

Health and energy efficiency: uncertainties in the calculation of ventilation flow rates and design criteria in building renovation

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Abstract

In the current context of building retrofits and decarbonization, energy efficiency cannot be considered independent of health. This article analyses the uncertainties involved in calculating ventilation rates according to standards such as EN 16798-1 and demonstrates the need for high rates, adjusted according to indoor air quality levels.

Introduction

The concentration of pollutants in indoor environments, where people spend between 80% and 90% of their time [1], can be between two and five times higher than levels found outdoors [2], due to the combination of multiple emission sources and insufficient air exchange. For this reason, indoor air quality (IAQ) is a critical factor in ensuring health and comfort. Poor IAQ can impair cognitive performance and productivity, contribute to the development and worsening of respiratory diseases and allergies, and act as a risk factor in the transmission of airborne infectious agents. To ensure adequate IAQ, coordinated measures must be implemented throughout the building's entire life cycle, including: controlling sources of pollutants; installing mechanical ventilation systems with heat recovery, filtration and adequate air distribution; and carrying out the necessary maintenance during the building's operational period.

Results and discussion

This paper argues that, regardless of the methodology adopted, design flow rates should not be limited to the minimum requirements set out in standards such as EN 16798-1 or ASHRAE 62.1; rather, it is technically necessary to adopt wider margins that account for the sources of variability identified below.

Temporal variability in indoor emission levels:

The application of new wall coverings or the carrying out of partial refurbishments can transform a building initially classified as low emission into a space with

levels of VOCs, formaldehyde and airborne particles significantly higher than those specified in the original design. Added to this variability associated with materials is the dependence of emission rates on indoor environmental conditions, particularly temperature and relative humidity. Numerous studies [3,4] have shown that VOC and formaldehyde emissions increase significantly with temperature.

Unpredictable reactions: Secondary pollutants may form from interactions between different substances. For instance, the interaction between outdoor ozone and terpenes (particularly limonene and α -pinene) found in cleaning products, air fresheners and wood finishes can generate aldehydes, hydroxyl radicals and ultrafine particles.

Geogenic sources: The variability of indoor pollutant levels is not limited to compounds of indoor origin. Radon is a source of exposure whose intensity is subject to marked seasonal variation of a meteorological nature, depending on atmospheric pressure.

Filter clogging: The gradual clogging of filters between scheduled maintenance intervals reduces the effective volume of ventilation air supplied.

Air distribution efficiency (Ez): This parameter depends on the supply strategy adopted and on the temperature gradients between the supply air flow and the ambient air; as a result, it may decrease significantly in summer conditions or with variations in internal load. An Ez value below unity necessitates supplying air flows greater than the theoretical values in order to maintain an equivalent effective dilution of pollutants in the breathing zone.

Free cooling: An adequately sized ventilation system is a prerequisite for free-cooling strategies. In systems with a primary air handling unit, the potential for free cooling is strictly limited by the capacity of the supply air ducts, which in many projects are sized to the minimum regulatory

requirement, making them insufficient for significant heat dissipation by this means.

Continuous monitoring of IAQ provides an objective way of verifying whether ventilation rates are adequate. For this reason, as a case study, 16 air quality sensors have been installed in the recently refurbished and extended Faculty of Philosophy and Letters. Temperature, humidity, CO₂, total volatile organic compounds, formaldehyde, particulate matter and, in some cases, O₃, NO₂ and CO have been monitored.

High levels of formaldehyde were detected in classrooms, particularly during July and August, when temperatures were high and the building was unoccupied, with readings of up to 445 µg/m³ (recommended limit is 100 µg/m³). Consequently, the ventilation system should be modulated not only according to CO₂ levels, but also according to other parameters, such as formaldehyde concentrations or temperature (Figure 1). Furthermore, a minimum ventilation flow rate should be maintained, adjusted on the basis of continuous monitoring.

It has been observed that, when a space is occupied, TVOC values typically reach 500 on the index (relative scale 0–500) due to factors such as higher temperatures or the presence of people. Conversely, when the space is unoccupied, the daily TVOC value ranges between 0 and 250, due to temperature variations that affect the emission of gases from building materials and furniture.

Finally, during periods of peak occupancy, CO₂ levels can reach or exceed 1500 ppm in certain areas. These results demonstrate that ventilation is insufficient.

Conclusions

Given the apparent trade-off between the health of occupants and energy efficiency, it should be noted that the historical restriction on air flow, although justified by the high heat losses associated with conditioning outside air, has now been rendered obsolete by the current state of heat recovery technology. The installation of dual-flow mechanical ventilation systems equipped with high-efficiency heat recovery units, filtration, proper air distribution and demand-controlled ventilation (DCV) ensures both health protection and energy efficiency. When combined with free-cooling strategies during periods of favourable outdoor conditions, increased ventilation rates can result in a positive net energy

balance for the building, especially in certain climatic conditions and with significant internal loads. Furthermore, designing the system with high ventilation rates using VCD strategies allows the flow to be modulated in real time based on continuously monitored parameters.

Figures

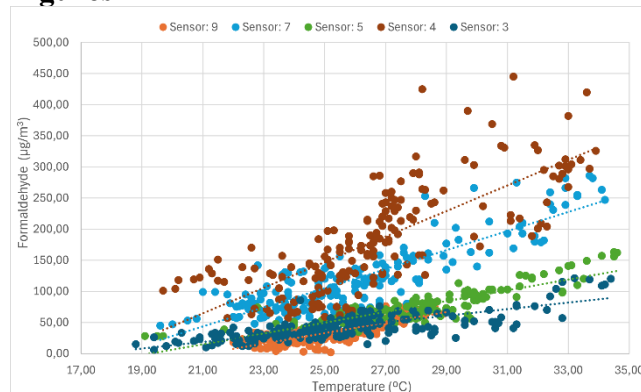


Fig. 1. Correlation between daily maximum formaldehyde and temperature levels in different classrooms.

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