants may be accumulated in building material and later emitted into the indoor air.

second group comprises those pollutants which are more or less bonded, for example formaldehyde in a chemical compound which is reasonably stable, mineral wool fibres in sound-absorbent panels in acoustic ceilings or asbestos fibres in panels and walls. The third group relates to pollutants which occur by adsorption or accumulation, for example in wall-to-wall carpeting.

"It is important to single out the particular relevant group. Those pollutants which may be suspected in a sick building depend upon the length of time which has elapsed since the building was first constructed," says Ole Valbjörn. The free, unbonded pollutants are present in large concentrations during the first six months after the building was completed. Hence, a new building should be given six months to 'degas' before people occupy it daily. By raising the temperature and increasing the level of ventilation when the building is new, it is also possible to cause the unbonded pollutants to disappear more quickly."

Bonded pollutants can be released

The bonded pollutants are not always fully bonded but may be released if mechanically damaged or if they are exposed to damp or high temperature. "There is always a certain risk that a bonded pollutant may be released," Ole Valbjörn emphasizes. In Denmark, the most serious problems in this area have related to formaldehyde and fibres from mineral wool ceilings which have been released in conjunction with damp or water damage.

Ole Valbjörn points out that an immense amount of mineral wool ceiling has been installed in many of today's Danish and Swedish office buildings. When some types of mineral wools are damaged by damp, the water-soluble adhesive that binds the mineral wool fibres is then dissolved and the fibres come loose.

Ole Valbjörn would most like to recommend that mineral wool should not be employed at all unless it is thoroughly wrapped. In addition, there should be a systematic and careful cleaning operation to remove the tiny amount of mineral wool which, under any circumstances, will leak out.

Pollutants adsorbed by the fittings

Building materials which adsorb and accumulate pollutants in the indoor air should be avoided or replaced over a phasing-out period. It has been shown that buildings in which the users have complained of headaches or mucous membrane irritation often have wall-to-wall carpeting or other adsorbent or accumulating material.

One example of adsorption and emission of pollutants is a case of an allergic child who experienced problems with the air in his room. To establish the cause, the Building Research Institute approached the problem methodically and first conducted a chemical measurement of formaldehyde in the room. This showed 0.21mg/m^3. The furniture was then removed from the room and the formaldehyde concentration fell to 0.17mg/m^3. When the chipboard in the ceiling had been removed, the formaldehyde content fell to only 0.15mg/m^3. Finally, the wall-to-wall carpeting was removed, giving a formaldehyde concentration of 0.09mg/m^3. Hence, the carpet had adsorbed formaldehyde and emitted this pollutant into the indoor air. When the carpet had been cleaned it could be relaid. After all, it was the chipboard in the ceiling which had been the true source.

Organic dust affects health

Ole Valbjörn is convinced that many problem buildings have a number of factors in common. They are between 10 and 15 years old, have complicated ventilation systems, and have wall-to-wall carpeting. The buildings of the 1980s are becoming simpler, with fewer, manually operated installations and with interior decorating materials which are easy to clean.

"This said, the cleaning operation may constitute a problem in itself. Many cleaning agents are a source of pollutants, for example ammonia. When a carpet is sent to the dry-cleaners, there are always chemical residues left in the carpet.

This study would seem to indicate that the organic components in the dust have an effect on human beings. Consequently, proper cleaning is of vital importance. Another measure to reduce the emission of pollutants from building materials is to maintain a low indoor temperature. This reduces the level of biological activity.

Dimensions of emission from materials

What we need now is a dimension of the performance capacity of building materials, a scale for specific functional requirements. The emission of smell from materials can then also be indicated. A building purchaser can then insist that building materials which are guaranteed odourless within two months are to be used. It is also possible to impose clearly defined demands on the emission of fibres, sensitivity to water and moisture etc.

Ole Valbjörn believes that this program is perfectly feasible if we can only increase the awareness of both users and producers of building materials of the importance of a good indoor climate.

Birgitta Bruzelius

Literature:

Rådhusundersögelsen. Ole Valbjörn, Statens Byggeforskningsinstitutt and Peder Skov, Arbejdsmedicinsk Klinik Rikshospitalet. Särtryck Dansk VVS No. 12, 1987.

Nielsen Peter A. *Indendors luftforureninger fra byggematerialet. Sunda och sjuka hus,* the National Board of Physical Planning and Building, Stockholm, Report 77, 1987.

Volatile substances in the indoor air

Building materials emit different types of fumes and vapours. By ventilating, it is possible to reduce the concentration of volatile substances in the air. However, every attempt should be made to choose building materials of low emission levels. At the Department of Chemical Engineering at the Royal Institute of Technology (KTH) studies are in progress into the various factors behind the emission processes.

It has long been known that building materials emit different types of vapours. Activities in premises may, on occasion, be a contributory factor in large-scale emissions of different volatile substances. For example, the latter is an extremely common problem in work in chemical and other laboratories where solvents are handled. Some of these vapours may be irritant and some may even give rise to pathological symptoms. In many cases where there is a mixture of a number of substances in the air, it may be difficult to pinpoint any particular substance as that which causes the irritation. Consequently, attempts are made to reduce the concentration of foreign substances in the air as far as is possible.

Three ways of reducing the concentration of volatile substances in the air

Fundamentally, the concentration of such substances in the indoor air may be reduced by three ways: by ventilation, by cleaning and by reducing the input of such substances.

Normally, all premises are ventilated without the need to adopt special measures but in some cases such ventilation is insufficient to reduce the concentration to an acceptable degree. Laboratories and industrial premises are often ventilated ten times or more than is the case for normal dwelling rooms. It is not a practical proposition to ventilate dwelling rooms more than is the current standard, because the energy costs for heating would then rise very steeply indeed. Nor is the air in normal dwelling areas purified of vapours, simply because no suitable technology has been evolved to this end. The emission of vapours from building materials may be greatly reduced by employing materials that contain little or no volatile substances. Another way of reducing these emissions is to select materials whose emission rate is so low that the standard ventilation can remove them to a sufficient extent.

In order to enable materials with a low concentration or low rate of emission to be selected, these properties in the building materials must be identified. At present, there are no standardized methods available for carrying out such measurements.

Materials tested in climate chamber

A large number of different materials have been tested in so-called climate chambers. In such a chamber, the building material is caused to emit its vapours into the air which flows through the chamber at an air change rate which approximately corresponds to normal ventilation. The amount of building material is also adapted so as to correspond to the room volume. The temperature and humidity of the air are regulated. The concentration of vapours in the exhaust air is measured.

This method shows at once those substances which are emitted and how quickly they are emitted. On the other hand, it does not show the total number of substances present, nor the length of time during which the emissions will continue. Consequently, it would be greatly advantageous if, as a complement, there were methods by means of which it would be possible to determine the concentration of these substances in the material. In addition, it would be of value to know exactly what determines the "dissipation rate" from the material itself. It will readily be perceived that it can be a more serious problem if the material continues to dissipate these substances for many years – or even decades – than if the concentration is initially high but emissions cease after a short time.

The dissipation will be of longer duration if the material is thick than if it is thin, even if the concentration of substances is the same.

The dissipation rate for substances from a building material may depend upon several factors. In addition to the concentration and vapour pressure of the volatile substances, the emission rate is greatly influenced by the diffusion of the substances in the material. Factors such as solubility and adsorption capacity of the volatile components in the solid constituents of the building material influence this emission.

Research into the emission processes

In a research project in progress at the Department of Chemical Engineering at the Royal Institute of Technology we have begun to examine a number of the abovementioned factors. The purpose of this project is to increase our understanding of the emission processes so that:

☐ the emission rate for different substances may be predicted;
☐ the duration of the emission rate may be predicted;
☐ materials may be designed to minimize such emissions; and
☐ the effects of different types of covering layers may be predicted.

In a literature study /1/ it has been revealed that building materials emit a very large number of different substances. Among these, mention may be made of the groups alkanes (n-hexane, n-heptane, n-decane etc.), alkenes (l-heptene, l-decene), terpenes (alpha terpenine), cyclohexanes (ethyl methyl cyclohexane), aromatic compounds (toluene, 2-xylene, 3-xylene ethyl and methyl benzenes), ketones (2-propanol, 2-butanon), alcohols (n-propanol, n-butanol), esters (n-butyl acetate, etoxy ethyl acetate), aldehydes and halogenizing alkanes (1,2 dichloroethane).

In a further literature study devoted to the transport mechanisms in the materials /2/ it was revealed that the transport of the volatile substances in the materials may be extremely slow because of the fact that the molecules diffuse slowly in the solid material. This diffusion rate is greatly influenced by the thickness and structure of the material. In a number of plastics, such diffusion may be extremely powerful depending upon the concentration of solvent. It is also extremely temperature-dependent.

A number of preliminary measurements taken on plastic carpets have been carried out to create a further documentary basis for designing measurement methods and measuring procedures.

Ivars Neretnieks

Ivars Neretnieks is Professor at the Department of Chemical Engineering, the Royal Institute of Technology.

Literature:

/1/ Wistedt P., Svedberg G. *Avgivning av hälsofarliga ämnen från byggnadsmaterial* (The Emission of hazardous substances from building materials). Literature report. September 1985. The Department of Chemical Engineering, the Royal Institute of Technology.

/2/ Wistedt P. *Avgivning av hälsofarliga ämnen från byggnadsmaterial* (The emission of hazardous substances from building materials). Situation report, October 1986. The Department of Chemical Engineering, the Royal Institute of Technology.

/3/ Wistedt P. *Avgivning av hälsofarliga ämnen från byggnadsmaterial.* Diffusion i polymerer (The emission of hazardous substances from building materials. Diffusion in polymers), October 1986. The Department of Chemical Engineering, the Royal Institute of Technology.

Manufacturers of paint, lacquer, glue:

Time for product control of hazardous materials

Increase knowledge into the relationship between materials and the indoor climate. Grade the problems. Then focus the interest and work on the major problems. Among a hundred new building materials there may be one or two which are substandard. Build up a control apparatus which discloses the real problems. - This is the method of approach that Ove Mattsson, Managing Director of Casco Nobel, thinks we should adopt for solving the problems with hazards in new building materials in the future. Casco Nobel is Scandinavia's leading producer and distributor of paint, lacquer and glue.

Casco Nobel's operations have traditionally been geared to manufacturing products for building purposes in a broad sense: for new building, renovation and repair. Their customers are to be found in the building materials industry, among craftsmen and DIY enthusiasts. The question is whether it is possible to find a room anywhere in Sweden which doesn't have a product from Casco Nobel. Products from the company are to be found between wood and concrete, between carpets and concrete or wood, behind tiles, on and in wall materials, roofing tiles, insulation, particle board, plywood and many other places.

What is the line of reasoning of the company management when it comes to the increasingly alarming problems with the indoor climate in our buildings?

Ove Mattsson.

Damp worse than materials

Ove Mattsson, who has been Casco Nobel's Managing Director for ten successful years, during which time the company multiplied its turnover by 20 to reach SEK 6.5 billion in 1988, believes that many of the problems of today's indoor climate can be traced to damp and poor ventilation.

"For example, our indoor paints are not designed for constant exposure to water or damp. Such a situation may occur, for example, when water condenses on a window. Our products are made for use in a 'normal environment'."

However, Ove Mattsson concedes that building materials can naturally also influence the indoor climate. The major emphasis of R&D work at Casco Nobel is to eliminate or reduce the negative environmental effects of the company's products. Modern analytical methods have made it possible to trace most of these. However, this wealth of new knowledge has created new difficulties. Not only the man in the street, but even our development technicians have difficulty in sifting out the really serious problems.

Reduced formaldehyde concentration, a voluntary process

One example which Ove Mattsson quotes is the systematic and exhaustive work that Casco Nobel has devoted to the problems inherent in formaldehyde. For many years, the company has worked on developing products that exhibit little or no emission of formaldehyde. In the 1970s, the demand for particle board far outstripped supply. From previously having only been included in furniture or shelving, particle board began to be used in interior decorating and building materials. The problem with irritating smell from particle board grew with increasing use and as a consequence of the energy crisis which demanded more airtight buildings and reduced ventilation.

"Sixteen years ago we were already aware that the emission of formaldehyde from particle board was a serious problem which demanded its solution. But there is a certain inertia in the system. It simply was not enough that we at Casco Nobel recognized that there was a problem here, we also had to get our customers - and their customers - to act for the acceptance of a new technology which was aimed at reducing formaldehyde emission from building materials," Ove Mattsson explains.

"Introducing new technology always entails problems and new risks. The company has to learn how a new product is to be manufactured, the customer has to learn how it is to be used, and so on. This is a matter of a long chain which must hold together. Perhaps one link in the chain will not realize the magnitude of an environmental problem, but prefers to await the decrees of the powers that be."

"The evolutionary process towards a steady reduction of formaldehyde emission from particle board was, generally speaking, a voluntary one," Ove Mattsson emphasizes and at the same time warns against any rash prohibition of products. Such prohibition may engender a process which is impossible to control and which may have negative consequences. There is an imminent risk of jumping out of the frying pan into the fire.

Regulation code for certain chemicals

Ove Mattsson feels that the regulation code now in existence for formaldehyde is sound. And he believes that there are grounds for regulating certain other chemicals in the same way. On the other hand, he does not believe in a general product regulation code for all building materials.

"I think that we need greater knowledge of the relationship between the indoor climate and building materials," says Ove Mattsson. However, he wishes to emphasize the importance of concentrating research efforts on finding the major problems. Among a hundred new building material products, one component might slip through which is substandard. It is crucially important to find and replace that product.

No obstacle to specifying components

One problem which Ove Mattsson would like to pinpoint is the use of the products.

"We have realized that our imagination does not stretch as far as giving us a picture of how our customers can use our products. It is a major task to inform consumers of the fields of application of the products and the conditions under which they will function. Here, it is important to concentrate on the retail trade. Our experience is that word-of-mouth information has the best effect. The consumer is not as receptive to directions for use and other instructive text."

Is there any obstacle to prevent Casco Nobel from specifying the components that are included in their products? Ove Mattsson feels there is none. The company is obliged to provide information on the hazardous substances included in their products.

One problem in certain types of adhesive is that they dissolve in water and glued constructions can come apart. Would it not be possible to manufacture more water-resistant adhesives? "Of course it's possible, but would it not be a better idea to reduce the level of damp in the indoor environment instead? After all, damp can damage many other things besides adhesive. Materials are manufactured for certain purposes, but will not hold up for others," he stresses.

Advice to developers

What advice would Ove Mattsson like to give to developers about to launch a new project?

"More efficient inspection and control of ventilation and damp problems, a certain caution with new and untried building materials. A continuous and careful assessment and evaluation of new materials is required before they are used on a large scale."

Nor is Ove Mattsson out of sympathy with the idea that new buildings could be left to stand and "degas" for a short while after the building is completed. He believes that with increased ventilation and heating, the building would dry out and become healthy more quickly.

Birgitta Bruzelius

The Testing Institute documents building materials

The construction industry has gone through many changes down the years. Right now, energy saving in building is the watchword – insulation is increased at the expense of ventilation through the building. To rationalize and speed up the building process, new materials are constantly being tried. Unfortunately, these changes are moving at such a pace that different phases may easily get out of step – and new problems then arise.

The need for a quickly setting adhesive for board material led to the first warning signals of a formaldehyde problem at the end of the 1970s. Progress has been made in both improving gluing processes and in measuring the emission of formaldehyde. Today, particle board manufactured in Sweden is subject to control and inspection as regards emission of formaldehyde. For the last couple of years, similar control and inspection has also applied to self-levelling screeds. Both of these inspections are carried out at the Chemical Analysis Section of the National Testing Institute. The screeds are inspected in respect of such matters as protein content (including kasein), ammonia emission and the tendency to emit other foul-smelling substances.

Methods

At the beginning of the 1980s, the Chemical Analysis Section developed an emission testing method for control of the emission of formaldehyde from different carbamide glued board materials. At the same time, we worked towards a standardization of the so-called perforator method which is used as a production control method. This latter method has now been listed as a European standard and is currently employed by most particle board manufacturers in Europe. The emission method which is based on a load factor = 1, i.e. 1 m^2 emitting surface enclosed in a chamber of a volume of 1 m^3 with an air change rate of 0.5 m^3/h under controlled conditions (+25°C and 50% RH) is now listed as Swedish standard and is also applied in the rest of Europe. The Federal Republic of Germany uses this method as a basis for its classification of particle board. Developments in this field are now pointing in two directions: first towards a requirement of steadily lower levels of emission from board material (which demands new production control methods), and secondly towards a wish for control over a growing number of product types which may emit formaldehyde, including interior furnishings and fittings such as cupboards and cabinets, kitchen joinery and furniture (new rules are on the way in the Federal Republic of Germany). This implies that new testing methods for complete interior decorating systems, furniture etc. are needed.

A "smallest room"

One of the more recent studies at the Chemical Analysis Section shows that the smallest room which is acceptable by the authorities in control of the construction industry in most European countries corresponds to a volume of approx. 17 m^3. A method based on such a room would most likely have every possibility of being accepted throughout Europe for classification of building materials and interior decorating fittings and fixtures. We are currently engaged in project planning for such a climate chamber.

Field studies

Field studies of problem buildings in respect of self-levelling screeds held between 1982 and 1985 demonstrated emissions of many different chemical substances in our indoor environment. Up to about 300 substances can be identified. The vast majority of these substances are present in infinitesimal concentrations. But there are also other substances which are present in manifestly higher concentrations than the first group. As far as these are concerned, we are now aware of the consequences of formaldehyde emission and smell problems with 2-ethyl hexanol when the degradation of plasticizers in polymeric materials has been stimulated by various means. Certain chemicals can, thanks to our experience, be linked to certain material types. In other cases, we are as yet unable to document the origin.

Any attempt to ascertain the consequences and risks which are related to the presence of chemicals in the indoor environment is fraught with difficulties. Our current assignments are limited in scope and they are primarily a matter of solving acute problems: should the carpet in the apartment be changed? Should board material in walls be replaced by some other material? and similar questions. As far as we are concerned, the results have so far been that we have not been able to quantify any risk for the substance under examination, but nor have we been able to exclude any risk. Acutely toxic – i.e. immediately acting-effects of different chemical substances are quite comprehensively documented. But in the indoor and dwelling environment, we are currently studying the effects of low concentrations over a long period of time. Such investigations are difficult and time-consuming and, for those reasons, are documented to only a limited degree.

What are we doing about the problems?

Our goal over the next few years is to work with systematic examinations and documentation of buildings and building materials to the extent our funding allows. We ourselves will be implementing a search through available toxicological information in this area for an appraisal of the risks, but our major objective will be on the one hand to develop relevant and decisive testing methods for building materials and on the other hand to gather data and other material which may be utilized by medical and professional hygiene expertise for risk appraisal and which may further serve as a basis in project planning. Prototype studies in accordance with our existing emission chambers have been started, at the same time as we are now putting new, more rational and efficient chemical analysis equipment into use within the fields of gas-chromatography and mass spectrometry.

Björn Lundgren

The Testing Institute documents building materials.

Björn Lundgren holds a Ph.D. in chemistry and is head of the Section for Chemical Analysis at the National Testing Institute in Borås.

Healthy buildings with a sound indoor environment

Part of the business of the National Testing Institute is to monitor the development of damage and its effects on the indoor environment of buildings. – The advice given to project planners is:
– Choose materials with known properties.
– Avoid problems in the design and in the material combination.
– Plan for the right level of ventilation in all areas.

The National Testing Institute works with questions relating to the indoor environment both in conjunction with such matters as investigation of damage, inspection of emissions from different materials, design of ventilation in buildings and in the planning of new constructions. The Testing Institute is often commissioned to evaluate the effects of measures adopted to counteract an unhealthy indoor environment.

Most of the problems which the Institute deals with relate to chemical pollutants or smells in the indoor environment, damage caused by damp or mould, and ventilation problems. These problems are often intimately related to one another. For instance, an examination of ventilation problems may lead to investigations of formaldehyde emissions from particle board, emissions of plasticizer from PVC flooring materials and mould in timber structures.

Healthy buildings

A healthy building offers good thermal comfort and suitable lighting. The building suffers from no noise and no pollutants. Unfortunately, not all buildings are healthy. A number of problems have arisen in recent years. It may be smell from mould and self-levelling screed which, it is believed, lead to tiredness, headaches and other sources of discomfort. It may also be completely new substances which have not been used before or have not been pinpointed as a problem source. The emission of formaldehyde, smells from building materials and radon emission from materials and ground are examples of just a few such sources.

The Testing Institute is in regular contact with the private sector, particularly in the field of ventilation. Materials and designs are inspected, and new products and designs are assessed and tested in the development stage. The knowledge gained from such activities, together with the experience of any number of damage claim investigations, constitutes the basis of the activities of the National Institute of Testing with regard to the indoor environment.

Sick buildings

Inefficient or faulty ventilation is often the reason why a concentration of pollutants accumulates in a building. There are also cases in which people living or working in a building become ill without it being possible to find the cause of the complaint. Such buildings are usually called sick buildings.

Materials and designs are checked and new products and designs are assessed and tested in the development stage at the National Testing Institute.

Emissions into the indoor air

The most important measure to be adopted for solving problems in the indoor environment is to reduce the emission of pollutants into the indoor air. Accordingly, planning for adequate ventilation is a key aspect.

There are two ways in which emissions can take place into the indoor air. They may come from materials which themselves emit pollutants. Examples of this are radon from blue aerated concrete, formaldehyde from certain types of particle board and plasticizer emissions from PVC.

But the emissions may also come from materials that emit pollutants in contact with other materials, or in an unsuitable design. One example of this is self-levelling screed which, in a damp alkaline environment, emits ammonia.

In both cases, the National Testing Institute has devoted a great deal of work aimed at clarifying the relationship between emissions and problems in the indoor environment.

What can be done?

If a building is to become healthy, it is vital to plan and construct the building in a certain way. But even so, this does not guarantee that the indoor environment will be healthy. The activities conducted in the building, the interior fixtures and fittings may also emit pollutants.

Some advice to planners:

☐ Select materials whose present and future properties are known.

☐ Design the structure and combine materials so that no problems can arise.

☐ Plan the ventilation so that every room and every space receives the correct degree of ventilation. Check the efficiency of the ventilation both on installation and after one year's operation. Draw up simple operational and maintenance instructions.

Ingemar Samuelson

Ingemar Samuelson, D.Eng., is a department head at the National Testing Institute, Box 875, S-501 15 Borås.

Comprehensive SML study:

Do radon-affected houses cause cancer?

Radon is dangerous, but how dangerous? Investigations have been in progress since the end of the 1960s, but research workers are still far from agreeing on a final assessment. "The current radon daughter concentrations in dwellings will cause approximately 1,100 future cases of lung cancer" (SSI 1982). "300 people a year will be afflicted by lung cancer caused by radon daughters" (the Cancer Committee 1984). This year sees the start of the largest radon study in Sweden so far. The relationship between the frequency of lung cancer and living in a radon-infested house is to be plotted with the help of 4,500 test subjects in 109 Swedish municipalities.

Radon is that noble gas which is formed when the radioactive substance radium disintegrates - and radium is found in the ground, in building materials and in the groundwater.

It is not radon itself which poses the greatest threat to people, it is the so-called radon daughters. Those which "stick" in dust and tobacco smoke and are then inhaled into the lungs. On average, the radon daughters indoors give a radiation dose in Sweden that is ten times higher than the fall-out from Chernobyl.

Miners the first to suffer

Many radon investigations have been carried out both in Sweden and internationally. A common denominator for these investigations is that they have concentrated almost exclusively on facts from a group at extreme risk - miners. Those studies which have been conducted to elucidate the relationship between lung cancer and radon in dwellings have not been equally exhaustive. They were rather of a pilot nature, with a view to testing new research methodology.

The Swedish epidemiological survey which is now being started on the initiative of the Swedish Cancer Committee differs markedly from its predecessors - primarily as regards the size of the survey material.

Professor Göran Pershagen from the National Institute of Environmental Medicine (SML) will be leading the project.

"Sweden is in a unique position, having built so many houses with radon-contaminated materials. We also suffer from problems of high concentrations of radon in the ground. At the same time, Sweden is well-suited to this type of study, thanks to our civic registration number system and the fact that we have a cancer register."

11,000 dwellings

Of the envisaged test subjects, 1,500 are lung cancer cases and 3,000 are reference subjects. The lung cancer cases consist of people aged between 35 and 74 who became ill in 1980–1984.

The research group intends to measure the radon daughter concentrations in all dwellings in which the test subjects lived for at least two years since 1945. Calculating on a certain loss, it is expected that roughly 11,000 dwellings will be examined. The National Institute of Environmental Medicine, the Department of Occupational Medicine at the Linköping Regional Hospital and the Oncological Centre at the Umeå Regional Hospital are responsible for administration and gathering of measurement data – an assignment which is expected to take five years. Hence, a report should be ready by 1992 and it has been calculated that the entire project will cost a good SEK10 million.

"We hope that this survey will enable us to quantify in a manner which has never been done before", says Göran Pershagen, adding the disclaimer, "but there will still be a number of uncertainties".

In addition to the relationship between radon and lung cancer, the effects of the interaction with other factors that influence the risks, in particular tobacco smokes, will also be studied. It was recently born out in a study conducted by the Department of Occupational Medicine in Linköping that the risks for lung cancer increase considerably for smokers who live in radon-affected houses. Occupiers of radon-affected houses who are passive smokers also run a greater cancer risk than other occupiers of radon-affected houses, to be precise a risk which is three times as great.

Great uncertainty

While awareness has already been focused on the risks posed by radon at the end of the 1940s, in-depth studies have come up with widely diverging conclusions.

Gun-Astri Svedjemark PHD is head of the Environmental Laboratory at the National Institute of Radiation Protection (SSI) and is one of the authors of the situation report published by SSI "Radon in dwellings" from 1987.

Like Göran Pershagen, she points to the considerable degree of uncertainty and the widely differing study results in the risk assessments which have been carried out hitherto.

"A number of studies have been conducted relating to lung cancer and its link with radon daughter exposure in dwellings both in Sweden and abroad. The greatest difficulties in such studies are in establishing the level of exposure to which people have been subjected and in the realizing that it is not only exposure to radon daughters that may cause lung cancer," Gun-Astri Svedjemark writes in her report. As an example, she mentions the Environmental Protection Agency in the United States which has calculated a relationship risk which is four times higher than that forecast in corresponding European research studies.

International consensus

While the risk assessments in themselves differ from one part of the world to another, some degree of consensus can be discerned as regards recommendations and the limitation of radon daughter concentrations in dwellings.

The International Commission on Radiation Protection (ICRP) recommend that measures should be adopted when radon daughter concentrations in existing dwellings exceed 200 Bq/m^3. In those cases where such measures are of a complex nature, a reduction of the radon concentration is recommended at levels of more than several times 200 Bq/m^3. The Nordic radiation protection authorities and the World Health Organization WHO have issued a similar message: "Measures should be taken if radon daughter concentrations in new and existing dwellings exceed 100 becquerel (Bq) per cubic metre, if such measures are of a simple nature. In those cases where the solutions are greatly complicated, measures are recommended at levels of 400 Bq or more per cubic metre of indoor air." All three organizations are agreed that new buildings should always be designed so that the level falls beneath 100 Bq/m³.

Sweden first

In most of the countries where measurements were carried out, the concentrations proved to be higher than expected.

So far, the Nordic countries have the largest proportion of buildings with very high concentrations and it is also here that the highest land mean value concentrations are to be found.

According to a nation-wide study carried out in 1980–1982, it is calculated that half of Sweden's dwellings have radiation levels of around 30 Bq per cubic metre. On average, the cubic metre value is at about 50 Bq.

Sweden was first to introduce general restrictions on the radon daughter concentrations in dwellings. The annual mean value limit is 70 Bq per cubic metre in new dwellings, while, for renovated buildings, this limit has been raised to 200 Bq per cubic metre. When an annual mean value of more than 400 Bq per cubic metre has been ascertained, this constitutes a sanitary inconvenience. Approximately 1 per cent of Sweden's housing stock belongs to this group.

Authorization

So much for research, international and national directives. But if anyone suspects the presence of radon in his home, who carries out the investigation – and WHO is entitled to carry out the investigation?

The municipal environmental and health protection authorities themselves carry out such measurements, but to a limited extent. Private consultants ranging from the conscientious to the cowboy are also prepared to undertake such jobs.

"Some believe that authorization may be warranted. This business is not without its swindlers and back-street offices," says Gun-Astri Swedjemark, who also tells us that lots of people come to the testing rooms at the SSI in order to have measuring equipment tested and calibrated.

Last autumn, the Radiation Protection Board, the National Board of Physical Planning and Building and the National Board of Health and Welfare submitted to the Government a request for an official inquiry into the question of authorization. This matter has now been embodied in a green paper and will, in all probability, become a government bill within the near future.

Jan Örnéus

Literature:
SSI report 87–17, *Radon i bostäder* (Radon in dwellings). Situation report 1987.

It takes more than ventilation to deal with radon

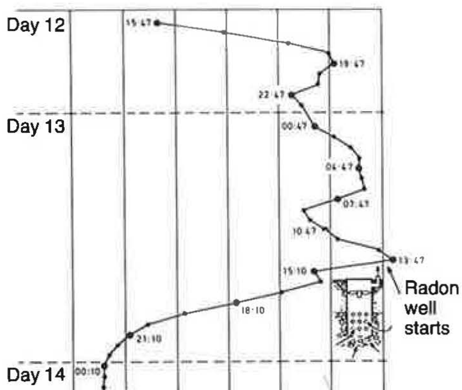
Radon – a noble gas with an incredible ability to frighten people. Radon is present in every Swedish dwelling. It has been estimated that the mean value of the radon daughter concentration for all apartments is 53 Bq/m³, is slightly higher for single-family dwellings and slightly lower for multiple dwelling blocks.

When the problem of radon in dwellings hit the front pages at the end of the 1970s, it was the alun-shale-based lightweight concrete – so-called blue light-weight concrete or simply blue concrete – which was pinpointed as the major radon source. This material has been widely used, primarily in outer walls and non-structural partition walls. There are also many floor structures that consist of light-weight concrete elements or are thermally insulated with crushed light-weight concrete.

It was already known at that time that the ground could emit radon into the indoor air, but the significance of this knowledge was not properly understood. In conjunction with a building research project commenced in the autumn of 1980, a closer study was made of the effects of the ground on radon concentration and gamma radiation indoors. The results of this project may be summarized in the following points:

☐ Radon is, for the most part, transported with ground air into the building through cracks, gaps and other untight spaces in the building structure. Diffusion of radon from the ground is normally so slight that this method of transport is hardly likely to have any effect on the radon concentration indoors.

☐ The ground air is sucked into the building because of the partial vacuum which normally prevails in the building in relation to the ground. The amount of ground air which is sucked into the building depends not only upon the magnitude of the untightness in the building, but also to a large extent upon the air permeability in the ground beneath and around the building. Minor openings in the foundation structure of buildings on rubble filling or levelling material may give rise to considerably greater air flows from the ground than larger openings in buildings sited on clay.



The radon daughter content measured with continually measuring instruments for 24 hours before and after starting the fan in the well.

☐ In air-permeable ground, air is sucked from a large ground volume, with the result that the air change rate in the ground will be smaller, despite the fact that a relatively large volume of air flows into the building. In turn, this implies that the radon concentration in the ground air is maintained at a higher level than would be the case if the ventilation in the ground had been dimensioned on a larger scale.

An account of this project is presented in BFR report No. R9:1983.

It has been calculated that radon from building materials may give rise to as much as 700-800 Bq/m³ in radon daughter concentration if the ventilation system is substandard, while the ground radon may give rise to several thousand Becquerel per cubic metre in the indoor air.

How can ground air be prevented from leaking into the building?

The first measure should be to seal those points of leakage which are accessible without any major operations being carried out in surface layers etc. Such points of leakage may be large cracks in the cellar floor, holes at pipe and cable entries, and at cleaning hatches or manholes. When these operations have been completed and the result is still unsatisfactory, one of the following measures may be adopted. All four measures influence the difference in air pressure in the ground and air pressure indoors.

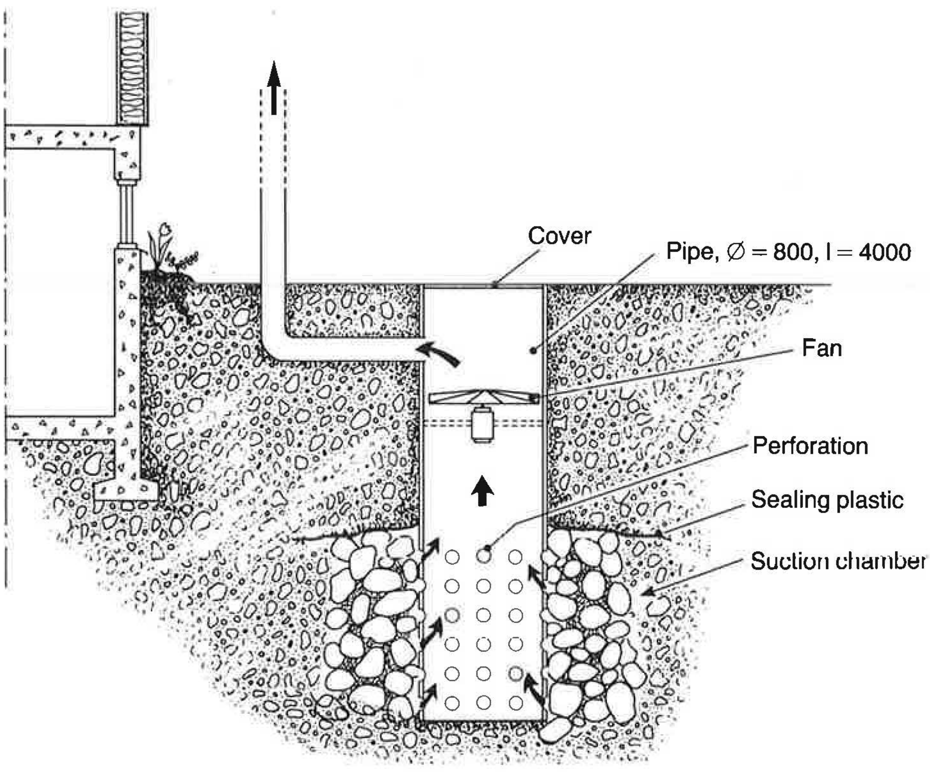
Installation of balanced ventilation, i.e. a mechanical supply and exhaust air system. This measure is relatively costly but provides vastly improved air comfort indoors. Noise from fans and the whisper from flowing air may be perceived by dwellers as disturbing. The plant should be provided with a heat exchanger to reduce energy costs. However, an improved effect on the radon daughter concentration can be obtained using the following methods even though they are cheaper than the installation of a balanced ventilation system.

Installation of a radon suction extractor to create a partial vacuum beneath the concrete slab into which holes are drilled at one or more points. A ventilation duct is then connected to each respective hole and coupled to a small duct fan. The effects of this measure depend upon how the vacuum that prevails in the duct opening beneath the concrete slab may be propagated out under the slab. In buildings with no cellar (built on a slab on the ground), and in split-level housing, this method can ensure cooler floors since cold outdoor air is sucked down beneath the slab.

The principle of the air cushion method is that the radon-contaminated earth air is forced out from beneath the house by indoor air being forced under the foundation slab by means of a fan.

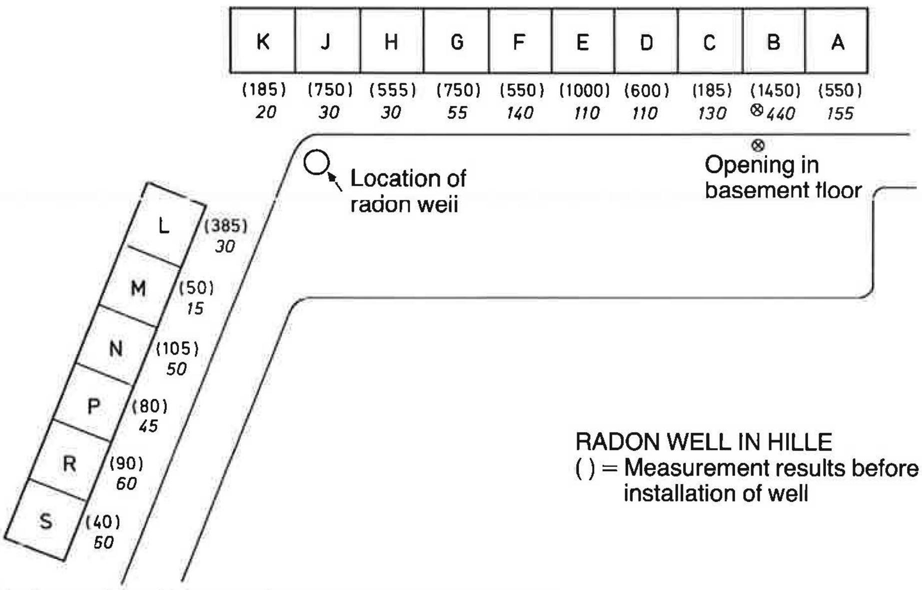
Whether these measures are sufficient to reduce the radon daughter concentration to the desired level depends upon the degree of success in getting out the excess pressure beneath the concrete slab; compare the radon extraction method.

Advantages of this method are that it provides warm floors and may eliminate certain problems relating to damp. Cost may be a disadvantage.



Radon well at Brunkebergsåsen in Sollentuna.

The effects of a radon well are based on the same principle as a radon suction extractor. The advantages of the radon well in relation to the radon suction extractor are that the entire installation is sited outside the building, which means that no holes are required in concrete floors, that there is no risk of leakage from the plant itself and that there are no noise problems. Moreover, the risk of cold floors is considerably reduced, since the radon well does not suck in cold air beneath the building in as concentrated a manner as the radon suction extractor may do. One disadvantage of the radon well is, however, that it requires air-permeable ground, for example levelling material, between the well and the building.



Radon well for 16 houses in a terraced housing estate.

Shutting out the radon...

It is also possible to prevent ground air contaminated with radon from leaking into the building by coating the concrete floor with a glued asphalt mat. However, it should be remembered that leakage most often occurs in the angle between floor and wall and at pipe lead-ins and hatches.

When it comes to preventing radon emission from the surface of a wall of alun-shale-based light-weight concrete, other radon-tight materials are conceivable, for example certain types of vinyl wallpaper or epoxy paint. The problem, however, is that even if the radon exhalation from the surface is completely eliminated, a certain amount of radon will still emanate from the wall, namely at floor and ceiling angles, behind frames and at recessed fuse boxes etc.

Since the methods of treatment listed above provide layers which are also diffusion-tight to water vapour, the greatest attention must be paid to the moisture conditions in the different constructions.

...and ventilating

If the measured radon or radon daughter concentration is caused by radon solely emanating from the building material, it is possible to halve the measured concentration by doubling the air change rate.

The air change rate in many buildings can be improved after an overhaul of the existing ventilation system no matter whether this is of the natural or mechanical type. Ducts may become more or less completely blocked by dust and fat or by leaves and branches blowing in from the outside – and much else besides – for which reason thorough cleaning may be necessary and may prove quite successful. In mechanical exhaust and balanced ventilation systems, it is particularly important that duct walls and connections to devices, hatches etc. are air-tight. Existing supply air devices must be kept open and be of such condition as to allow air into the building. In small buildings and private homes, it is usual that there are only supply air devices such as disk valves in one or a few spaces in the basement. Naturally, these valves must be open or ajar in cold weather, but it is also necessary that the air may pass further into the building from these spaces through gaps at the doors, if these are often shut, or through special transfer air devices.

One simple measure for rapidly improving ventilation in buildings with natural ventilation or mechanical exhaust ventilation systems where the air supply is insufficient is to cut away 15–20 cm of the sealing strip at the upper edge of the windows. This measure may then further be improved by mounting so-called slot air terminal devices which are suitably installed in the window frame head in those rooms where priority has been given to increasing the air change rate. One of the reasons for siting these devices in the window frame head is to reduce discomfort caused by draught. There are also other types of supply air devices, grilles, which may be suitable as alternatives to the slot valves.

A natural ventilation system is difficult to finely tune. Its effect depends upon the temperature difference indoors/ outdoors, wind conditions etc. In the winter it may provide adequate ventilation, but in the summer no ventilation at all unless rooms are aired by opening windows. In many small buildings and private houses, an existing natural ventilation system can be modified to a mechanical exhaust air system by connecting the exhaust air ducts and adding a fan. Existing exhaust air valves should, if the ducts are of acceptable tightness (a pressure test should be carried out by an expert), be replaced by modern exhaust air devices with a larger pressure drop than that prevailing in the natural ventilation system. This will result in a ventilation system which may be regulated to the desired air change rate in the building as a whole, on condition that a sufficient volume of air is obtained through valves, grilles and other openings. However, there may be certain difficulties in achieving the desired air change rate in each individual room.

Since one or more exhaust air duct may, in natural ventilation, act as a supply air duct, there is a risk, in conversion of a natural ventilation system to a mechanical exhaust air system, of an increasing amount of ground air contaminated with radon resulting in a drastic increase of the radon concentration in the room unless the corresponding amount of supply air can be obtained through newly-installed grilles in outer walls. Consequently, care should always be taken not to increase the partial vacuum indoors.

Bertil Clavensjö

Bertil Clavensjö is a research engineer with Bjerking Ingenjörsbyrå AB, Uppsala.

Literature:

Andersson, P., Clavensjö B and Åkerblom G. Radon i bostäder. *Markens inverkan på radonhalt och gammasträlning.* Byggforskningsrådet R9:1983.

Clavensjö B. and Kumlin H. *Radon i bostäder. Byggnadstekniska åtgärder vid ny- och ombyggnad.* Byggforskningsrådet R90:1984.

Erikson B. E. et al. *Markradon i småhus. Undersökningar och förslag till åtgärder.* The National Institute for Building Research. Publication M 83:1.

Radon wells–and all's wells

Almost half of the buildings that stand on gravel outcrops have unacceptably high radon daughter concentrations. The installation of a radon well has succeeded in reducing the radon daughter concentration to only 2–4 per cent of the original level.

In two of the building research information leaflets (No. 2 and 3/68) written by senior officials at the National Board of Radiation Protection and published some 20 years ago, it was stated that the radon daughter concentrations in our dwellings could be considerably reduced by improved ventilation.

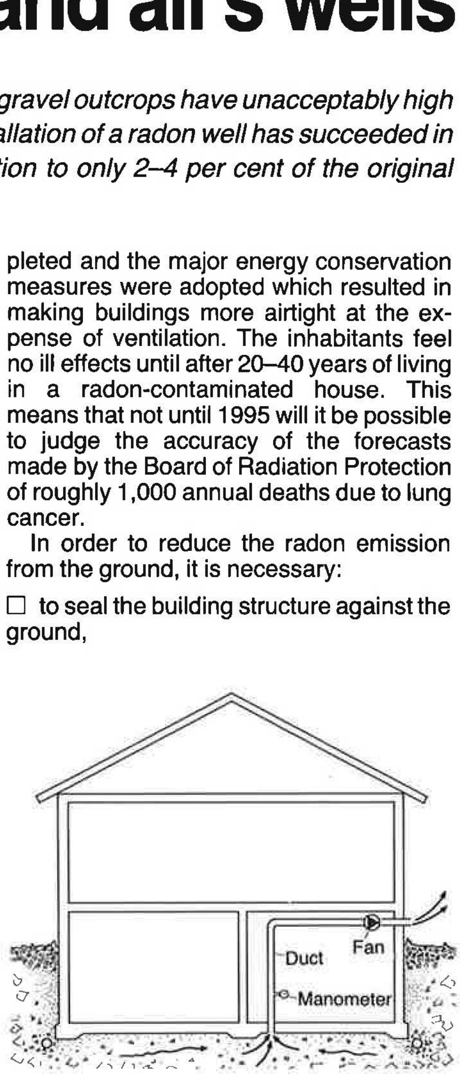
However, radon enters dwellings not only from the building materials, but also from the ground and water contaminated by radon. A major problem in this context is the Swedish gravel outcrops. As such, the outcrops are not particularly radioactive, but, on the other hand, they are highly permeable, in other words they readily allow the passage of air and water. As a result, houses built on gravel outcrops and not airtight towards the ground may be affected by radon gas which leaks in because of the partial vacuum created by the ventilation system. Almost half of such houses built on the crown of a gravel outcrop suffer from excessively high radon daughter concentrations, i.e. above the statutory limit of 400Bq/m^3 and are therefore in urgent need of remedy.

Energy conservation – the reverse side of the coin

It is generally assumed that the radon daughter content in our dwellings rose in about 1975, which was the time when the "million dwellings program" was completed and the major energy conservation measures were adopted which resulted in making buildings more airtight at the expense of ventilation. The inhabitants feel no ill effects until after 20–40 years of living in a radon-contaminated house. This means that not until 1995 will it be possible to judge the accuracy of the forecasts made by the Board of Radiation Protection of roughly 1,000 annual deaths due to lung cancer.

In order to reduce the radon emission from the ground, it is necessary:

- ☐ to seal the building structure against the ground,
- ☐ to reduce the vacuum beneath the building by means of a fan indoors,
- ☐ to reduce the vacuum by means of a radon well.



Ventilation of substratum in, for example, houses built on rubble filling.

Not so costly

The installation of a radon well will prove highly successful if the building rests on a gravel outcrop. Basically, a well pipe is sunk approximately 4 metres down into the ground outside the building (or buildings) in question. A fan is installed in the well. For a small well, the installation costs need be no higher than for a fan installed in the house itself. There is a further advantage with a radon well – quite simply the absence of irritating fan noise in the dwelling. Nor does it take up any space indoors for fan and installations.

To cite one example, a single radon well has lowered the radon daughter concentration in ten to fifteen buildings. If the well is, moreover, correctly dimensioned, it will be capable of reducing the radon daughter content in the dwelling to as little as 2–4 per cent of the original concentration. This said, further experimental building in this field is likely to be needed.

Both of the research workers, Bengt Clavensjö at Bjerkings in Uppsala and Bengt E. Eriksson, the designer of the well, at the Institute for Building Research in Gävle, who have further developed this method, also emphasize the necessity of continuously acting radon daughter measurement instruments and the need for competent staff to handle them. Besides, the Council for Building Research has, in its green paper response to the Department of the Environment and Energy, strongly approved voluntary authorization in respect of determining the annual mean value of the radon daughter concentration indoors for comparison with the statutory limits.

Bengt Steen

Research into mildew in buildings

What is mildew? How do we recognize it and diagnose it? Is it dangerous? How do we get rid of mildew? Questions relating to mildew – causes, effects and countermeasures affect all of us in our use of buildings. The following article provides a brief survey of where building research stands today on the question of mildew.

Mildew is not a new phenomenon, but in just a few years it has become one of our major headaches in buildings. Why has this come about? There is no single answer to that question and, in many areas, there is insufficient knowledge to allow for an answer.

Mildew – or rather mildew fungi – occur generally in our environment. They are multicell micro-organisms with a well-developed cell nucleus and complex metabolism, and may occur in different forms of life. The following general conditions are necessary if mildew fungi are to grow and propagate:

- ☐ moisture (more than 70 per cent RH)
- ☐ oxygen
- ☐ nutrients (for example wood, but also other organic substances)
- ☐ a suitable temperature range (from slightly above 0 to approximately 45 °C).

In addition, it is also necessary that there are no fungicides, ultraviolet radiation, ozone and antagonistic fungi or other organisms.

Mildew is everywhere

Given the fact that there are tens of thousands of mildew fungi strains, and given the above conditions for growth, it may come as no surprise that the conditions for mildew growth are present in every building. However, it is not known why, for example, buildings from the late 1970s and early 1980s are more subject to mildew problems than older buildings in the same conditions. This problem has been approached from several directions and there are a number of different hypotheses which, however, still remain to be proved.

Another problem in this context is that it is far from every type of fungus which emits the "typical" mildew smell. To make the picture even more complicated, one and the same type of fungus may smell quite differently depending upon the nutrient on which it lives!

Thus, mildew grows everywhere but – as luck would have it – we are troubled by mildew in only a limited number of cases. Often, mildew attack is an esthetic problem in the form of patches etc. However, most commonly it is the smell that causes the trouble. But, as we have seen above, it is not self-evident that mildew will smell, nor that the mildew fungi smell the same in different places.

Mildew attack causes a more serious problems in cases where the spores give rise to allergic reactions. Today's knowledge about mildew fungi and their effects on people's health is uncertain, although we do have a number of strains that we know with certainty to cause allergic reactions in sensitive people.

Damage caused by damp beneath a roofing structure. This damage has been caused by a high humidity level in combination with poor insulation in the attic. Photo: Rune Pehrsson, Familjebostäder, Stockholm.

Pink-coloured mildew!

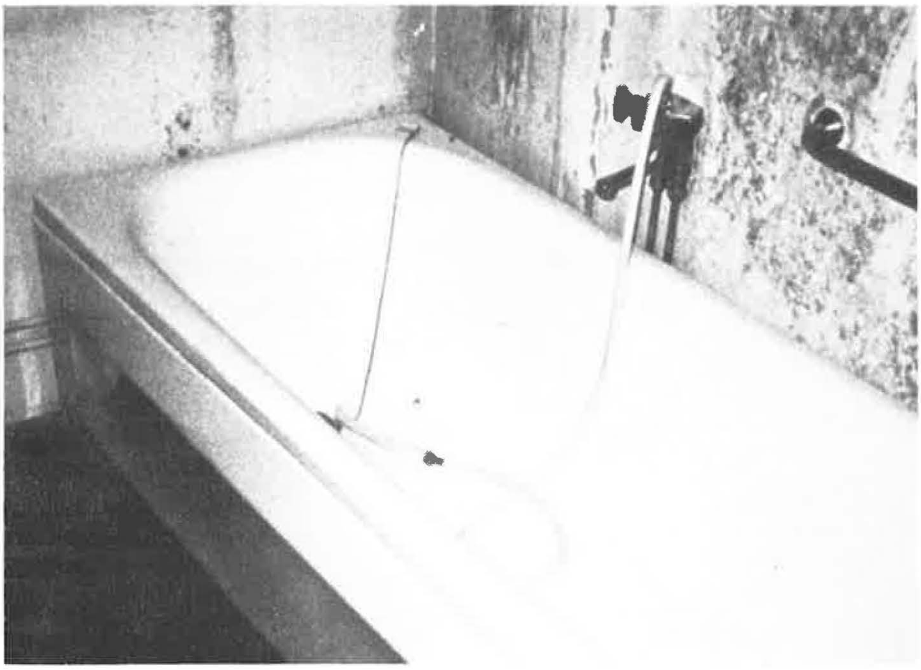
Mildew normally occurs at a few particular places in buildings. First there is the simplest type: brownish green, sometimes black, or on plastics even pink eruptions on walls and ceilings, normally in bathrooms or other wet areas. This type of "visible" mildew may also occur outdoors on wooden cladding etc. The stains can be scrubbed off using a strong detergent, but will normally return after a few weeks. In a number of research projects, this problem has been studied and different remedial measures have been tested.

The causes of mildew growth in this case are either materials or poor ventilation with a consequential unacceptably high humidity level. In such publications as "Mögel i våtrum" (Mildew in wet rooms) (Building research report R5:1986), countermeasures against damp and mildew in this case have been presented. However, it should be kept in mind that even if the level of damp is reduced as a result of increased ventilation, mildew may nevertheless germinate simply because the materials employed not only contain suitable nutrients but also bind water (chemically or by other means) so that the mildew spores may survive long periods of "drought".

Mildewed buildings

Discussions concerning mildewed buildings do not normally refer to buildings afflicted with the problems mentioned above. Instead, a mildewed building is generally taken to mean single-family dwellings where the damage is beneath the floor or within the structure itself and cannot be seen. If the floor boards in such a mildewed building are lifted, everything beneath may seem dry and healthy without any visible sign of mildew. It is often an extremely complex job to find out where the damage is, what it is caused by and what is to be done about it.

In a number of projects, the National Testing Institute in Borås have inspected, measured and evaluated damp and mildew in single-family dwellings. Remedial measures have also been proposed. This work has been documented in the report "Mögel i hus" (Mildew in buildings), in which an account is presented of the research financed



Severe mildew damage to bathroom walls. The walls have been painted with water-based latex paints on glass-fibre fabric. Photo: Rune Pehrsson, Familjebostäder, Stockholm.

by the Swedish Council for Building Research and the Institute's independent research in this field.

In the report, the chief culprits are materials and damp conditions, but also construction types. However, it is of greater importance in this case to evaluate carefully the causes of excessive damp. Otherwise, there is a risk of literally – pouring money down the drain by draining off the ground when it is in fact another source of damp which is the culprit. It should also be mentioned in this case that there are hardly any mildew spores in the open air, for which reason these problems are "restricted" to the problem of smell. However, a disclaimer should be added to the effect that medical expertise do not know if there is a relationship between smell and hypersensitivity reactions in the long term.

Countermeasures against mildew

Broadly speaking, we fully understand how new buildings are to be constructed to avoid mildew problems. The engineering skills and the installation technicalities for remedying mildew problems in existing houses are also both well-known and well-documented. However, in many cases it may be unjustifiably expensive to repair a mildewed house according to the principle of "remove everything which has been attacked by mildew" and "ensure that it is dry". Nor is it always absolutely necessary to proceed along these radical lines. It goes without saying that a clean-up operation must always be carried out – so that smell and mildew spores in the air disappear – and the final objective must always be to achieve as dry an indoor climate as possible.

As was described earlier, there may nevertheless be good conditions for mildew growth. Consequently, attempts are often made to reinforce the effects of the constructional and installation measures by chemical eradication treatment using some form of fungicide. However, the effects of these fungicides are of but limited duration. In addition, it is most likely that they have a negative effect on the environment which is, as yet, not known.

Of greater interest in this category of countermeasures is the knowledge that mildew fungi cannot germinate in a basic environment, i.e. an environment where the pH is high. Simple experiments have shown that, by employing basic substances such as soda or ammonia, mildew growth can be effectively combated. Other experiments are in progress into the biological combating of mildew fungi. It is probably in these areas that the most important – and most exciting results may be expected in the next few years.

Summary

To sum up, it can be established that we know how to build new houses to reduce the risk of mildew attack. The state of affairs is also satisfactory in respect of the knowledge of how to clean and remedy mildew-attacked buildings by constructional and installational methods. However, there is an urgent need to find cheaper and simpler methods of repair. With this in mind, research workers are engaged in studies within the scope of building research along two major themes.

First, there is a continuous follow-up program of repair methods which are evolved both inside and outside research circles. Secondly, more fundamental and open-minded research is under way whose objective is to gather knowledge of the reasons why mildew occurs, why mildew smells and so on – in short to understand the mechanics of mildew.

Mildew fungi and their effects on people and buildings is a typical interdisciplinary field. Considerable efforts are being devoted to this area both by the Swedish National Board Swedish Board of Technical Development and by medical research teams. The work which has been described in brief above, should, therefore, only be seen as the contribution made by building research to the generation of new knowledge within this interdisciplinary field.

Jan Lagerström

Literature:
Samuelsson, I. *Mögel i hus* (Mildew in buildings). The National Testing Institute. SP report 1985:16.

Building research publications on mildew in buildings:
Essunger, J. and Hellström, B. *Åtgärder mot skador i golv på flytspacklad betong* (Remedial measures for damage to floors on self-levelling screeded concrete). R148:1985.

Pehrsson, R. et al. *Mögel i våtrum. Analys och åtgärdsförslag* (Mildew in wet rooms. Analysis and proposed measures). R5:1986.

Phyringer, J. and Makes, F. *Biologisk mögelbekämpning. Systemskiss, principer och hypoteser* (Biological mildew combating. System sketch, principles and hypotheses). R93:1986.

Kreuger, C-H. *Fukt i småhus. Studier i skadefall* (Damp in private dwellings. Studies in cases of damage). R84:1985.

Axén, B., Hyppel, A. and Moquist, S. *Mögel i bjälklag. Undersökningsrutiner och skadefall* (Mildew in flooring structures. Investigation routines and cases of damage). T7:1984.

Nilsson, L-O. *Utformning av fuktskydd vid golv på mark. Nuvarande kunskaper och exempel på lösningar* (Damp protection to floors on ground. Present knowledge and examples of solutions). R90:1983.

Lundgren, S. *Möglets mekanik. Etablering på trä* (The mechanics of mildew. Establishment on wood). R138:1983.

Dawidowicz, N., Lindvall, T. and Sundell, J. *Det sunda huset. Rapport från ett nordiskt seminarium mars 1987* (The healthy building. Report from a Nordic seminar, March 1987). G20:1987.

Want to know more? This is where to write:

Fuktgruppen. The Department of Building Science, Lund Institute of Technology, Box 118, S-221 00 Lund, Sweden. Tel. No. Int. + 46 46 10 70 00.

Fukt och mögel i flerbostadshus (Damp and mildew in multiple unit dwellings), SABO, Box 474, S-101 26 Stockholm, Sweden. Tel. No. Int. + 46 8 24 10 20.

Småhusskadenämnden (the Committee on Damage in Private Homes), Box 16117, S-103 23 Stockholm, Sweden. Tel. No. Int. + 46 8 14 22 65.

Air – handle with care

We have the technology today for satisfying the strictest of requirements on the air quality in buildings. But developers, administrators and constructors remain to be convinced that ventilation is important. We must promote the construction and preservation of "healthy buildings". Leif Norell throws some light on a number of important factors and working duties which are crucial for creating purposeful purchasing and for meeting requirement specifications.

In recent years, the importance of a healthy indoor climate has become the centre of much attention. Product and system development work in the sector of air treatment has, over a number of years, been concentrated on reduced energy consumption. A blissfully uncritical reduction of fresh air flows and an increased use of recirculated air together make up a contributory factor to many of the problems which arise today in both new and older buildings. This may relate to manifest problems such as damp and mould, but may also relate to more diffuse symptoms such as a general feeling of discomfort and hypersensitive reactions.

With only a modicum of overstatement, it may be said that an energy crisis was needed before the importance of good air quality was to become obvious.

Healthy buildings

Following the experience of recent years and current research results, a healthy indoor climate and good air quality should be a self-evident and expressed wish by every developer.

In practice, the demands stretch as far only as:

☐ in hotels where a good indoor climate in rooms and restaurants is a means of competition,
☐ in offices to improve general comfort and thereby working efficiency,
☐ in manufacturing industries where production places high demands on air quality.

Seldom are such corresponding demands raised in such places as schools, day nurseries and private dwellings. Here, the minimum requirements of Swedish building standards form the ceiling of the climate engineering ambition – even though levels of performance in schools must be just as high as in offices. The demands placed on ventilation are also raised for different reasons. New and untried materials are introduced.

User habits change. For example, dishwashers and washing machine are now household words. People take a shower instead of a bath. These are factors which greatly increase the moisture load in the house or apartment and, thereby, the risk of mould and mildew.

It is also in this type of building where complaints about poor ventilation are commonest.

But of course the demands on the indoor climate and air quality should not be limited solely to avoiding problems and complaints. A further demand on the indoor climate is that people are entitled to be comfortable and enjoy a sense of wellbeing in their environment.

In addition, Doctor D. Wyon of the National Institute of Building Research asserts the importance of striving, on a third level of ambition, for an optimum climate in view of the nature of the activities carried on in the building and the individual wishes of the users. Efficiency at work begins to fade long before the indoor climate is experienced as being uncomfortable.

Key factors

Why is air quality not always on the list of priorities? How is the construction and preservation of "healthy buildings" to be promoted? The limitations are often found in the purchasing process and in unclear demand specifications.

A number of important factors and tasks are:

☐ Convince developers, administrators and builders, including purchasers, that *ventilation is vital!* Unfortunately, it is precisely these people who are conspicuous by their absence from conferences which deal with the indoor climate and air quality.
☐ Place verifiable functional demands on the ventilation installation and follow up these demands. Define practical measurement methods for checking the ventilation. This is a cardinal task for research.
☐ Do not purchase part systems and components. Air quality is an indivisible product. There must be a well-defined assumption of responsibility for design, installation, fine-tuning and function.
☐ Draw up medical demands on the air quality. Today's requirement of approx. 0.5 air changes per hour is essentially based on an appraisal of pollutants caused by people themselves and not by any pollutants which may possibly lurk in building materials.
☐ Make efficient use of the ventilation air. Show developers and users what can be expected of different methods of supplying ventilation air.
☐ Include maintenance and service in calculations. For example, it is the filters' job to clean the ventilation air and, consequently, they must be replaced or cleaned regularly.

And what of the future?

Today, we possess the technology for satisfying the strictest demands on air quality. It is actually possible to create virtually particle-free environment as in "Pure Rooms" in the electronics industry, or a pleasant, draughtfree individually governable indoor climate as in the better hotel rooms. One condition is, of course, that there is a demand.

It is not first and foremost new components that are needed for constructing "healthy buildings", but rather systematic thinking and a methodical employment of the experience which has been gained.

Air should be treated as a perishable commodity and the use of recirculated air will thereby be reduced. Different forms of requirement control of ventilation will be developed. Systems using a variable air flow (VAF) are a suitable point of departure. It will be a major challenge to phase out nuclear power stations without reducing the standard of the indoor climate. More research is needed, but most of what we need to know, we know already. It is up to us to use it.

Leif Norell

Leif Norell, M.Sc., works at Fläkt Indoor Climate AB in Stockholm.

A set of rules for "Healthy buildings"

Convince the decision makers. Ventilation is vital!

Make functional demands which can be followed up.

Demand undivided responsibility.

Include maintenance in all calculations.

The technology is there. Let experience guide!

Choosing an air treatment system

Pollutants are created in practically every building, healthy or sick. Cooking smells in an apartment, tobacco smoke in a restaurant, excess heat in an office, welding smoke in a workshop are just a few examples of normal and "natural" pollutants. Over and above such pollutants, an unknown number of pollutants have made their appearance in the last decade and have caused so-called "sick buildings". The relationships between these pollutants and their effects on people have not been clarified. Whether it is individual factors of a physical or psychological nature, or whether it is the sum total of the effects of a large number of pollutants that lead to pathological symptoms in unhealthy buildings – that is the question.

The primary duty of air treatment plants is to evacuate these pollutants, the quicker the better. This will create favourable conditions for people's comfort, health and working performance. It is primarily the ventilation efficiency of the system and the volume of the air flow that decide how well – or how badly – the air treatment system functions.

Choice of system determines ventilation efficiency

In the 1980s, valuable research efforts have been devoted to developing methods for measuring the efficiency of ventilation systems. In essential terms, ventilation efficiency is a measurement of how quickly the system can entrap and remove pollutants created in the room. We now have methods for measuring ventilation efficiency. By this means, instruments have been placed in our hands which make it possible to evaluate different air transport systems.

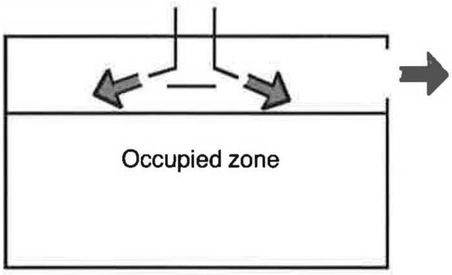
In traditional air treatment systems, we first dilute the polluted air in the premises with supply air, and thereafter evacuate the air mixture. There are risks that the system will operate with a "short-circuited" ventilation as the figure shows. In this case, only a minor amount of the supply air will reach those areas occupied by people. In the healthy building, systems should instead be used by which the air is supplied to the occupied zone. These systems operate according to the principle of displaced air supply. Experiences from practical measurement have shown that the occupied zone in the latter case enjoys a lower level of pollutants and improved temperature conditions than is theoretically possible using a traditional remixing system.

Dimensioning the air flow

One of the main results of the energy crisis was that we construct more airtight buildings with a lower air change rate. It goes without saying that this will lead to poor ventilation. One example may serve to illustrate this trend. Office buildings constructed at the beginning of the 1970s were dimensioned for a supply air flow of 20 l/s per person. The corresponding standard for offices built at the end of the 1970s is approximately 4 l/s per person. It is quite clear today that this considerably worsened ventilation standard has contributed to the problems which have arisen in sick buildings.

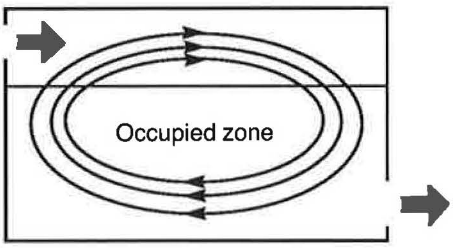
The healthy building, therefore, should be dimensioned for air flows which greatly exceed today's standards. Studies carried out by such experts as Professor Ole Fanger have confirmed this. The use of recirculated air is still far too common. A majority of experts in the field of air treatment have today rejected this form of energy conservation in healthy buildings.

Short circuit flow



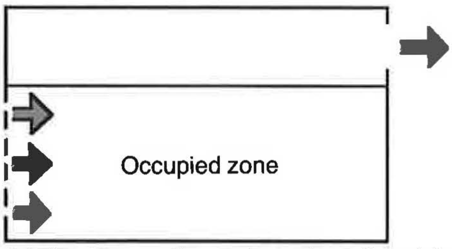
Traditional air treatment system. The polluted air is diluted with supply air and the resultant air mixture is evacuated. There is a risk that the supply air does not reach the zone occupied by people.

Complete mixture



In this case, there is a complete mixture since the air mixture is evacuated within the occupied zone. Ventilation thereby becomes acceptable.

Displacing flow (carbon principle)



It is best to use the system where the air is supplied to the occupied zone according to the displacing air supply principle. The degree of pollution will be lower and temperature conditions better than in traditional air mixture systems.

Quality control of the indoor climate

As suggested above, the correct selection of an air treatment system is the very basis on which the healthy building rests. To sustain the system at top-level function throughout the entire life of the building, much effort must be devoted to running and preventive maintenance.

Examples of recommended measures are:

☐ Inspection of the thermal indoor climate at least twice a year.
☐ Random checks of the air quality in premises once a year.
☐ Cleaning of supply and exhaust air ducts as required and on the basis of the air quality measurements.
☐ Measurement of the ventilation efficiency at regular intervals in representative premises.

Against the background of the far too common problems in sick buildings, the need for improved standards in respect of air quality is urgent indeed. Research in this field has long been in progress, but so far the project results have not established any criteria which are usable for air treatment technicians. An interchange of experience between research workers, construction engineers and installation engineers should have every potential to hasten the evolution of practical rules. The conference HEALTHY BUILDINGS 88 may be a suitable forum for this exchange of experience.

Kurt Jonsson

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Literature:

Fanger P. O. *A solution to the sick building mystery.* Plenary paper presented at Indoor Air 87 International Conference 17-21 August 1987, Berlin.

Sandberg, Mats. *Distribution of ventilation air and contaminants in ventilated rooms – Theory and measurements.* Thesis, the Royal Institute of Technology, Stockholm, 1984.

Bacteria from humidifiers

In buildings where the supply air is humidified, bacteria can in some cases give rise to health problems, primarily in the form of feverish reactions. However, such complaints are normally of a brief nature. When problems have arisen in working premises, they usually occur on Mondays and this state of ill health is, therefore, called "the Monday shakes".

While this health problem cannot be said to be particularly common, it has nevertheless been the centre of considerable attention in recent decades. By selecting suitably designed humidifiers, it is, however, possible to eradicate the problem almost completely. In those cases when bacteria emission from humidifiers has been the source of trouble, this has almost always been because the humidifier emits water in droplet form and because the concentration of bacteria in the water system of the humidifier has been abnormally high. On this point, it might be mentioned that problems involving bacteria emission occur particularly often in small, individually roomsited humidifiers which are not provided with a continuous water drainage system.

One reason why bacteria multiply in the humidifier water may be that the air which is supplied to the humidifier carries high concentrations of organic dust. Consequently, purifying the supplied air is often a simple method of avoiding the bacteria problems. For example, this solution has been successfully applied in printing houses where the concentration of paper fibres in the air is high in many cases.

Normal types of humidifiers

As a rule, the humidifiers employed in air treatment systems operate according to one of the following principles: mechanical atomization of water, evaporation of water from wet surfaces or the supply of water vapour.

In humidifiers which supply the water by mechanical atomization, sprinklers or nozzles are often used to finely-divide the water into tiny droplets. Such humidifiers are commonly known as air washers.

Humidifiers operating on the principle of evaporation from wet surfaces, so-called "prevaporators", are often fitted with contact blocks of moisture-absorbing material. These blocks are sprayed with water so that the entire surface is kept wet.

In the case of humidification by water vapour in the air treatment system, the water vapour is normally generated in an electrically heated pressure vessel.

Bacteria emission

The above-described humidifiers have very different properties as regards bacteria emission.

Air washers transfer a portion of the bacteria present in the water directly into the ventilation air via the water droplets which are given off. However, this bacteria emission can be greatly limited if these humidifiers are fitted with a drip separator.

In prevaporators, the bacteria emission from the water should be practically negligible. However, it is important to ensure that water is supplied to this type of humidifier in such a manner as to avoid splashing and drop formation.

If the air is humidified by the supply of vapour, no dissemination of bacteria will take place primarily. However, in vapour humidification, it is of particular importance to take into account the risk of condensation gathering in the duct system or the humidifier. Otherwise, such condensation may secondarily cause the growth and spread of bacteria.

Studies carried out so far

The concentration of bacteria in the indoor air in buildings with different types of humidifiers has been studied in conjunction with a large number of research projects.

For example, a major Finnish project relating to the quality of indoor air also embraced a study of the concentration of bacteria /1/. One result which might of general interest in this context is that it was not possible to indicate higher contents of bacteria in buildings employing humidifiers.

Comparative tests with air washers and prevaporators have recently been carried out at Fläkt Evaporator's laboratory in Jönköping with the support of the Swedish Council for Building Research /2/. These tests show that the bacteria emission from humidifiers of the prevaporator type is very low or almost wholly negligible. This result tallies with earlier laboratory tests with prevaporators /3/ and with the results from the above-mentioned Finnish study.

Recommendations

When humidifiers are installed in air treatment systems, the following recommendations should be kept in mind in view of the problems which may occur with bacteria:

☐ Choose, in the first instance, a humidifier which does not emit the water in droplet form, for example a prevaporator. If any other type of humidifier is chosen, this should be fitted with effective drop separators.

☐ Follow the manufacturer's running instructions, in particular as regards cleaning the humidifier.

☐ Avoid supplying the humidifier with air which contains large amounts of organic dust.

Ove Strindehag

Ove Strindehag, Associate Professor, is a member of Fläkt's Central Research Department.

For trouble-free production in printing works, it is vital that the paper is kept at the correct humidity. But paper also gives rise to organic dust. Consequently, the air supplied to the humidifier is purified to avoid bacteria problems. Photo: Gustav Hansson, Bildhuset.

Literature:

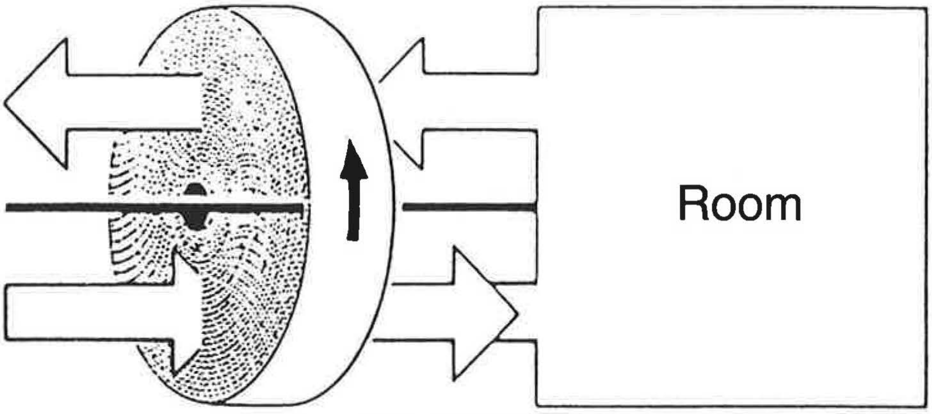
/1/ *Rakennuksen sisäilmaston laatu ja ilmanvaihdon tarve.* Report D:104, the Department of Trade and Industry, Helsinki, 1986.

/2/ Strindehag, O., Josefsson, I. and Henningson, E. *Emission of bacteria from air humidifiers.* Contribution to the conference on Healthy Buildings 88, 5–8 September 1988, Stockholm.

/3/ Völksch, G., Horn, H. and Günther, A. *Investigations on individual indoor humidification.* The 4th Int. Conf. on Indoor Air Quality and Climate, 17–21 Aug., 1987, Berlin.

Air quality in offices

Much of the success in the Swedish energy conservation program can be attributed to the increasing use of heat exchangers in ventilation systems. Today, heat exchangers are a self-evident element in new production, but they are also used widely in renovation or extension of the existing building stock.



Rotary heat exchanger (from Munther's "Heat recovery. Technical handbook.")

Of the numerous different types of heat exchanger available on the market, it is primarily the plate and battery heat exchanger and the rotary heat exchanger which have been put into operation. The rotary heat exchanger consists of a slowly rotating wheel provided with fine axial channels in which the air flows in a laminar pattern. Half of the wheel is in the exhaust air duct and half in the supply air duct. As a result of the rotation, the heat stored in the exhaust air channel is transferred to the cold supply air.

Passing on pollutants?

From the point of view of air hygiene, the risk of recirculation of pollutants as a result of the function of the rotary heat exchanger has been highlighted. It is theoretically possible to maintain direct leakage at a very low level. For this purpose, extremely high manufacturing accuracy, correct siting of supply and exhaust air fans and workmanlike installation are all vital. The rotor entraps a certain amount of air when it departs from the exhaust air side. This air will be transferred to the supply air unless special preventive measures are adopted. To avoid such transfer, the heat exchanger is often fitted with a blow-out sector. The sorptive transfer is affected in that gaseous substances in the exhaust air are absorbed on the rotary surfaces and evaporate into the supply air.

The degree to which transfer of pollutants takes place has long been the subject of discussion. Those studies which have been carried out hitherto have demonstrated that polar, chemical substances (alcohols, kretones, esters) may be recirculated. The same also applies to water-soluble substances such as terpenes. Theoretically, formaldehyde ought to be recirculatable to an even greater extent, perhaps even as effectively as water.

Investigation gives the answer

At low concentrations, the adsorption properties of chemical substances change. In our project, we are openly studying the extent to which chemical air pollutants may be recirculated in the low concentration range (the ppb range) in a rotary heat exchanger under normal operation. (It is our expressed opinion that the concept of the rotary heat exchanger is well-nigh ingenious. But that must not prevent research workers from proposing hypotheses!)

We are studying the phenomenon of recirculation in rotary heat exchangers by measuring the concentration of formaldehyde immediately ahead of and after the rotor. This measurement is carried out on heat exchangers under normal operations at separate sites in the Umeå region. The function of each respective heat exchanger is assessed by measurement of leakage across the rotor using pressure measurement instruments and laughing gas, as well as the air flows in ducts closest to the rotor, using laughing gas.

Formaldehyde is a suitable tracer substance because it is present in all indoor air (10–250 ppb) and because we have a highly sensitive method for determining low concentrations.

The project group

The actual work is carried out by Barbro Andersson, Ph.D., a chemist at the Department of Chemistry at the Working Environment Institute. Department Engineer Margit Sundgren has assisted her. The group also includes Per-Anders Zingmark and Jan Sundell who have specialist responsibility for matters dealing with ventilation engineering. Kurt Andersson is Professor and Head of the Department of Chemistry at the Working Environment Institute at Umeå.

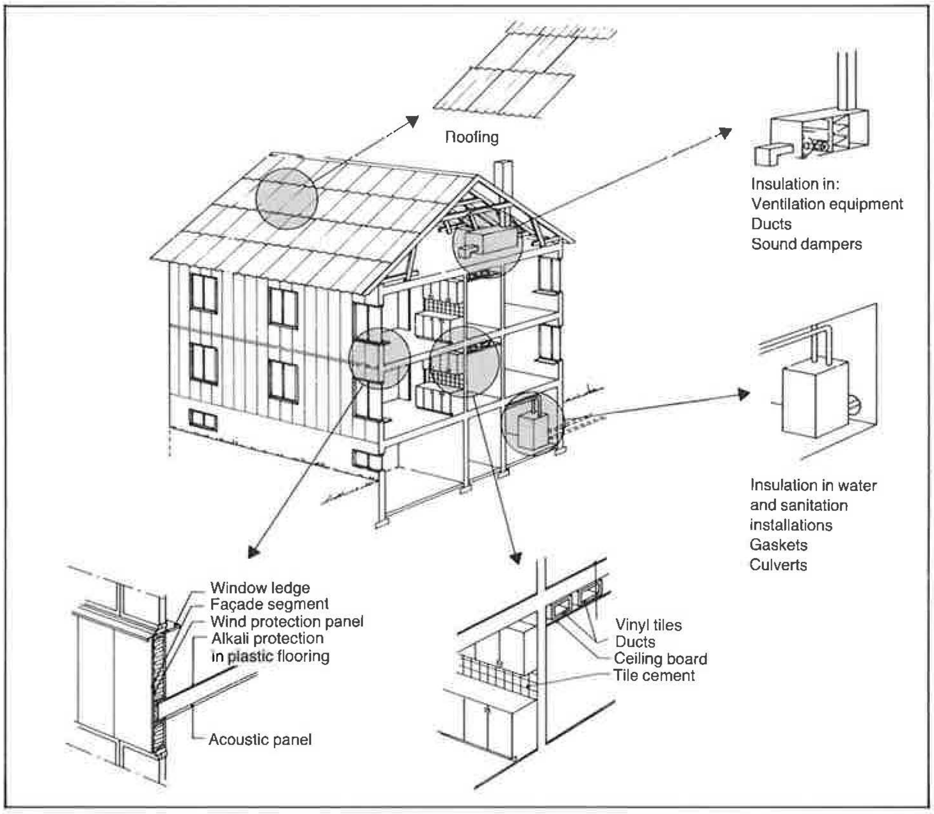
Kurt Andersson and Barbro Andersson

Professor **Kurt Andersson** works at the Department of Chemistry at the Working Environment Institute in Umeå. **Barbro Andersson** is a research worker at the same institute and department.

A heat exchanger saves energy, but wrongly installed it may result in the recirculation of air pollutants into the office. Photo: Per B Adolphson, Bildhuset.

Asbestos in buildings

Asbestos may no longer be used in building work in Sweden, since it is a known cause of, for example, lung cancer. – This article shows where asbestos can be found in buildings and those measures which are necessary to reduce the health hazards.



Before the serious risks involved in the use of asbestos became clearly apparent, this material was highly favoured and has been used in a large number of products both in the construction sector and in a number of other fields as well. In buildings, asbestos is to be found in many building parts and installation components. The figure shows a few of them.

Asbestos possesses many good technical properties. It withstands high temperatures and is thermally insulating, sound damping, mechanically durable and pliable. In addition, asbestos is cheap. Consequently, asbestos has been regarded as a very useful material and has been used in a large number of products not only in the construction sector but in a number of other areas as well.

The commonest, and probably best known, building materials are asbestos-cement sheets which are available in a large number of formats and appearances. Asbestos-cement sheets have been produced both at home and at a large number of factories abroad. At about the turn of the century, production began in Austria of a new material for roofing. This consisted of asbestos and cement and was given the name "Eternite". Production of Eternite slate for roofing began in Sweden a few years later. Sales were on a relatively modest scale during the first years, but as the slate began to be marketed in new formats and colours, demand increased.

In the 1920s, the company Skandinaviska Eternit AB introduced corrugated sheeting for roofing into the product range. This was a major success, enjoying as it did many highly appreciated advantages, in particular for industrial and agricultural buildings. At a relatively early stage, cladding sheet was also introduced in the product range. Sales turnover for this gradually grew and the major breakthrough came in the 1930s.

As suspicions were aroused in the 1950s and 1960s (which were later to be confirmed) that asbestos could give rise to lung cancer and a tumour disease (mesotelium), the National Board of Occupational Safety and Health decided on the adoption of stricter rules for the use of asbestos.

In 1976, the use of asbestos in building work in Sweden was forbidden, but despite this ban, asbestos has been found in plants built as late as 1982.

Asbestos in building components

The major use of asbestos in building materials is primarily linked to the following parts of the building:

1. The roof. Roofing in the form of overlaid tiles and corrugated sheeting.
2. Outer walls. Cladding sheet of different sizes and appearance as the external façade layer. In many stud walls, wind protection is provided consisting of asbestos cellulosic cement panels. On the inside of the walls, cladding panels, acoustic panels or laminated panels may be found with asbestos in one of the layers. Asbestos was also included in the spray-on rendering applied on the walls.
3. Inner walls. The same types of panels as on the inside of the outer walls. Spray rendering also applied here.
4. Flooring. Roll-out flooring or floor tiles of asphalt, rubber or plastic. Screeding compounds. Membrane insulation. On the underside of the flooring structure, there may be cladding panels, acoustic tiles or laminated panels. Spray-on rendering.
5. Ceilings. The same types of panels as in the underside of the flooring structure.
6. Ventilation installations. Insulation boards and intake ducts, supply air plants and supply air ducts. Sound damping insulation panels in sound dampers and supply air ducts. Sound traps/throttles behind supply air devices. Rotors in rotary heat exchangers. Asbestos spray or insulation panels on the outside of the ducts.
7. Water, sanitation and electrical installation. Thermal insulation in the form of fuller's earth-magnesium compound etc. on pipes and boilers. Sealing materials in the form of strips and tapes etc. in hatches, valves, stuffing boxes etc. Pipes in the ground, protective pipes for culvert elements, flue ducts etc. of asbestos cement.

Asbestos can also be found in a number of other building materials and components such as

- ☐ Window sills
- ☐ Tile cement
- ☐ Glazing putty
- ☐ Masonry bricks
- ☐ Blocks and elements of certain plastics
- ☐ Rubber and plastic profiles
- ☐ Felt
- ☐ Coatings on steel sheeting
- ☐ Wallpaper
- ☐ Fire resistant agents and paints
- ☐ Fire doors (inner insulation)
- ☐ Various other compounds such as filler and jointing agents, sealing mastics, plugging compounds.

Vital to carry out asbestos inventory in buildings

As will be apparent from the above list, there is a very large number of parts in a building which contain either pure asbestos or asbestos in compounds. With the promulgation of the decree on obligation to report concerning asbestos in ventilation equipment which became law in 1986, ventilation installations with mechanical supply air have been inventoried. In many cases, measures have been adopted to remove, encapsulate or build-in the existing asbestos in the ventilation installations. Concerning asbestos in building structures and other installations, there is no decree in force today pursuant to which these are to be inventoried. However, it is of vital importance to scrutinize these parts as well, since the asbestos may, in the usage phase, and in operational and maintenance work – or even in future demolition or renovation work – constitute a health risk. There are many who may be affected by both risks and financial difficulties when the asbestos is "discovered" when a building is renovated.

If, for example, information on the presence of asbestos is provided in the invitation to tender, there is every prospect that undesirable costs and downtime do not occur and that the clearance work is carried out in a reliable manner, since both costs and time consumption can be specified on purchasing.

Per Höjerdal and Bertil Clavensjö

Per Höjerdal is a graduate engineer with Wahlings Installationsutveckling AB where he works as project manager in the field of water, heating, sanitation and the working environment. **Bertil Clavensjö** is a research technician with Bjerking Ingenjörsbyrå AB and works with environmental questions – primarily radon and asbestos.

Literature:

Clavensjö, B., Höjerdal, P. *Handledning för inventering av asbest i ventlationsanläggningar* (Guidelines for an inventory of asbestos in ventilation installations), Working Environment Fund, Swedish Council for Building Research, T12:1986.

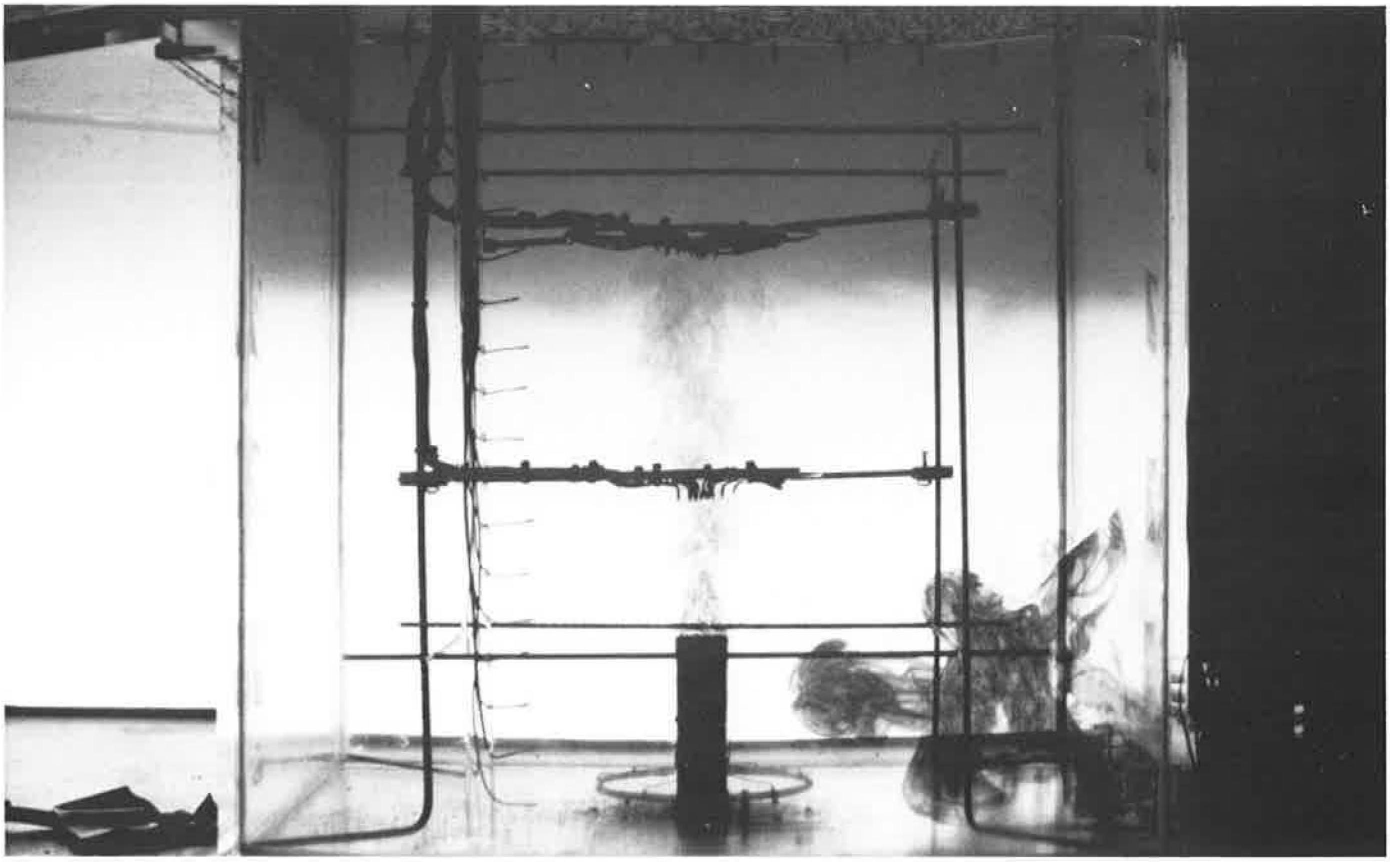
Clavensjö, B., Höjerdal, P. *Handledning för inventering av asbest i rör, pannor och elinstallationer* (Guidelines for an inventory of asbestos in pipes, boilers and electrical installations), Working Environment Fund, Swedish Council for Building Research. In preparation.

Clavensjö, B., Höjerdal, P. *Handledning för inventering av asbest i byggnadskonstruktioner* (Guidelines for an inventory of asbestos in building structures), Working Environment Fund, Swedish Council for Building Research. In preparation.

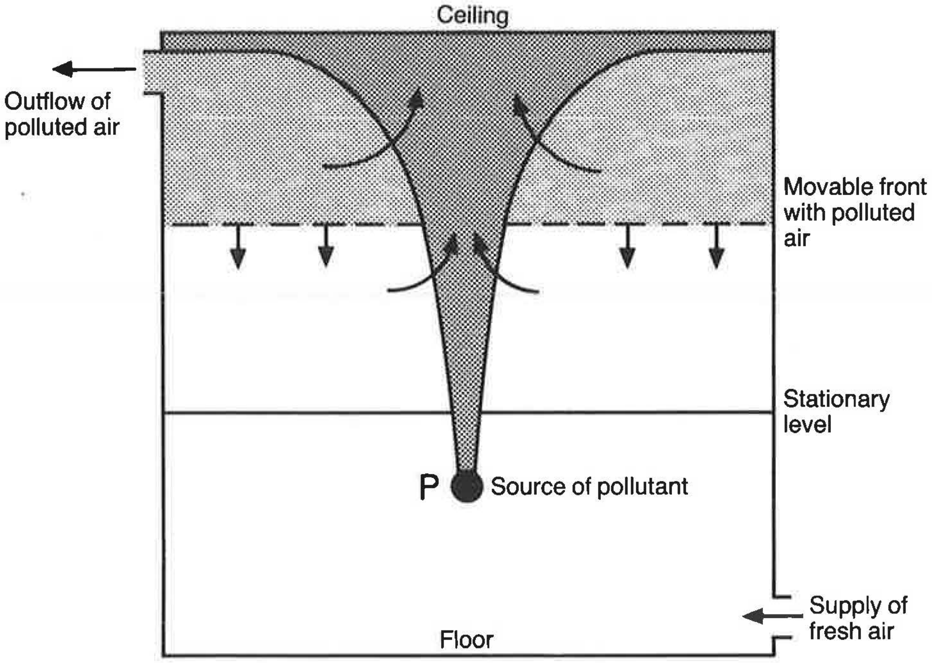
This is what SIB is doing for a better indoor climate

The research conducted by the Institute into the indoor climate falls under the responsibility of the Section for Climate and Installations. By indoor climate, we mean not only air quality and thermal climate, but also the sound and light climate, since human beings are exposed to a combination of all of these factors.

It is the combination of these factors that is decisive for our state of health, how well we can work and rest and the state of health of the building itself. Naturally, different aspects have differing impact on different oc-



A model trial in water with displacing ventilation.



Displacing ventilation entails supplying fresh air to premises in such a manner that it can effectively force out the existing polluted air. The highly schematic illustration shows how pollutants from P are removed by air flowing in at the floor and taken out at the ceiling. The supply there may be said to act as a pump piston.

casions and therefore each aspect is normally studied individually. But it is important to keep all of the other environmental factors in mind at all times when commenting on any particular part of the climate.

For many years, the emphasis of the Institute's indoor climate research has been concentrated on the importance of the thermal climate and on the technical function of the ventilation system. No research has been conducted into the medical effects of the air quality on human beings.

The interaction between building, development, and the outdoor climate

Naturally, it goes without saying that the climate outside the building influences the conditions for creating a healthy indoor climate. In our Section, the interaction between building, development and the outdoor climate is also studied in respect of the local climate, with temperature, wind and solar radiation as planning conditions and the direct effect of the wind on the pressure distribution throughout an individual building shell. This is of importance not only for the load exerted on a building structure, but also for the function of the ventilation system, irrespective of whether this is based on natural ventilation or mechanical ventilation. By model tests in wind tunnels, the dissemination of air-borne pollutants is also studied, for example exhaust fumes from traffic or factories in the neighbourhood, or emissions from the building itself.

The outdoor climate, including solar radiation, not only influences the energy balance of the building – radiation from the sun and the sky is also decisive for the possibility of creating healthy daylight illumination inside the building. Growing awareness is being attached to the importance of daylight for people's health and wellbeing, at the same time as a general awareness is emerging of the conscious utilization of daylight as a light source.

Back to ventilation research

With a known thermal load from outside and known activities inside a building, with known air quality outdoors and pollutants indoors, the task is to create a heating and ventilation system that provides a healthy air quality and suitable thermal climate indoors.

The Institute's research has been concentrated on knowledge of the task of the ventilation system and of how air behaves in rooms and groups of rooms, for example in an apartment, in different cases of loading and with different fundamental technical solutions.

A primary goal is to achieve as efficient a ventilation system as possible. By this we mean that the air quality in every area occupied by people in a room should be as good as possible - pollutants must be removed from the zone of occupation as quickly as possible.

For studies of the quality of air in an apartment, accurate measurement methods are required which are suited both for laboratory research into how, for example, air moves between rooms in an apartment, and for practical measurement of the function of the ventilation in buildings, i.e. large-scale measurement. For this purpose, it is necessary that the method be as simple as possible without, for that reason, giving unacceptably inaccurate measurements. Nor should the method be too expensive. Such measurement method development is in progress alongside the research into air flow.

Perception of the thermal climate

Large temperature gradients, excessive air flow rates together with unsuitable air temperatures, cold and warm surfaces in the room etc. are all decisive for how we perceive the thermal climate, besides our perception of the air quality. It is therefore natural for there to be intimate cooperation between the ventilation-engineering research and the criteria research at the the Institute of human laboratory.

Ventilation in older multi-family dwellings

A major, and more practically directed project relates to how ventilation functions in older multi-family dwellings before and after redevelopment. After all, the goal is to select a redevelopment scheme which entails both good energy conservation and a healthy air quality in the dwellings. Different technical solutions are tested and the technical and economical consequences are evaluated set against the obtained ventilation function. A result which, it would appear, is almost generally applicable is that while the outer shell of the buildings becomes more airtight on redevelopment, the degree of untightness inside the building increases between apartments and storeys. This has an influence on both the sound conditions and the risks for undesirable air exchanges between different apartments. From the point of view of fire spread, leakage between the apartments is wholly unacceptable. Methods for sealing slots and openings must be developed.

Radon measurements

The Institute has also been engaged for many years in the radon problems in our dwellings. Measurements of radon are carried out on assignment as a matter of routine and practical methods for reducing radon concentrations indoors have been tested in a number of buildings. One successful way of reducing the concentration of radon penetrating from the ground into buildings sited on gravel outcrops is to employ a so-called radon well for sucking radon out of the ground. The radon well, which was designed by one of the members of the Institute, is now commercially available.

Hans Allan Löfberg

Hans Allan Löfberg is Head of the Section for Climate and Installations at the National Institute for Building Research, Gävle.

Those interested in our research after reading this small selection from a very broad scope of activities are welcome to contact the Institute in Gävle, telephone number + 46 26-10 02 20.

G18:1988
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