Assessing IAQ in existing residential buildings within a performance-based regulatory framework through a predictive model

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SUMMARY

In many countries, the traditional method of ventilating dwellings involved natural ventilation, based on the operation of windows and high levels of infiltration through the building envelope, particularly through windows and window-wall joints. In Spain, in the middle of the last century, the use of vertical ventilation shafts in the wet rooms of dwellings became widespread, and it is currently the most common ventilation system in existing dwellings. It is a dedicated ventilation system with exhaust of stale air from wet rooms, circulation of air from dry to wet rooms and intake of fresh outdoor air to dry rooms by infiltration [1]. This passive stack ventilation employs the principles of thermal buoyancy and the Venturi effect to remove stale air from wet rooms.

Despite its widespread use, this system has four principal limitations. Firstly, there is a lack of ventilation in the absence of thermal buoyancy and even thermal inversion during periods of high temperatures, which can result in the circulation of stale air back into dwellings. Secondly, there is no ventilation when there is a lack of Venturi effect during periods of low wind speed. Thirdly, there are thermal losses due to involuntary infiltrations and uncontrolled aeration. Finally, there is uncertainty associated with natural ventilation systems. As a result, the actual IAQ in the majority of the current housing stock is unknown.

It can be reasonably assumed that the implementation of this ventilation system would result in a superior IAQ during the winter months in comparison to the summer season. However, field studies [2] indicate that this is not the case. In monitored dwellings, IAQ is generally superior in summer than in winter. This discrepancy may be attributed to the influence of occupants and their varying responses to factors affecting ventilation, such as the opening and closing of windows or the compartmentalisation of dwellings through the use of interior doors. If the season or weather exerts a significant influence on occupant behaviour, can this be statistically linked? Can IAQ be predicted by taking into account occupant behaviour at the macroscopic level?

A plethora of studies have been conducted on the determination of IAQ when the ventilation flow rate is known, the calculation of the ventilation flow rate, and the impact of specific actions of occupant behaviour. Nevertheless, the proposal is to analyse the relationship between influencing factors and final IAQ without calculating the specific ventilation rate or the behaviour of occupants.

At the Eduardo Torroja Institute for Construction Sciences (IETcc), which is a research institution belonging to the Spanish National Research Council (CSIC), studies are being conducted to correlate the outcomes of real CO_2 measurements in rooms where the occupants have been able to behave freely with factors such as the season of the year, the surface area of the dwelling, the permeability, or the number of occupants. The a priori intention is not to ascertain how occupants behave, but rather to ascertain the final effect and other factors may have on IAQ. These relationships are proving to be significant enough to develop predictive statistical models with high predictive capability. The current approach is to use parameters that are easily obtainable on a large scale, such as floor area, year of construction, etc., in order to avoid factors that require field measurements such as permeability.

The objective of these models is to provide useful insights that could inform the development of IAQ regulations, guidelines or building renovation plans. These insights could be used to:

- assess the potential IAQ in a given neighbourhood based on its building typology and construction characteristics;

- identify building typologies that are more prone to IAQ problems;

- evaluate the differences in occupant behaviour according to geographical location, climate, socio-economic level, etc.

In the case of Europe, based on the European directives on energy efficiency, until now renovation policies have been directed almost exclusively towards energy renovation rates. This has meant that IAQ aspects have been relegated to second place or ignored. Furthermore, the increased airtightness of buildings in pursuit of enhanced thermal insulation has resulted in a deterioration of IAQ.

However, the recent Directive (EU) 2024/1275 on the energy performance of buildings [3] appears to take action by stating in its Article 1 that indoor environmental quality requirements must be taken into account, including factors such as ventilation rate and presence of contaminants. This will necessitate the utilisation of analytical tools such as the aforementioned predictive models.

KEYWORDS

Natural ventilation; Occupant behaviour; Dwellings; Indoor air quality; Predictive model; CO_2

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[3] Directive (EU) 2024/1275 of the European Parliament and of the Council of 24 April 2024 on the energy performance of buildings ELI: http://data.europa.eu/eli/dir/2024/1275/oj