VENTILATION AND INDOOR AIR QUALITY

Olli A. Seppänen
Helsinki University of Technology
Laboratory of Heating, Ventilating and Air-Conditioning
Espoo, Finland

Abstract

A large project was conducted in Finland to evaluate the present indoor air quality, climate and ventilation and to establish new criteria for ventilation and indoor climate. Great differences were found out in the ventilation rates and operation of HVAC-systems. In general indoor air quality was good. More problems were found out in the thermal climate. In many cases the HVAC-system didn't satisfy the variation of the loads of the rooms. As a result of the project some recommendations for good indoor air quality was given. The most important of those were the optimum temperature 21 - 22 °C and maximum air speed 0.1 m/s during the heating season. The ventilation rates should depend on occupancy being 7 - 8 litres/s per person, however, the minimum ventilation rate should not be less than 0.4 air changes per hour.

Introduction

Ventilation and air infiltration will use app. 40 % of the all energy consumed by buildings in Finland. Due to the wrong energy conservation measures the ventilation rates have been reduced too much in many cases. This has been partly due to improved airtightness of building envelope partly due to wrong operation of ventilation system and too low design air flow rates. At the same time new building materials have been introduced and people have become more sensitive for air pollutants. Ventilation has become a very important national issue in respect of energy consumption and public health. A question has arisen in many countries, also in Finland. What is the relation between ventilation and health and what are the appropriate design values for ventilation and other parameters of indoor climate?

Methods

A large research project was established to study the situation in Finland and to answer question above. Ultimate goals were the design values but lot of other goals such as need for system and product development, testing methods, design tools etc. were established. Interdiciplinary nature of research and need of coordination on the national level was understood in the beginning. Helsinki University of Techonology accepted the role of the coordinator. Twelve research units worked together in the project. Their expertise covered areas such as:

- medical sciences, particularly public health
- fine particle physics
- radon problems

- micro organism
- air cleaning
- building materials
- particle boards
- ventilation and air distribution
- design of residential and commercial ventilation systems.

The project lasted four years. Total cost was equivalent to 1 million USD. The research methods selected according to the subtasks. A survey on air quality and operation of ventilation systems was done with cooperation of several research institutes. Laboratory tests were made to study ventilation effectiveness and air distribution. Computer programs were written and verified with measurements. The performance of various equipment were tested in laboratory. Health effects of ventilation and indoor climate were studied with field tests and large questionnaires. Existing measuring methods were tested and new developed.

Results

Over 40 reports were printed (in Finnish). Some of the major results are described in the following. Several more detailed papers are printed in the proceedings of the 4th International Conference on Indoor Air Quality and Climate.

Air pollutants

Because of individual differences the effects of indoor climate on human being may vary considerably. The number of allergic people is large. Their wellfare can be essentially improved with good indoor air quality. This can be achieved with ventilation, source control of pollutants and air cleaning.

Absolutely safe limits of the pollutant concentrations are not known. The effect of pollutants are also individual. The simultaneous effects of various indoor climate variables on human being are not either known. Inspite of difficulties the project has ended up to certain recommended values on some indoor air pollutants and other indoor air parameters.

Thermal climate

The effect of thermal climate was found to be even greater than assumed. The temperature had not only an effect on thermal sensation but also on the sensation of air quality, dryness and amount of various symptoms. The temperature has not only an effect on comfort but also on health. The recommended temperature for sedentary activity is 21 - 22 °C. If the temperature is much above this the prevalence of symptoms increases rapidly and if the temperature is much below the prevalence of draught complaints will increase. Individual temperature control of two degrees C is recommended.

The selection of air humidity is a complicated question. It looks like relative humidity of 40 to 60 percent is ideal in respect of health, however, the lower relative humidity has not proven to be hazardous to the healthy persons. Although in the field studies up to 70 % of office workers complained of dryness of air during winter months /1/.

The recent studies have shown that people are more sensitive for draught than what was earlier anticipated. Thermal radiation and temperature has strong effect on draught sensation in addition to the mean velocity of the air. The mean velocity of the air should be under 0.1 m/s during the heating season and under 0.15 m/s during the summer.

Control of ventilation

The concentration of indoor air pollutants depends not only on ventilation but also on many other factors such as: sorption, general hygiene and human activities. The calculation of concentration of indoor air pollutants is possible only in some simple cases. The greatest difficulty is to find out the strength of the pollutant sources and sinks.

The actual ventilation air flows in buildings are in many cases not based on ventilation requirements. Some buildings have too large ventilation rates and some too small. The measured ventilation rates in residential building varied from 0.1 - 1.6 $m^3/h\ m^3$. The ventilation was especially low in bedrooms. Due to low ventilation the carbondioxide concentrations up to 3000 ppm were measured.

The ventilation effectiveness was studied also in the project. The air exchange efficiency and ventilation effectiveness which are part of ventilation effectiveness have a great influence on the air quality energy economy of ventilation. In many cases the ventilation effectiveness could be improved by avoiding short circuiting flow pattern. Ventilation effectiveness is often low in residences. The displacement flow pattern seems to provide the same air quality as mixing flow pattern with lower air flows /2/.

The feedback control of air flows based on air quality seems to be possible at least with carbondioxide concentration. The system is particularly applicable to the spaces with variable occupancy. Expected savings in the energy consumption for ventilation are 20 - 30 %. Commercial air quality sensors were tested simultaneously with CO_2 and particle measurements. It was found out that their output was unpredictable in real buildings /3/.

Air filtration has some effect on air quality. Particularly the concentration of particles originating from outdoors is lower in the buildings with mechanical ventilation with good filtration than with natural ventilation. Sources of particles were traced with element analysis of collected dust. Concentration of elements such as S, Pb, K, Ca, Cl were measured /4/.

Air circulation and filtration will reduce the concentration of fine particles ($d < 1.7\ \mu m$). The concentration of coarse particles ($d > 1.7\ \mu m$) will not be so much influenced by the circulation and filtration. The outdoor air rates can not be reduced due to increased use of return air, however, there seem not to be any measurable reasons why the return air couldn't be used for temperature control of the spaces /5/.

Outdoor air and return air filters should meet at least the requirements of Eurovent's class EU 6 and have adequate dust holding capacity.

Most of portable filter units in the market proved to operate unsatisfactorily in respect of cleaning properties and noise generation.

Chemical air cleaning seems to be able to remove some compounds from the air, however, its dynamic performance and health effects are not known.

The operation of HVAC systems and equipment

The performance of heating systems proved to be usually good. The greatest need for improvements may be in too large temperature differences between the rooms. This is often due to the variation in the thermal performance of the exterior envelope and internal loads.

There seemed to be lot to improve in the design, installation, and operation of ventilation and air conditioning systems. The interaction between air conditioning system and indoor climate is not always understood. The requirements are often not well enough established and bad performance is too often accepted by building owner. The design do not always correspond the use of the spaces. The installation does not always follow the design and the use of the spaces differ from what originally designed.

The operation of natural ventilation was studied with measurements and theoretical models. It seems to be possible to obtain adequate ventilation rates also with natural ventilation, however, the ventilation rate will vary more than in a mechanical system. This and the difficulties in heat recovery will usually lead to worse energy economy than in the mechanical ventilation systems. The influence of wind on air flows can not be eliminated with present technology. The natural ventilation will not operate properly in one floor detached houses generally. Kitchen range hoods with fans will easily reverse the air flow in other exhaust ducts. During the warm weather natural ventilation has to be combined with window operation.

Ventilation rates

Ventilation rates should be defined based on the number of persons because the generation of many pollutants depend on that, too. In respect of human odors 7.5 l/s per person seem to be an acceptable air flow rate. With sedentary activity this will increase the carbondioxide concentration up to 0.1 %. These values are in agreement with the latest international recommendations /6/. If this air flow rate will not decrease the concentrations of other pollutants to the acceptable level the source control is usually better strategy for indoor quality control than the increase of ventilation rates.

The minimum air exchange rate is 0.4 times per hour which means the time constant of ventilation in complete mixing is 2.5 hours. It will take 5 hours to replace all room air.

Pollutant sources

The measurement of emissions from building materials and furniture showed that other sources of formaldehyde except particle board exist. The glues and various plastic materials seemed to emit organic gases. The emission rates depend not only on the material but also on environment, loading and ventilation. This makes the calculation of the concentration of pollutant uncertain. The emission is strongest in the new buildings. This gives a reason to ventilate the new buildings more than the old ones.

The ventilation and air conditioning systems studied were not in general the sources of bioaerosols. The concentration of bacteria was much lower in the supply air than in room air eventhough return air was used. However, the duct system may be a source of spores when it becomes wet for example due to improper construction. This was found in two of 32 investigated detached houses with warm air heating system.

Discussion

The project started lot of research activities in the area of indoor quality and climate. Although many problems became solved lot of new questions arose. As a result from the project a better understanding of indoor air climate was achieved. A criteria for good indoor air climate was established. The results of the project had influence on the revision of Finnish building code in the area of ventilation. Numerous projects for new products have started also as a result of the project. Very important was also to find out how far the every day building industry is from the results of the research. Much higher satisfaction on indoor air climate and quality could be achieved if the all known indoor air criterias would be fullfilled. Unfortunately the practical questions in building industry seem to rise as a major obstacle for better indoor air quality and climate.

References

1. Jaakkola, J.K., Heinonen, O.P., Seppänen, O. Mechanical ventilation in an office building and sick building syndrome. A short-term trial. The 4th International Conference on Indoor Air Quality and Climate, Berlin 1987.

2. Majanen, A., Helenius, T., Seppänen, O. Air Quality and Ventilation Efficiency in Residential and Office Buildings. The 4th International Conference on Indoor air Quality and Climate, Berlin 1987.

3. Suomi, U., Seppänen, O. Field Measurement of Air Quality Controlled Ventilation. International Symposium on Recent Advances in the Control and Operation of Building HVAC-Systems, CIB's Working Commission W-79, 1985.

4. Raunemaa, T., Kulmala, M., Saari, H., Olin, M. Outdoor Air Influence on Indoor Air. The model of Aerosol Behavior. 2th International Aerosol Conference. 1986. Pergamon Press Oxford 1986.

5. Kulmala. M., Saari, M., Raunemaa, T., Olin, M. Indoor Air Aerosols: Outdoor Air Influence on Indoor Air. 4th International Aerosol Conference. 1986. Pergamon Press Oxford 1986.

6. International Energy Agency. Energy Conservation and Community Systems Programme, Annex IX Minimum Ventilation Rates, to be published in 1987.

2803

MINIMUM VENTILATION RATES AND VENTILATION STRATEGIES

Lutz Trepte
Dornier System GmbH, Friedrichshafen, Federal Republic of Germany

André Le Mariê
Project Management for Biology, Ecology and Energy (PBE)
in KFA Juelich GmbH, Juelich, Federal Republic of Germany

Abstract

The ventilation of dwellings is essential for the removal of chemical contaminants, indoor pollutants as carbon dioxide, body odour, and water vapour but at the same time it effects comfort and energy consumption for space heating. The main sources of contaminants giving rise to health effects in dwellings were found to be tobacco smoke, some building materials and under certain conditions, combustion appliances. For indoor pollutants being most important within the work of International Energy Agency's Annex IX "Minimum Ventilation Rates" air exchange rates have been defined which prevent 1) damage to the health of occupants, 2) annoyance or reduction in amenity, 3) damage to the building fabric. Technical solutions which can meet the controverse requirements for good indoor air quality and energy conservation have to integrate the following aspects: 1) tight building's envelop, 2) mechanical ventilation with the possibility to adapt outdoor air supply to demand, 3) inhabitants behaviour fitting these requirements and acceptance of the technology by the inhabitants, 4) heat recovery, and 5) an important key to economical solutions: design and realization of ventilation systems of high efficiency.

1. Introduction

The earliest recommendations for ventilation rates were based on the carbon dioxide level or more or less weak definitions of a comfortable and healthy indoor air atmosphere. More than 100 years ago Pettenkofer (1) expressed his view that carbon dioxide may be a good indicator for indoor air quality. The Pettenkofer number of 0,1 % carbon dioxide content as the highest acceptable level is still applied in many national ventilation standards. Tredgold (2) recommended an air exchange of 4 cubic feet per minute and person which corresponds with 1,9 l/s per person, to prevent stuffiness. Others as e.g. Carnelly et al. (3) refferred to microorganism in the indoor environment and suggested that a concentration of 20 organisms per liter should not be exceeded for healthy conditions in schools and dwellings.

The experts cooperating in International Energy Agency's Annex IX "Minimum Ventilation Rates" tried to summarize the different approaches and the available knowledge in the fields of indoor air quality to come to a more homogenous picture. The aim was to define ventilation rates which prevent that concentration of the main pollutants will not exceed levels which may give rise to one or more of the following categories: