Ventilation and "Building Sickness" - A Brief Review

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Introduction

As the thermal performance of buildings continues to improve, air exchange will eventually become the dominant mechanism for building heat loss. Although, therefore, an essential parameter of the energy equation, ventilation is nevertheless vital for the dilution and removal of pollution generated within buildings. An inadequate supply of fresh air or poor air distribution will result in high levels of indoor contaminants, discomfort and a poor living environment, it could also result in more serious health related problems. As a consequence, reduced air change as a means to minimise energy demand has become inextricably linked to the problems associated with unhealthy buildings. The purpose of this note is to summarise some of the International Energy Agency related and other activities in this field and to introduce the AIVC's Literature List on "Sick Buildings".

Minimum ventilation rates to secure adequate indoor air quality have been the subject of intensive investigation within the International Energy Agency and elsewhere. Recent publications on the subject include AIVC Technical Note 26, which describes the work of IEA Annex 9 on measures to control indoor air quality (Trepte 1989) and ASHRAE Standard 62-1989 on Ventilation for Acceptable Indoor Air Quality (ASHRAE 1989) (Figure 1). Technical Note 26 provides a summary of common building source characteristics, in terms of the origin and special features of pollutants (ie the effects of pollutants in relation to risk, annoyance and damage to building fabric), control measures such as source control and ventilation, and ventilation strategies.

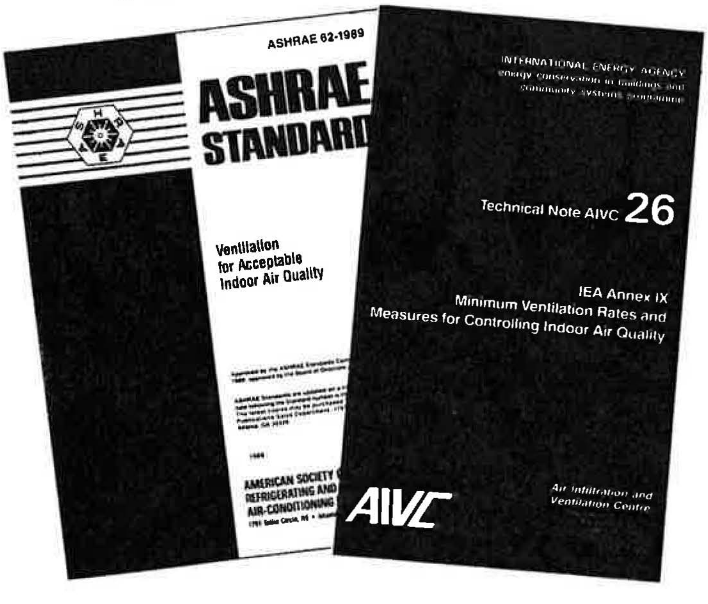

Figure 1 Recent publications on minimum ventilation

In many instances, the control of pollution should involve the restriction or elimination of the polluting source but often it falls upon ventilation to provide an answer. The derivation of minimum ventilation rate is dependent on identifying the dominant pollutant, its source strength and its maximum acceptable indoor concentration. Often the maximum permissible concentration of a pollutant is dependent on environment and exposure times. Thus, in an industrial area for example, concentrations are often expressed in terms of 1 hour or 8 hour exposure period threshold limit values. These are set with health and safety as prime concerns and, for many pollutants, are concentration levels which would be wholly unacceptable in an office or dwelling, where other factors such as intrusive odour would create discomfort. Acceptable concentrations of many common pollutants, for various occupancy conditions, are summarised in the appendix section of ASHRAE Standard 62-1989.

Where energy conservation is of concern, the need to provide ventilation above what would normally be necessary, in order to mitigate a particular pollution problem (eg tobacco smoke), can be directly equated in terms of extra energy consumption and hence additional costs.

AIVC "Sick Buildings" Literature List

While by no means an exhaustive reference list on the subject, a search of the term "sick buildings" in the Air Infiltration and Ventilation Centre's Bibliographic Database - AIRBASE reveals over 90 references. These have recently been compiled into a Literature list which is available from the Centre. A brief analysis of these articles reveal several suggestions as to the causes of the problem. These can essentially be categorised into the following three broad themes:

- ventilation system performance
- contaminants
- other parameters

A summary of the first theme is presented in Table 1. While insufficient or inadequate ventilation was widely cited as a cause, and in many instances is undoubtedly a contributory factor, the measurement of air change is, as yet, not a common feature of air quality investigations. Without having routine knowledge of air change rates, it is probably difficult to prescribe sensible adjustments to ventilation rates in order to improve building air quality. To facilitate an understanding of measurement methods, the AIVC has published a handbook on measurement techniques (Charlesworth 1988). This provides comprehensive guidance on the range of techniques available and on how they should be applied. In addition IEA Annex 20, which is concentrating effort on the calculation and measurement of air flow patterns within buildings, is currently producing an update to the AIVC handbook to incorporate the measurements of room air flow and air leakage in multi-zone structures.

Other ventilation related problems found in the literature relate to excessive air change, leading to discomfort through insufficient heating or cooling, and general failures in the ventilation or air conditioning system as a result of either poor maintenance or design.

Table 1 Reasons for "Sick" Buildings

1 - Ventilation Systems

- Ventilation too low
- Ventilation too high
- Inoperative Ventilation System
- Air Conditioning
- Poor Filtration
- Poor Maintenance

Building contaminants investigated as part of indoor air quality studies are listed in Table 2. Some, such as asbestos and formaldehyde, are specific to building components or choice of thermal insulation. Others, such as outdoor pollution and radon are more dependent on building location, although much can be achieved through good building design to eliminate radon problems. The remainder tend to be contaminants which depend on building use and occupancy patterns. Since, over time, the pattern of building use can vary, the relative concentrations of occupant generated pollutants and hence ventilation needs may also vary.

Odour is widely used as an indicator of air quality, although it provides no warning of dangerous odourless gasses such as radon and carbon monoxide. The quantitative measurement of odour using instruments is not possible but a subjective approach has been developed by Fanger (1988). This technique introduces the unit of "OLF" as a measure of the emission rate of pollutant from a "standard" sedentary person and the "decipol", which is the pollution caused by one standard person ventilated by 10 l/s of unpolluted air. A specially trained team of assessors is needed to evaluate odour within a room by making comparisons with known decipol levels established by a reference gas. A full description of this technique is published by Bluyssen (1988) in the February 1989 edition of "Air Infiltration Review".

Since Fanger's approach to the classification of odour levels demands a trained panel of specialists, its

Table 2 Reasons for "Sick" Buildings

2 - Building Contaminants

- Asbestos
- Carbon Dioxide
- Carbon Monoxide
- Dust
- Formaldehyde
- Fungal Spores
- Humidity (too high, too low)
- Ions
- Odour
- Outdoor Pollution
- Ozone
- Radon
- Smoke
- Volatile Organic Compounds

widespread application is, as yet, limited. Instead, carbon dioxide concentration is often used as a measure of occupancy and occupancy generated pollution.(Figure 2) ASHRAE Standard 62-1989 sets an upper concentration limit of 1000ppm for comfort (odour) criteria. Because carbon dioxide concentration, along with other occupant generated pollutants such as moisture, can be measured with relative ease, appropriate detectors are beginning to be used in the monitoring and control of ventilation rates, especially in

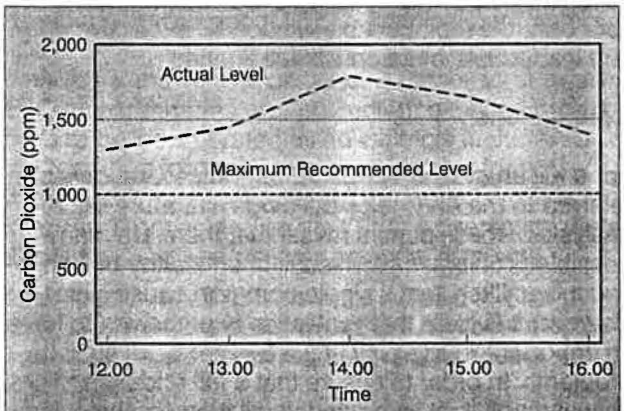

Figure 2 Carbon Dioxide Monitoring

transiently occupied buildings. This topic is being investigated in detail by IEA Annex 18 on "Demand Controlled Ventilation" (Raatschen and Mansson 1990). The principal objective of this task is to develop guidelines for demand controlled ventilation systems based on the varying needs of domestic, office and other environments. While essentially focusing on carbon dioxide and humidity sensors for ventilation control, mixed gas, tobacco smoke and carbon monoxide sensors are also being considered. Additional work, within Annex 18, includes the development of guidelines for the implementation of demand controlled ventilation systems.

Table 3 Reasons for "Sick" Buildings

3 - Other Parameters
Psychological Factors
No User Control
Stress
Noise
Lighting

The control of indoor climate by the actions of occupants has also been investigated by IEA Annex 8 (Dubrul 1988). This work concentrates on how occupants satisfy ventilation needs and possible ways of improving user efficiency.

Other reasons which are cited in the literature as causes of "sick buildings" are indicated in Table 3. These problems are beyond the scope of the Air Infiltration and Ventilation Centre but include psychological or work related problems, the absence of user controls (eg openable windows), excessive noise and inadequate or inappropriate lighting.

Conclusions

For a full analysis of AIRBASE references, readers are referred to the AIVC "sick buildings" literature list. An analysis of these papers reveal that there are many possible problems which result in unhealthy buildings and it is unlikely that a single common cause exists. However it is clear that ventilation is perceived to have an important role to play in the avoidance of such problems. In order to ensure that a full understanding between pollutant levels and ventilation can be clearly understood, the measurement of air change rates and air flow patterns needs to form a fundamental aspect of any building air quality study. Appropriate measurement techniques varying from relatively inexpensive passive sampling methods to comprehensive interzonal air flow measurement methods are now well established and it is up to researchers in this field to implement these techniques more widely in their studies.

On the theoretical front, the concepts of air change efficiency and ventilation effectiveness need to be rationalised and adapted to provide quantitative links between measurement results and pollutant concentrations. The AIVC has recently published a Technical Note on air change efficiency (Sutcliffe 1990) and is currently preparing a review on ventilation effectiveness in relation to the removal of airborne pollutants.

Of related interest to this topic is AIVC Technical Note 30, to be published in July, which contains an up to date summary of standards in AIVC countries on airtightness and ventilation requirements.

References

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