This article is based on a paper presented at the 43rd AIVC - 11th TightVent & 9th venticool Conference "Ventilation, IEQ and health in sustainable buildings" held on 4-5 October 2023 in Copenhagen, Denmark.

Assessing draught, noise and ventilation effectiveness in bedrooms with MVHR

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Keywords: MVHR, bedrooms, low-carbon housing, draught, noise, ventilation effectiveness.

Introduction

Mechanical Ventilation with Heat Recovery (MVHR) has been proven to maintain a healthy ventilation rate for occupants in bedrooms during night. However, due to improper design, specification, installation, and commissioning, a gap in performance exists. These issues have a negative consequence on occupant comfort and ventilation effectiveness which affect sleep quality and next day performance. This article presents a quantification of these issues by carrying out detailed monitoring and evaluation at two case study sites in Wales, UK. Results are presented of a Predict Mean Vote (PMV) experiment for thermal comfort prediction, sound and frequency measurements with the MVHR system in different modes of operation for acoustic comfort prediction, and tracer gas experiments for ventilation effectiveness evaluation.

Case study details

The two case study sites were social housing, 2-story, 3-bedroom dwellings equipped with MVHR systems. Case Study A comprised of a cluster of 25 new build dwellings, whereas Case Study B was a single retrofit dwelling. Dwellings in Case Study A had a measured air permeability of 4-5 m^3/m^2 h @ 50 Pa, whereas Case Study B dwelling had a measured air permeability of 10.5 m^3/m^2 h @ 50 Pa. All MVHR systems were in

Figure 1. Case study sites in (a) Case Study A and (b) Case Study B.

balance and were commissioned according to Part F (2021) of Building Regulations. Thermally insulated rigid ducting was used throughout except for at ends that connect the supply and extract terminal to the vents.

Thermal Comfort prediction

The impact of having an MVHR supply vent on thermal comfort was predicted by setting up a Predict Mean Vote (PMV) experiment. Results were analysed using Lin and Deng (2008a) model which is an adoption of Fanger's model (given under EN ISO 7730 (2005) and ASHRAE 55 (2020)) for sleep environments. The experiment was run in one bedroom at Case Study B for 4 nights during end of January 2023. The experiment was set up by placing measurement equipment at breathing level (0.6 m off the ground) as to represent an occupant lying on bed. Supply vent temperature was monitored during the experiment by placing a T/RH inside the supply vent **(Figure 2)**.

Figure 2. T/RH sensor in supply vent (left) and PMV experimental probe and sensor (right).

The set point temperature for the entire dwelling was dropped from 24°C to 21°C at the start of the experiment as shown under **Figure 3**. **Figure 4** shows that air velocity at breathing level remained under 0.07 m/s during the experiment. **Figure 5** and **Figure 6** show PMV and PPD values obtained from the experiment for bedding systems of different insulation values (clo). Each insulation value represents a different combination of quilt, sleepwear, and body coverage. These values were obtained from an experimental study conducted by Lin and Deng (2008b). Results show that when an occupant's bedding has an insulation value in the range of 3.18-2.68 clo, draught from an MVHR supply vent is unlikely to cause thermal discomfort. This suggests that the occupant would need to wear half-slip sleepwear and have at least ≈80% of their body covered with a summer quilt in order to achieve thermal comfort. During the experiment the difference in room and supply vent temperature was approx. 3°C (**Figure 7**). Data on ambient temperature during the experiment is given under **Figure 8**. The system was in balance, ductwork was rigid and insulated, and the unit was located in a thermally insulated loft.

Acoustic Comfort prediction

Sound measurements were recorded with the MVHR system on and off in three bedrooms of 6 dwellings at Case Study A and sound measurements were recorded with the system on, off and in boost mode in three bedrooms at Case Study B*. **Figure 9** shows that all measurements were below the Part F (2021) of Building Regulations recommended limit of 30 dB(A) for bedrooms. This implies that sleep disruption is unlikely to be caused. Frequency measurements were taken for one bedroom at Case Study B. Results show higher sound levels in the lower frequency range with the system in boost which is indicative of noise from the MVHR unit (**Figure 10**). Noise mitigation measures taken by the design team at the two case studies included installing as much rigid ducting as much as possible, keeping the ductwork short, avoiding curves as much as possible, having the duct width as large as possible, and installing silencers at each supply end of the unit.

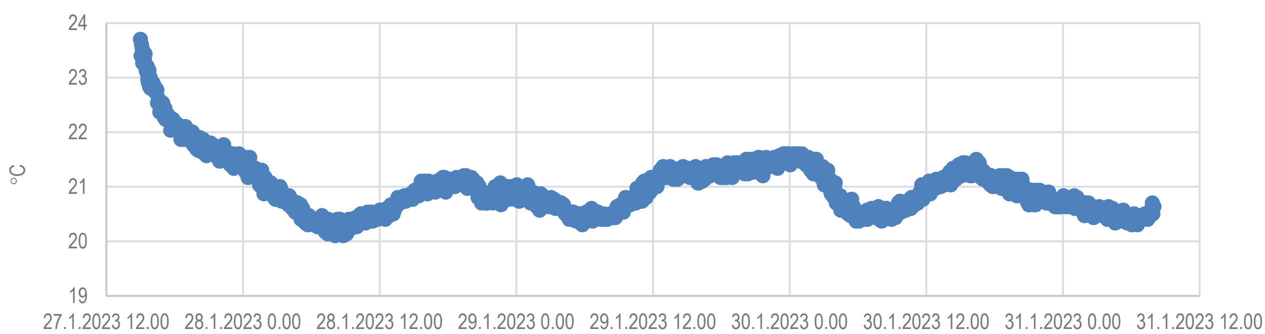

Figure 3. Results of air temperature measurement.

* Sound meter was placed at 0.6 m off the ground (**Figure 11**)

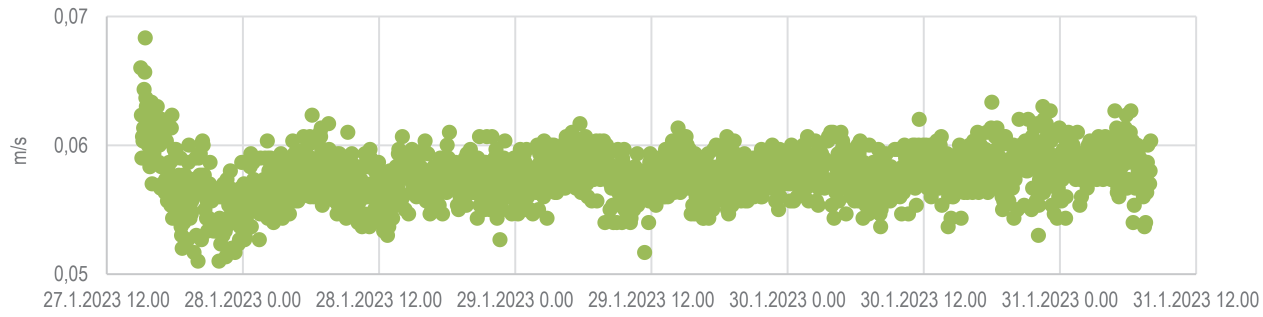

Figure 4. Results of air velocity measurements.

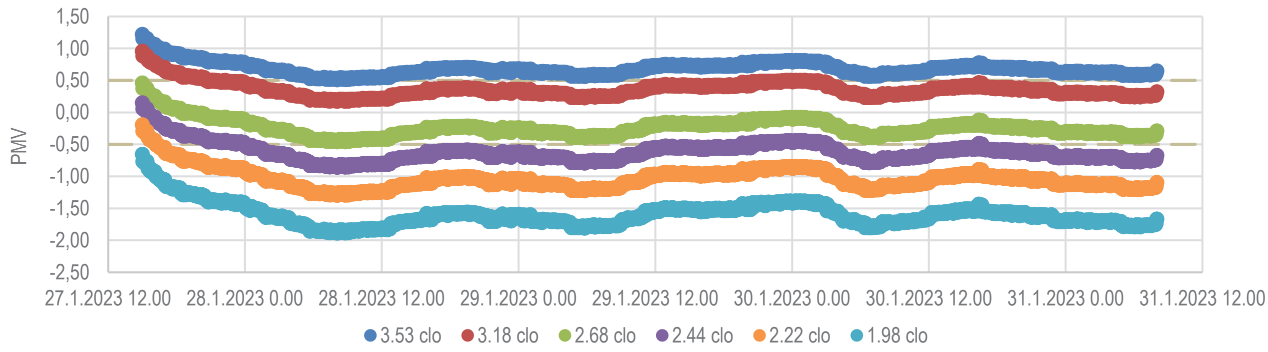

Figure 5. PMV results from bedding systems of different insulation values (clo).

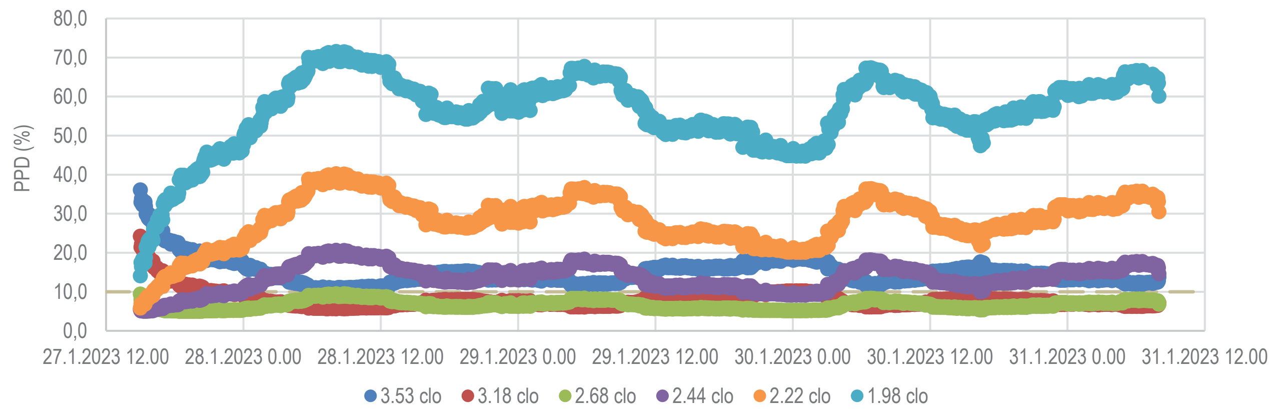

Figure 6. PPD results from bedding systems of different insulation values (clo).

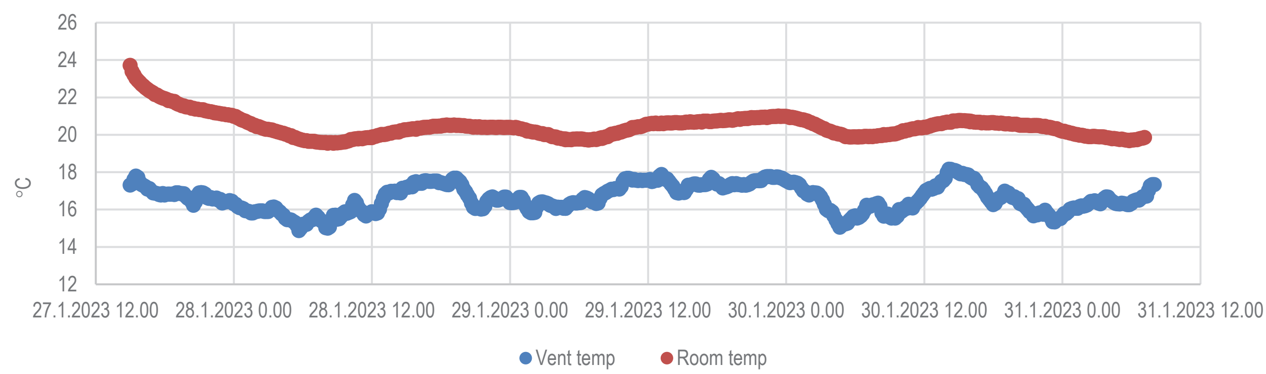

Figure 7. Room Vs Supply vent temperature during the experiment.

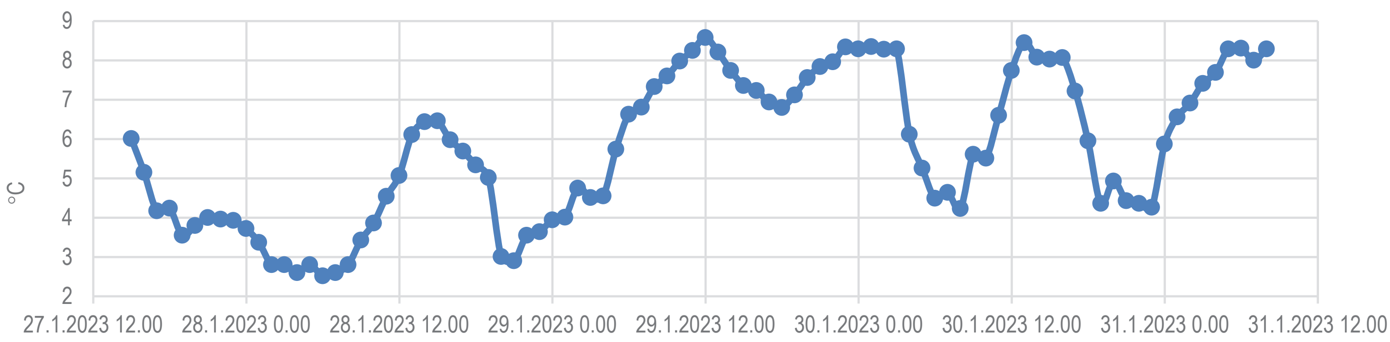

Figure 8. Ambient temperature during the experiment.

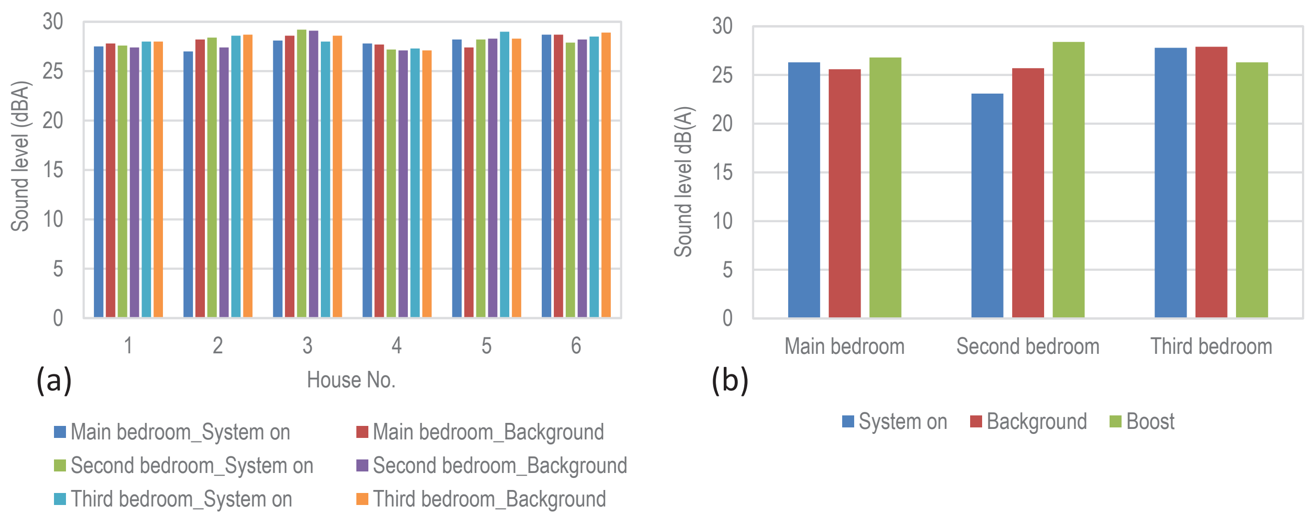

Figure 9. Sound measurements in dB(A) at (a) Case Study A and (b) Case Study B.

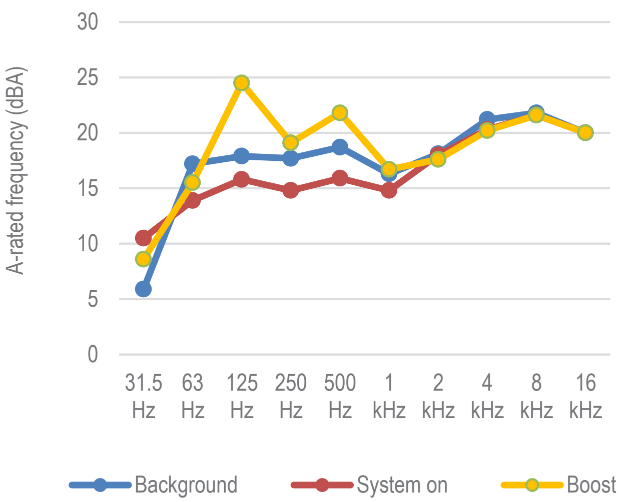

Figure 10. Frequency distribution with the system in different modes of operation for a single bedroom at Case Study B.

Figure 11. Sound measurement experimental set-up.

Ventilation effectiveness evaluation

The relationship of supply vent/door undercut arrangement with ventilation effectiveness was evaluated using the Air Diffusion Effectiveness (ε_{ADE}) index developed by Fisk and Faulkner (1992). The experiment was run in 3 bedrooms of a single dwelling at Case Study A. CO_2 gas was filled in the rooms and left to decay for 1 hour with the MVHR system on normal mode. CO_2 sensors were placed at breathing level (0.6 m off the ground) and the door undercut (**Figure 12**). **Figure 13** shows decay curves obtained from the experiment and **Table 1** gives values for age of air at door undercut (τ_{DU}), age of air at breathing level (τ_{BL}) and Air Diffusion Effectiveness (ε_{ADE}) for the three bedrooms respectively.

Table 1. *Tracer gas experimental results.*

	τ_{DU} (hr)	τ_{BL} (hr)	ε_{ADE}
Main bedroom	0.78	0.76	1.02
Second bedroom	0.84	0.81	1.04
Third bedroom	0.81	0.79	1.02

Results from **Table 1** show that τ_{DU} remains higher than τ_{BL} for all 3 cases. This indicates that air changes at breathing level are greater than air changes at door undercut, and ε_{ADE} is greater than 1 which indicates perfect mixing of supply air before it reaches the occupant. This can be attributed to the prevalence of low air velocities in the room and to the shape of the

Figure 12. Tracer gas set-up in rooms of different sizes and layout.

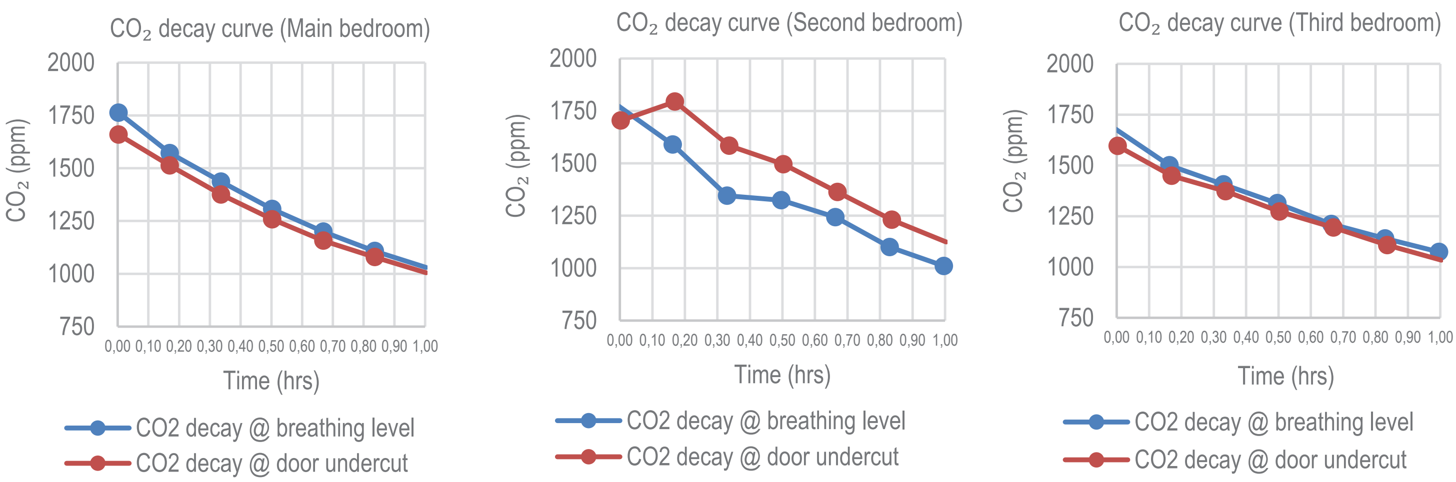

Figure 13. Tracer gas curves for the three bedrooms.

supply terminal which causes supply air to stick to ceiling and walls. The minimum distance between the supply vent and door undercut was 1.2 m (on plan). All systems were commissioned according to Part F (2021) of Building Regulations minimum ventilation rate requirements.

Conclusions

This article presents results of experiments taken at two case study sites to predict the likelihood of supply air from an MVHR system to cause draught and noise for occupants at night, and the likelihood of supply air to short-circuit from the door undercut. Results from the PMV experiment show that some form of adaptive behaviour is required from occupants to achieve thermal comfort when exposed to supply air from an MVHR system during winter months at night. This includes wearing a half-slip sleepwear and having at least ≈80% of their body covered with a summer quilt. The average difference between the room and supply vent temperature during the experiment was approx. 3°C. Sound and frequency measurements showed all readings to be under the Part F's (2021) recommended limit of 30 dB(A). This was achieved by having as much rigid ducting as much as possible, keeping the ductwork short, avoiding curves as much as possible, having the duct width as large as possible, and installing silencers at each supply end of the unit. Prevalence of sound in the lower frequency range with the system in boost was observed. Results from the tracer gas experiments showed that ventilation was effective as long as systems were commissioned according to Part F's (2021) minimum ventilation rate requirement and as long as a distance of 1.2 m (on plan) was kept between the supply vent and the door undercut.

Although findings presented are of a limited sample, they provide a useful insight into the conditions that might exist in properties of similar built in regions with climate similar to Wales, UK. Designers, manufacturers, installers, and commissioners can use these findings to design and specify MVHR such that issues with draught, noise and short-circuiting can be avoided. Further work involves carrying out Computational Fluid Dynamic (CFD) modelling to predict thermal comfort when the difference in temperature between the room and supply air is increased, and the likelihood of supply air to short-circuit via the door undercut when the difference between the supply vent and door undercut is reduced.

Acknowledgements

The author would like to acknowledge the Low Carbon Built Environment (LCBE) Research Team at Cardiff University for allowing access to the case study dwellings.

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