GUIDELINES FOR MINIMUM VENTILATION RATES

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ABSTRACT

From a viewpoint of energy conservation air infiltration and ventilation in residential buildings should be minimized. However, a certain amount of outdoor air has to be supplied in order to maintain healthy and comfortable conditions for the inhabitants and to avoid structural damages. The 12 participating countries of the International Energy Agency's Annex IX "Minimum Ventilation Rates" investigated and studied for the most important indoor pollutants possible consequences of insufficient ventilation, and many of these countries concluded that their national ventilation standards should be revised or modified. Three factors have been used to develop minimum ventilation rates:

1. avoiding damage to the building fabric
2. decreasing annoyance of the inhabitants
3. minimizing health risks.

In some countries, these factors will demand minimum ventilation rates above 0.5 ach (Trepte 1983). In special cases, e.g. problem buildings with higher inner pollutant loads, ventilation rates in the order of 0.8 to 1.0 ach may be recommended (Erhorn et al. 1985).

INTRODUCTION

The work required to define minimum ventilation rates covers a wide range of disciplines, from hygiene and medicine on one hand to engineering and building physics on the other. Therefore, in 1980 the Annex IX "Minimum Ventilation Rates" within the International Energy Agency's (IEA) program "Energy Conservation in Buildings and Community Systems" was established in which experts from twelve countries in the various fields decided to cooperate for identifying objective criteria and other background data to recommend minimum ventilation rates or to define guidelines.

From the beginning it was clear that these guidelines cannot consist of well-defined numbers but rather should point out orders of magnitude, explain reasons for the recommendations, and show consequences of such recommended ventilation rates for health, comfort, building fabric, and energy consumption. Results and knowledge brought about in Annex IX work will give the participating countries the opportunity to establish standards and guidelines that take into consideration special national conditions and requirements. In such a way they will serve as a basis for developing optimum ventilation techniques, measures, and strategies.

As a first step, the participants have reviewed existing knowledge. In a concerted action, they investigated and studied for the most important indoor pollutants

- emission rates and their dependence on time and other factors including human behavior

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- indoor transfer and interaction phenomena
- technical measures for indoor air pollution control and air treatment
- different strategies for indoor air quality under the restraints of energy conservation.

For some of the pollutants considered in Annex IX as important it was more appropriate to recommend a maximum level of tolerable concentration than to define a minimum ventilation rate. In these cases, other measures including air cleaning techniques could be more efficient or opportune than increasing ventilation rates.

In connection with these efforts in many countries activities are going on to revise or to modify existing ventilation standards. For example the new German ventilation standard DIN 1946 X "Wohnungslüftung" is under development, and it has been influenced by the results of the Annex IX work and by the ASHRAE standard for indoor air quality for nonindustrial spaces.

PRESENT GUIDELINES AND THEIR BASES

With the primary aim of reducing energy consumption, building standards have been introduced in many countries. In most cases, priority was given to additional insulation and an increase in the tightness of the buildings' envelopes. Consistently, more and more attention had been paid to questions concerning necessary ventilation and to technical solutions that secure sufficient outdoor air supply.

The comparison of the present ventilation standards in different countries (among others, Thompson 1984) shows different approaches as well as several bases for defining such minimum requirements. Standards are specified in terms of air change rate, airflow rate, the area of ventilation opening, or in other terms.

Generally the carbon dioxide level serves as a basis. In the German standard DIN 1946 "Raumlufttechnik, gesundheitstechnische Anforderungen", minimum outdoor airflows between 20 and 50 m^3/h are recommended with an average at 30 m^3/h. Additional indoor air pollution by tobacco smoke requires an additional ventilation flow of 20 m^3/h/person. Estimates of the necessary outdoor airflow are based on the Pettenkofer number, which defines as the upper limit a carbon dioxide content of 0.15 % in the indoor air. Other German standards such as VDI 2088, "Lüftungsanlagen für Wohnungen", or DIN 18017, "Lüftung von Bädern und Spülaborten", refer to mechanical ventilation systems and specify necessary air change rates, such as 1 to 1.5 ach for living rooms. Here aspects of draught enter into the considerations.

The first standard to address air quality on a larger scale is ASHRAE standard 62-1981. Still containing the carbon dioxide level philosophy, it is extended also over other indoor air contaminants and includes such important aspects as "air quality procedure" and "ventilation efficiency" (Harrje 1984).

NEW APPROACHES

Facing the need to include indoor air quality aspects into the considerations, experts in the Federal Republic of Germany, as well as in other countries, and the participants of IEA Annex IX applied new approaches. They identified pollutants that are of most importance and for which research is likely to yield results within a reasonable timescale. Those pollutants are:

- formaldehyde
- tobacco smoke products
- radon
- moisture and microorganisms
- body odor and carbon dioxide
- organic substances as, e.g., biocides
- combustion products
- particulates.

The aim was to find out concentration levels of these pollutants that avoid

- damage to the building fabric
- annoyance of the inhabitants
- health risks.

Knowing this and including in the considerations different ways of controlling indoor air quality such as dilution by ventilation, removal of sources, and suppression of emission; minimum airflows have been recommended.

VENTILATION NEEDS

Typically enough, in the German standards the term "fresh air supply" changed to "outdoor air supply". This pays tribute to altered environmental conditions, but other reasons, such as climatic conditions in the different countries, may result in variations in the ventilation rates applied in national standards.

Moisture and Mold Growth Problems

Although moisture and mold growths may raise great problems in Middle European countries, especially in the transitional seasons, spring and autumn, most of the national standards do not take these aspects into consideration. Experience shows that in the past no consciousness of this problem existed in the public.

Condensation is a critical consequence of the cold outer surface of a building. One of the geometries bearing the highest condensation risk is the three-dimensional corner on the outside walls of a building under a flat roof ceiling (Gertis 1985). It was found that the surface temperature can fall below the room temperature and cause condensation. For some typical meteorological situations, the necessary air change rate has been calculated (Erhorn 1985); Meyringer 1985). Depending on the conditions, it varies between 0.5 and 0.8 ach and may in many cases exceed the air change necessary to avoid annoyance and risks by other factors.

The inhabitants contribute to humidity emission, but there are other sources too. The ventilation rate, therefore, is to some extent independent of the number of persons living in a dwelling. Thus, a basis of minimum ventilation rate is needed also if no persons are present.

In northern European countries, humidity and moisture are of minor importance unless the ventilation rates are very low.

Aspects of Inhabitants' Annoyance

Common indoor air pollutants giving rise to annoyance such as carbon dioxide, and body odor are created by the inhabitants, but human activity source control is out of the question. The minimum ventilation rate will be dependent on the number of persons. Earlier approaches use carbon dioxide as an indicator for body odor and fall back upon the Pettenkofer number or other carbon dioxide concentration levels.

In recent investigations (Fanger 1983) odor intensity and acceptance by persons have been compared. They show a good correlation between the percentage of dissatisfied persons entering a room and odor intensity. On the other side, increases in the percentage of dissatisfied persons are correlated with an increase in the carbon dioxide concentration. This indicates that carbon dioxide is a useful indicator of body odor.

The recommendation of a minimum ventilation rate is correlated with the question of how many dissatisfied visitors should be accepted. Obviously no final answer is possible. The ASHRAE 62-1981 suggests 20 % dissatisfied persons as acceptable. In this case a ventilation rate of about 30 m^3/h per person is necessary, in good accordance with many present European standards. Some experts consider this percentage too high because the corresponding carbon dioxide level is about 0.12 %. Lower recommendations would result in higher outdoor air supply rates.

HEALTH RISKS

Typical indoor air pollutants are combustion products, tobacco smoke, radon, organic vapors, and gases, formaldehyde, etc. Apart from the question of which risk level could or should be accepted, ventilation is usually the only suggested means for decreasing pollutant concentration. More appropriate measures eliminate emitting sources or reduce or prevent emission.

In the case of tobacco smoke, investigations show that a constant smoking rate of one cigarette per hour requires an outdoor air supply of about 33 m^3/h to keep the carbon monoxide below the proposed maximum allowable level of 2 ppm (Wanner 1983).

Apart from risk assessments which have to preceed recommendations for ventilation rates, the better approach is to define maximum acceptable pollutant concentration levels and to follow ASHRAE air quality procedures.

If we include the elimination of emitting materials with the removal and suppression of emissions, air change rates on the order of 0.5 ach seem to be sufficient for an appropriate indoor air quality.

VENTILATION STRATEGIES

If energy conservation is the only consideration, then the ventilation rate should be as low as possible. If air quality is also required, then low ventilation rates must be accompanied by the removal of pollutants sources or pollutant removal from the air. However, in the case of higher inner loads or because of other reasons, ventilation rates may be necessary that do not coincide with energy conservation. Then heat recovery from the air exhaust can contribute to an economical energy operation. A technical solution will be mechanical ventilation with controlled exhaust airflow. This requires a tight building envelope.

CONCLUSION

The first steps have been taken for a definition of indoor air quality and minimum ventilation rates. There are different but important aspects requiring individual and careful considerations:

- avoiding risks for the inhabitants and the building envelope
- acceptance of indoor air quality by the inhabitants
- energy conservation.

No ventilation strategy can be expected to result in a 100 % acceptance level of air quality.

The effect of dilution by ventilation is an important strategy to achieve acceptable indoor air quality, but it is not the only one. It is necessary to distinguish between a basis minimum ventilation rate, which is also needed if no persons are present in the dwelling, and an additional ventilation rate corresponding to the number of persons living in a dwelling.

The minimum acceptable ventilation rate is dependent on various factors. Ventilation rates below 0.5 ach, sometimes proposed for energy reasons, may cause problems for the building envelope and for the inhabitants' health and comfort.

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