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GUIDELINES FOR NORDIC BUILDING REGULATIONS REGARDING INDOOR AIR QUALITY

Jan Sundell
National Board of Occupational Safety and Health, Section for Ventilation and Thermal Climate, S-171 84 Solna, Sweden

A subcommittee of the Nordic Committee for Building Codes has released guidelines for building regulations regarding indoor air quality, especially concerning ventilation. The main features of the guidelines, such as acceptable outdoor air quality for ventilation and minimum outdoor air flows for dwellings and offices, are presented and discussed. Mechanical ventilation is, in principle, required in all buildings including dwellings, due to the requirement of a minimum outdoor air change of 0.5 h^{-1} and the normal highly airtight nature of new buildings. The guidelines are a basis for designing energy-efficient buildings while maintaining an indoor air quality which provides acceptable comfort and does not impair health.

Introduction

Of all primary demands on a building, the demand for a certain air quality achieved through ventilation has the most direct connection with the building's energy consumption. From an energy-efficient point of view, the air change rate should be as low as possible. Each reduction by 0.1 ach represents an energy gain of 1000–2000 kWh per dwelling annually in the Nordic countries. In the light of the energy situation it is easily understandable that measures have been taken to reduce the air change rate in buildings. As a result, however, "old" hygienic problems such as condensation and mould have once again occurred. Furthermore, serious new problems have appeared, for instance, in connection with radon and formaldehyde.

Within the Nordic Committee for Building Codes (NKB), the Subcommittee on Indoor Climate has attempted to find a balance point between energy waste and poor indoor climate. The result has been the creation of guidelines for building regulations regarding indoor air quality and thermal climate. The guidelines were adopted on June 5, 1981, and shall in principle be included in the national building codes of the five Nordic countries (NKB, 1981). The functional requirements shall then become mandatory.

Until now, the Nordic building codes contain little information on indoor climate. These aspects have been downgraded, compared to other areas in which specific requirements are listed, such as fire safety, structure, sanitary systems, insulation, and energy use. The guidelines will apply to all new buildings except recreational buildings, industrial buildings, and hospitals.

Air Quality and Ventilation

The general purpose of building legislation within this field is to establish a quality of indoor air which is acceptable to human occupants and does not impair health. However, measurement of approved concentrations can be performed for only a few components of indoor air pollution; in addition, verification of compliance with concentration limits is practically impossible at present. Instead, the method chosen has been to establish requirements with regard to air flow rates, complemented by certain basic requirements concerning the quality of the fresh air supplied. In this way, the actual air quality requirements have been given a conventional indirect form. The specified air flow rates for fresh air and air change rates are given in view of present knowledge concerning the types and quantities of airborne pollutants indoors. If the inlet air (fresh air) is of the required quality, the primary objective, that of keeping the concentrations of pollutants at acceptable levels, should be realised. In addition to these re-

quirements regarding ventilation there will be elaborated special requirements controlling outgassing and ionising radiation from building materials. Requirements regarding formaldehyde and radon already exist to some extent in the Nordic countries.

Dwellings

Since people spend the major part of their lives in dwellings, it is especially important to maintain an air quality there that does not impair health and comfort. For many years this was not a problem, since buildings were generally loose and had a rather high natural ventilation with rates greater than 1 ach. The progressive increase in the energy costs has motivated the development of much tighter constructions; the natural air change rate in new houses in the Nordic countries is now normally between 0.1 and 0.3 ach. With such low infiltration, excessively high concentrations of several contaminants can easily occur.

A vast number of airborne pollutants may be found in dwellings. They may originate outdoors and enter the building via infiltration or ventilation, or indoors from sources such as human beings, and activities such as tobacco smoking, cleaning, and hobbies. Building materials also contribute. The number is so vast and the knowledge regarding their occurrence and effects on human beings is so little that one must rely on generalisations. At best the pollutants so far discussed are indicators of the total pollution coming from different sources.

Some major principles that must be stated when discussing air quality regulations within building legislation are as follows:

1. An approach similar to that applied, for instance, to food or drinking water should be a fundamental characteristic of the strategy with regard to the air change rate required in dwellings. Air should not contain any substances in such concentrations which entail a documented or potential risk of harmful effects on the occupant's health.

In dwellings, the population consists not only of healthy adults. There are infants, the elderly, the sick, and the disabled. This must be considered when determining allowable concentrations in dwellings, because the exposure time of these individuals is closer to 24 h than 8 h. For pollutants for which more relevant information does not exist $1/x$ of Threshold Limit Values (TLV) applicable to the working environment is often used, with x varying from 5 to 20.

2. Pollutants should be controlled as close to the source as possible. For instance, precautions must be taken so that pollutants from heating plants cannot directly enter indoor air. The same applies to combustion products from gas-fired stoves or furnaces. Requirements regarding chimneys, heating units, and other installations should take care of these problems.

3. Outgassing of pollutants from building materials must be minimized; special control and requirements regulating this aspect will be needed. In view of considering the energy situation, buildings cannot be constructed with materials that are known to need extra ventilation.

4. Outdoor air used for ventilation must be of suitable quality.

5. Information and consumer goods legislation can perhaps stop extremely dangerous items from entering dwellings, but it is difficult to convince people to stop smoking or stop using pesticides, paints, glues, air fresheners, etc., in poorly ventilated rooms. For building legislation to deal seriously with this problem, there should be requirements for local exhausts in most rooms as a complement to the operable windows that are normal today. However, people cannot be compelled to use the local exhaust.

Pollutants considered by the guidelines

CO_2 and human body odor. At rest, a person produces about 15 L/h of CO_2, while during moderate activity the production is about 45 L/h. Assuming a state of equilibrium and perfect mixing, an air flow of 1 resp 3 L/sec/person will hold the concentration of CO_2 at the TLV for workplaces, 5000 ppm (μL/L). For the bedroom, with people at rest ($\sim$0.8 met), by adding a "safety factor" of 5 (due to imperfect mixing, exposuretime, and with respect to the mixed population) we get a requirement for a minimum outdoor air flow of 4 L/sec/person. In this context, one must also consider reports indicating that concentrations of more than 1000–1500 ppm (μL/L) may cause general discomfort as well as headache and lightheadedness. The same value ($\sim$4 L/sec/person), according to Yaglou, means that body odor would be held at a moderate level assuming normal bedroom space.

Pollutants from building materials and inventories. It is not possible to eliminate, for instance, all formaldehyde or radon via measures mentioned above. In addition, there are probably many other contaminants whose occurrence indoor or health effects have not yet been seriously considered.

The concentration of radon and daughters varies primarily with the foundation, the building material, and the air change rate. In the provisional requirements that are now in force in Sweden, 70 Bq/m^3 in radon daughter concentration is the highest approved level for new dwellings. Using normal approved foundation and building materials and assuming that opening of windows will take place in a normal way, a rate of 0.5 ach will keep the concentration of radon daughters below this level. There is, however, still a great uncertainty with regard to the deleterious health effects from radon.

Maximum allowable concentrations of formaldehyde in the indoor air in dwellings is or will soon be specified

in many countries. These levels implicitly indicate that the types of building materials must be changed, if they have not already been. In many cases, it is not possible (or at least not economical) to meet requirements of, for instance, 0.15 mg/m³ with the help of extra ventilation. Since formaldehyde can emanate from many sources, a minimum air change rate (~0.5 ach) might be required for this criterion regardless of the building material used.

However, the greatest problem with regard to pollution from building materials is the general low level of knowledge that exists in this field. There is, therefore, a need for a built-in safety margin; the 0.5 ach level may be too low.

Humidity, mould, mites. Moisture generates from many sources, such as persons, flowers, aquaria, food processing, baths, or showers. Humidity in itself may not be a problem but it might cause the growth of microorganisms such as mould and mites. House dust mites cause the frequently occurring house dust allergi. Mould may cause allergic reactions, and it may also be the cause of intolerable odor. If we consider only the moisture generated by people (40 g/h at rest), about 3 L/sec/person of outdoor air are needed to keep the humidity below 45%, assuming outdoor conditions to be 0°C and 80% RH. Maximum 45% RH is a practical limit for preventing growth of dust mites.

Intermittent pollutants from tobacco smoking, food processing, cleaning. Window opening and supplementary intermittent use of ventilation devices such as range hoods should handle these problems if and when they arise.

Pollutants from outdoors. The outdoor air serves to dilute pollutants generated indoors. Indoor/outdoor ratios of different pollutants are normally close to 1. In certain industrial regions or near densely trafficked roads, outdoor air in itself might be a problem. The solution of this problem within building legislation is to state a required quality of the outdoor air that shall be used for ventilation.

Summary of Ventilation Requirements for Dwellings

The NKB Indoor Climate Committee has reached the conclusions given in Table 1 with regard to minimum ventilation requirements for dwellings. To be used without treatment, the quality of the outdoor air shall meet some minimum requirements, in principle corresponding to EPA's secondary standard for ambient air (U.S. EPA, 1977). Other contaminants must not exceed one tenth of Threshold Limit Values or maximum allowable concentration applicable to the working environment. This will seldom be a problem in the Nordic countries, but in special cases in which the requirements cannot be met, the air should be cleaned or an alternative positon for the intake of outdoor may be selected.

To fulfill these requirements, as well as requirements regarding energy conservation, some kind of mechanical ventilation is needed, either an exhaust system with exhaust air terminal devices in every bedroom as well as in the kitchen and bathroom or by a combined supply and exhaust system.

In the loose, naturally ventilated house the ventilation—and therefore the indoor air quality—depends on wind and outdoor temperature. Energy for ventilation is spent whether the house is occupied or not. In the airtight, mechanically ventilated house the air quality is independent of weather and the house need be ventilated only when occupied. The energy efficiency of the mechanically ventilated house may be further improved by heat recovery. Economically, the guidelines will have a small effect. The installation cost will normally be somewhat higher, but the running cost might be lower if comparing a new mechanically ventilated one family house with a naturally ventilated one.

Commercial and institutional buildings

As in dwellings there is outgassing from building materials and inventories. The same minimum rate of

Table 1. Summary of NKB ventilation requirements for dwellings.

	Basic Ventilation		Supplementary Ventilation
	Outdoor Air	Exhaust Air	
Dwelling as a whole	0.5 ach		
Bedroom	0.5 ach, 4 L/sec/person		Operable window
Living room	0.5 ach		Operable window
Kitchen		10 L/sec	Operable window and range hood (30–100 L/sec)
Bath		10 L/sec	Operable window or adjustable ventilator with capacity of 30 L/sec
Toilet		10 L/sec	

0.5 ach is therefore required. Due to varying ceiling heights, this requirement is here expressed as 0.35 L/sec per m^2 floor area. In commercial buildings with moderate occupancy this figure determines the required ventilation. In spaces with higher occupancy the ventilation must be increased to handle the odor emitted from the occupants. In Fig. 1 the required outdoor air per occupant is given. Curve *a* is based on Yaglou's classical studies (1936). The required ventilation decreases with increasing space volume per occupant. However, in order to maintain a reasonably low CO_2 content, it should not be lower than 4 L/sec/person, assuming an activity level of 1.2 met and a safety factor of 3.

Smoking has a marked influence on the ventilation requirement. For reasons of hygiene and energy conservation it is expected that newer buildings will be divided into smoking and nonsmoking zones. For spaces where smoking is allowed the minimum flow of outdoor air is 10 L/sec/person as shown in Fig. 1 (curve *b*). At a normal smoking intensity of 0.5 cigarette/h/person this ventilation will hold the odor at a moderate level and the total suspended particulates in the space air would be less than 5 mg/m^3. By filtering recirculated air, the required outdoor air may be decreased as shown in Fig. 1 (curve *c*).

Thermal climate

The guidelines state minimum requirements regarding operative temperature, vertical air temperature difference, floor temperature, temperature asymmetry, and air velocity.

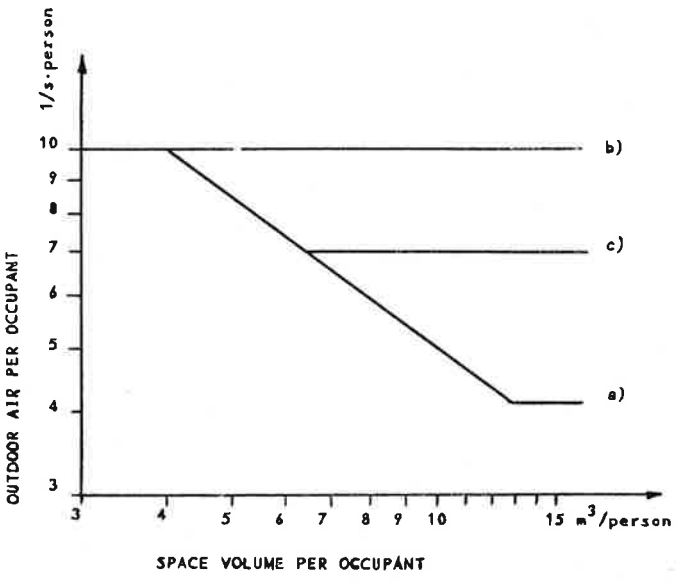

Fig. 1. Requirements of air flow in commercial and institutional buildings as a function of space volume per person. Curve *a*: no smoking; curve *b*: smoking allowed; Curve *c*: smoking allowed air recirculated and filtered.

Verification of the Parameter Values

Control should chiefly be carried out through examination and approval of drawings and specifications before the building is constructed. This must be supplemented by checks and tests in the completed building, mostly in the form of spot checks. Approved methods for measuring air flow shall be used; instruments shall be calibrated.

Since these required values of air flow rates and air change rates must be met at all times during the year, the guidelines specify that the ventilation in dwellings shall be checked when the difference between outside and inside temperatures is between 10 and 20°K and that the wind speed is less than 5 m/sec. When the temperature difference is less, for instance in the summer, windows can be kept open, and when the difference is greater, the thermal forces will increase ventilation.

Conclusion

The adopted guidelines are the results of an effort to create a building code with requirements for indoor climate. It is hoped that they will prove to be a useful tool for designing an energy-efficient building with an indoor climate which provides acceptable comfort and does not impair human health. Many of the values stated are debatable, especially when considering the limited knowledge regarding indoor air quality. But without values and requirements, the rising price of energy will cause buildings to be less and less ventilated. The health implication of such a situation might not be clear for decades.

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