NEW TRENDS IN IAQ AND VENTILATION

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Fifty six office buildings in nine European countries were audited during the heating season of 1993-1994 using an agreed upon procedure to investigate the indoor air quality and energy consumption. The results of this IAQ-Audit project show that the largest indoor pollution sources in office buildings are construction materials, furnishings and indoor activities, immediately followed by the HVAC systems themselves. Thus, priority must be given to source control. A better knowledge of the pollution sources, in particular of those associated with materials and improperly designed and managed ventilation systems, is required. The results confirm that more ventilation tends to lead to better indoor air quality. However, it is also demonstrated that there are cases where more ventilation does not necessarily give the expected IAQ results. That means that more energy use may not necessarily lead to better indoor air quality.

INTRODUCTION

Energy services in buildings include, among others, heating, cooling and ventilation. Ventilation, while necessary for hygienic reasons, is also used as an energy carrier both for heating and cooling. Even when used as a hygienic parameter, ventilation very often implies heating, cooling and dehumidification. There is thus an obvious link between ventilation and energy consumption in buildings and this raises a controversial issue, namely the connection between indoor air quality and energy consumption: does good IAQ call for more energy use or is it possible to reconcile good IAQ with energy-efficient buildings?

During the past twenty years indoor air quality has received growing attention. Many complaints with respect to indoor air quality occur and the causes of these complaints are often not found in spite of thorough measurements of indoor air. To some extent these complaints have been blamed on energy efficiency measures. Another cause of these complaints can be found in the sources of indoor pollution. The existing ventilation standards assume that the only polluters in buildings are the occupants. Good ventilation strategies require however more insight in the potential pollution by other sources than occupants.

In a workshop on Indoor Air Quality Management organised by the European Commission, it was identified that the achievement of health and comfort in the indoor environment combined with energy efficiency requires both minimisation of human exposure to indoor air pollution i.e. source control and a well-functioning and energy efficient heating, ventilating or air-conditioning system (1). As a result of this workshop, the "European Audit project to optimize indoor air quality and energy consumption in office buildings", was started, sponsored by the European Community through the Joule II programme.

Fifty six office buildings in nine European countries were audited during the heating season of 1993-1994 (2). 15 institutes from 11 countries (The Netherlands, Denmark, France, Belgium, United Kingdom, Greece, Switzerland, Finland, Norway, Germany and Portugal) participated.

PROCEDURE

The Audit procedure as described in the final manual (3) was prepared to ensure that the field tests were carried out with the same minimum requirements in each country. The research plan was concentrated on the investigation of one building per day and at least six buildings were investigated per participating country. In and outside each building (at five representative locations) the investigation included physical and chemical measurements (among others, total volatile organic compounds (TVOC)), assessment of the perceived air quality in the spaces by a trained sensory panel, and measurement of the outdoor air supply to the spaces. A questionnaire for evaluating retrospective and immediate symptoms and perceptions was distributed and collected at the day of the audit to the occupants of the buildings at the day of the audit. The building characteristics were described by use of a check-list. The annual energy consumption of the buildings and the weather conditions were registered.

RESULTS AND DISCUSSION

In the following some of the results of the IAQ-Audit project related to ventilation, energy consumption, sources and IAQ perception both by the occupants and the trained panels are given. More detailed information can be found in reference 2.

Ventilation levels and perceived indoor air quality

Ventilation measurements comprised measurement of supply of mechanical systems, of infiltration from outdoors and of supply from adjacent spaces. The outdoor airflow rates were quite high with an average of 1.9 l/s.m^2 or 25 l/s.person, which is well above existing ventilation standards.

The perceived air quality (PAQ) was assessed by a panel of trained persons assessing the air quality in decipol (4). The mean PAQ for all 56 European IAQ Audit buildings was approximately 6 decipol for office air, 4 decipol for supply air and 2 decipol for outdoor air. This corresponds to roughly 50, 40 and 25% dissatisfied visitors with the PAQ according to a draft European pre-standard (5). In this document, for the first time pollution sources other than occupants are taken into account and any source that emits molecules which can be perceived by the human nose is considered. The draft European pre-standard prENV1752 proposes figures for different levels of ventilation rates in office buildings (Table 1). These figures are recommended only for low polluting building materials and furnishings, and for a ventilation effectiveness of 1. They are based on air quality as perceived by persons coming from fresh, clean air and entering a room. Category A corresponds to 15% dissatisfied (1 decipol) only, while categories B and C correspond to 20% (1.4 decipol) and 30% (2.5 decipol) respectively. It is interesting to compare the recommendations of this document with the values measured in the audited buildings of this project. In Table 1 the percentage of audited rooms (total of 226 rooms) which complied with the recommendations of prENV1752 is presented. It can be seen that the ventilation rate in a majority of the rooms was higher than the minimum requirements. However, the corresponding PAQ levels were met in very few cases.

Table 1 Percentage of rooms complying with the recommendations of prENV 1752 (5). (Figures in last column assume clean outdoor air).

Type of room	Category	Required ventilation rate		% of rooms complying with prENV draft according to	
		[l/s.m^2]	[l/s.person]	Ventilation rate	PAQ
single office room	A	2.0	20	55	9
	B	1.4	14	67	12
	C	0.8	8	78	32

Standards are based on the hypothesis that a higher ventilation rate results in better PAQ because of the dilution of pollutants. In this study it was found that the PAQ assessed by the sensory panels (in decipol) was on the average slightly better in the buildings that had a high ventilation rate, a relation that is shown in Figure 1 (statistically significant at a 5% level). The mean PAQ (decipol) is, however, much worse than the theoretical relationship on which the prENV is based (see Figure 1). A reason for this may be that in this comparison the quality of the supplied air was not taken into consideration. Furthermore, pollution sources present in the ventilation system make a comparison difficult or even invalid.

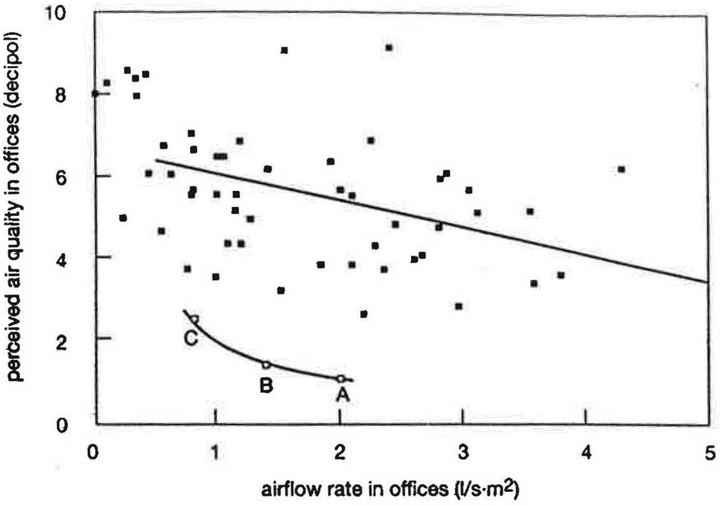

Figure 1 Mean PAQ versus the mean outdoor air supply for the investigated rooms per building. A, B and C indicate the relationship on which prENV1752 is based.

Energy consumption and Health

The total annual energy consumption of the audited buildings for all final energy forms was provided by the building owner or the technical manager. To compare the energy use of buildings of various dimensions an energy consumption index was calculated by:

Energy index = total yearly energy use/gross heated floor are [MJ/m^2] [1]

The gross heated floor area included all heated spaces of the building considered. From the energy consumption data for the year 1993, a huge variation in values appeared. There was a 7:1 ratio in total energy index between the highest and the lowest and a 20:1 ratio between the highest and the lowest energy use per person. The median value was little above 1000 MJ/m^2.

The questionnaire included mainly two series of questions concerning the occupants' health and their environmental conditions: during the past month and at this point in time. 6,537 occupants participated in the questionnaire survey (mean response rate of 79%). On average 27% of the occupants found the indoor air quality not acceptable at the time of the audit, and 32% found the indoor air quality not acceptable during the month preceding the audit. The mean number of building-related symptoms, from a list of 12 symptoms, during the month preceding the audit, defined as the BSI$_{ff}$, was 3.3, whereas the mean number of symptoms at the time of the audit, defined as the BSI$_{sf}$, was 2.1. BSI is an abbreviation for Building Symptom Index.

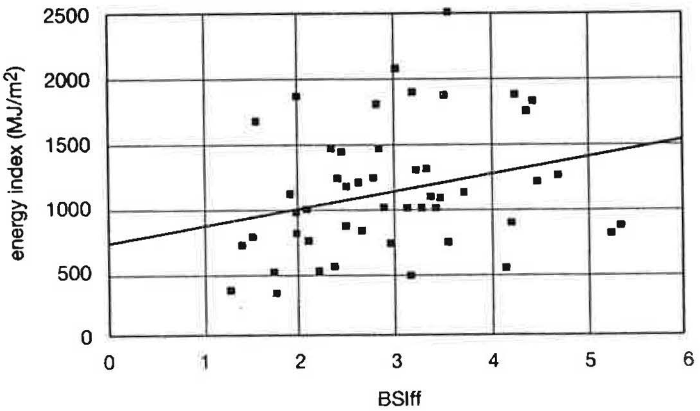

Figure 2 Energy index related to Building Symptom Index (BSI$_{ff}$).

Figure 2 shows that high energy consumption did not necessarily result in better health. However, there was a significant and positive correlation between the BSI and the energy index, indicating more complaints in the most energy consuming buildings ($R^2 = 0.43$). This may indicate that a potential exist for optimizing indoor air quality without consuming more energy.

Pollution loads and sources

Sensory assessments and chemical measurements of the indoor air quality together with ventilation measurements, were used to calculate pollution loads of sources in chemical and sensory terms (2). With the outcome, the most important pollution sources were identified.

The mean total sensory pollution load for the offices (including buildings materials, ventilation systems, occupants and previous and present smoking), was 0.7 olf/m^2. The occupants corresponded to 0.1 olf/m^2 and 0.3 olf/m^2 came from the ventilation systems (including in some cases previous smoking through recirculation). The total mean chemical pollution load for the offices (including building materials, occupants, ventilation systems and previous and present smoking) was 0.3 μg TVOC/s·m^2.

Pollution sources were identified using the calculated pollution loads (Figure 3). The most important sensory pollution sources (276 rooms were included in the analyses) were the materials and activities, closely followed by the ventilation systems. Among materials and activities, furnishing was identified most often as a source, as well as photocopying and building renovation. In the 50% of the situations where ventilation was identified as the most important pollution source, filters and air recirculation from other rooms were specifically identified equally often. It must furthermore be noted that the ventilation systems, which were the most important source in 29% of all rooms, were equivalent to 32% of those mechanically ventilated.

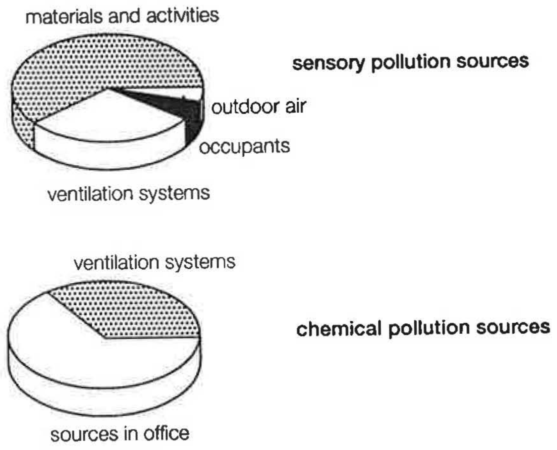

Figure 3 Most important sensory and chemical pollution sources estimated in audited buildings.

The TVOC data enabled chemical pollution sources to be divided into two main categories, the ventilation systems and the office which included materials, the occupants and all their activities. Rooms without mechanical ventilation systems were excluded from this analysis, since there was only one category of source in those cases. The identified chemical sources presented in Figure 3 are based on 211 rooms. The office, its occupants and their activities were identified as the most important source of chemical pollution in about two thirds of the rooms.

Ventilation standards and comfort

In spite of the generous ventilation rates, it is remarkable that nearly 30% of the occupants and 50% of the visitors (trained sensory panels) found the indoor air quality unacceptable. In 44 or 79% of the buildings studied the minimum ventilation rate of ASHRAE Standard 62 (0.7 l/s.m^2) (6) was met. Among these buildings with an average ventilation rate of 2.1 l/s.m^2 there were, however, only 17 buildings (36%) that met the aim of ASHRAE

62, namely that minimum 80% of the occupants should find the air acceptable. Furthermore, only a few of these buildings met the other ASHRAE 62 aim, namely that 80% of visitors should find the air acceptable. Meeting existing ventilation standards is obviously no guarantee for proper indoor air quality acceptable for people.
The average PAQ in the 56 audited buildings was 5.7 decipol, the average outdoor level was 1.9 decipol and the average source strength of the materials, persons and activities was 0.4 olf/m^2 (from which 0.1 olf/m^2 was caused by occupants). Using the assumption that outdoor air is clean and that ventilation systems do not pollute the incoming air, the average PAQ caused by materials, persons and activities would then be circa 4 decipol. For a source strength of 0.2 and 0.4 olf/m^2 (the prENV1752 assumes a source strength of 0.2 olf/m^2), this would lead to a ventilation requirement of 0.5 and 1.0 l/s.m^2 or 5 and 10 l/s.person, respectively. These values are lower than the current recommended values for categories A and B (see Table 1).
To make ventilation guidelines for existing buildings the levels given in the prENV1752 therefore need to be adjusted. More field-data are required for that. The IAQ-Audit project comprised only 56 European office buildings, which can not said to be representative for the total office building stock in Europe.

CONCLUSIONS

The results of the IAQ-Audit project show that the largest indoor pollution sources in office buildings are construction materials, furnishings and indoor activities, immediately followed by the HVAC systems themselves.

Bearing in mind the classical strategies for indoor air quality control, it seems nowadays that the trends for the future will be a good balance of the following three perspectives:

- to widen and improve the source control strategies
- to better define the ventilation criteria
- to enhance all means of designing, managing and maintaining the HVAC system.

Among the available strategies, the obvious priority must be given to source control. This requires a better knowledge of the pollution sources, in particular of those associated with materials and improperly designed and managed ventilation systems.

The results confirm that more ventilation tends to lead to better indoor air quality. However, it is also demonstrated that there are cases where more ventilation does not necessarily give the expected IAQ results. That means that more energy use may not necessarily lead to better indoor air quality.

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