# VENTILATION PROVISION AND OUTCOMES IN MAINSTREAM CONTEMPORARY NEW-BUILDING FLATS IN LONDON, UK

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**Keywords:** Housing, Ventilation, MVHR, Natural Ventilation, Occupancy

## SUMMARY

The drive toward reduced energy consumption is being enforced through increasingly stringent statutory regulation. This is impacting on the way that contemporary housing is designed and constructed is leading to the use of new materials, systems and technologies. The impacts of these, particularly when they become mainstream, are not yet well understood. This is an important problem for social housing providers who retain a contractual obligation to their tenants and are therefore concerned about possible energy and health impacts. This research undertook monitoring and evaluation of 20 new-build contemporary flats in London. Problems with ventilation provision were endemic and this paper describes the nature and causes of these.

## INTRODUCTION

The clear need to address climate change by reducing the significant energy use and consequent carbon emissions of housing (Palmer and Cooper 2011) is leading to increased performance requirements of Building Regulations in the UK (HMG 2010, SG 2010) and this in turn has led to the rapid adoption of new technologies for buildings that seek to reduce energy consumption and carbon emissions. However there is now clear evidence of performance gaps between design intentions and performance (Green Construction Board, 2012; Zero Carbon Hub 2014), and there is also emerging evidence that some measures (for example increasing building air tightness levels and mechanical ventilation) can have detrimental impacts in indoor air quality (Crump et al, 2009; Monahan and Gemmell, 2013). There is increasingly widespread use of Mechanical Ventilation with Heat Recovery (MVHR) and decentralised Mechanical Extract Ventilation (dMEV), but there is very little field information on how these perform in mainstream housing.

## METHODOLOGIES

The research was undertaken as part of a Knowledge Transfer Partnership (KTP) between MEARU and Cartwright Pickard Architects (CPA), in collaboration with 5 Registered Social Landlords **(**RSLs**)** in London. The project aimed to develop techniques for ‘light touch’ Building Performance Evaluation (BPE) and undertook a series of BPE studies of 4 houses in 5 new-build housing schemes owned by the RSLs. In each case a series of two-week monitoring periods were undertaken during three different seasonal conditions (spring, summer and winter) during which internal temperature (°C), relative humidity (%) and $CO_2$ concentration (ppm) was monitored in all apartments. Measurements of these parameters were made at 1-minute intervals using Eltek GD-47 transmitters and recorded as a 5-minute mean value on Eltek RX250AL data loggers. Information was gathered on the construction of the flats, and testing was undertaken including thermography and flow testing of mechanical ventilation systems. Evidence was also gathered from the occupants through surveys and interviews. The general characteristics of the dwellings are described in the Table 1below:

Table 1. Characteristics of dwellings involved in the study

| REF | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Certification | | CSH 4 | | | | CSH 3 | | | | EH 'very good' | | | | BR - 2009 | | | | CSH 3 | | | |
| Dwelling type | | MT (H) | GF M) | MT (H) | TF M) | MF F) | TF (F) | MF F) | TF (F) | GF (F) | GF (F) | MF F) | MF F) | GF (F) | MF F) | MF F) | MF F) | MF F) | MF F) | MF F) | MF F) |
| Floor area (m²) | | 104 | 77 | 71 | 76 | 70 | 70 | 104 | 104 | 77 | 113 | 72 | 56 | 92 | 47 | 46 | 46 | 79 | 86 | 70 | 47 |
| Bedrooms | | 3 | 2 | 2 | 2 | 2 | 2 | 3 | 3 | 2 | 4 | 2 | 1 | 3 | 1 | 1 | 1 | 2 | 3 | 2 | 1 |
| Occupants | A | 2 | 2 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 1 | 1 | 2 | 3 | 1 | 1 | 2 | 2 | 2 | 1 | 1 |
| | C | 2 | - | 2 | - | 1 | 2 | 4 | 3 | 2 | 4 | - | - | 1 | - | - | - | 2 | 3 | 1 | - |
| Occupancy | | 24 | 16 | 24 | 24 | 24 | 24 | 24 | 24 | 16 | 16 | 16 | 16 | 24 | 24 | 24 | 24 | 24 | 16 | 24 | 24 |
| Heating system | | HW+R | GB+R | HW+R | GB+R | GB+R | GB+R | GB+R | GB+R | HE+R | HE+R | HE+R | HE+R | GB+R | GB+R | GB+R | GB+R | GB+R | GB+R | GB+R | GB+R |
| Ventilation | | MVHR | | | | MVHR + kit extract | | | | MEV | MVHR | MEV | MEV | MEV | | | | MEV | | | |
| Extract flow rates (l/s) | T | - | 13 | 25 | 23 | 13 | - | 11 | 13 | 14 | 17 | 5 | 9 | 9 | 10 | 11 | - | 17 | - | 11 | - |
| | B | 19 | 17 | 26 | 25 | 19 | - | 22 | 26 | 16 | 17 | 13 | 15 | 20 | 12 | 14 | - | 21 | 34 | 24 | - |
| Supply flow rates (l/s) | T | - | 19 | 22 | 22 | 14 | - | 14 | 17 | - | 16 | - | - | - | - | - | - | - | - | - | - |
| | B | 33 | 26 | 22 | 22 | 21 | - | 27 | 32 | - | 19 | - | - | - | - | - | - | - | - | - | - |
| Air permeability in $m^3/h.m^2$ | | 2.9 | 2.9 | 2.9 | 2.9 | 2.7 | 2.8 | 2.3 | 2.6 | 7.0 | 2.6 | 7.0 | 7.0 | 5.0 | 5.0 | 5.0 | 8.0 | 3.0 | 3.2 | 5.0 | 4.3 |

CSH 3 / 4 – Code for Sustainable Homes level 3 / 4
EH - Eco homes
BR – Building Regulations
A – Adult C- Child(ren) D – Dog
T – Trickle (low rate)
B – Boost (high rate)

MT (H) – Mid-terrace house
GF (M) – Ground floor maisonette
TF (M) – Top floor maisonette
GF (F) – Ground floor flat
MF (F) – Mid floor flat
TF (F) – Top floor flat

HW+R – hot water cylinder + radiator
GB+R – Gas boiler + radiator
HE+R – heat exchanger + radiator
MVHR – Mechanical Ventilation and Heat Recovery system
MEV – Mechanical Extract Ventilation

These houses are typical of mainstream new-build flats currently being constructed in London and the UK. The sample houses are representative of approximately 1158 dwellings built in the 5 schemes, which in turn are typical of approximately 24,000 homes built in London in the same period.

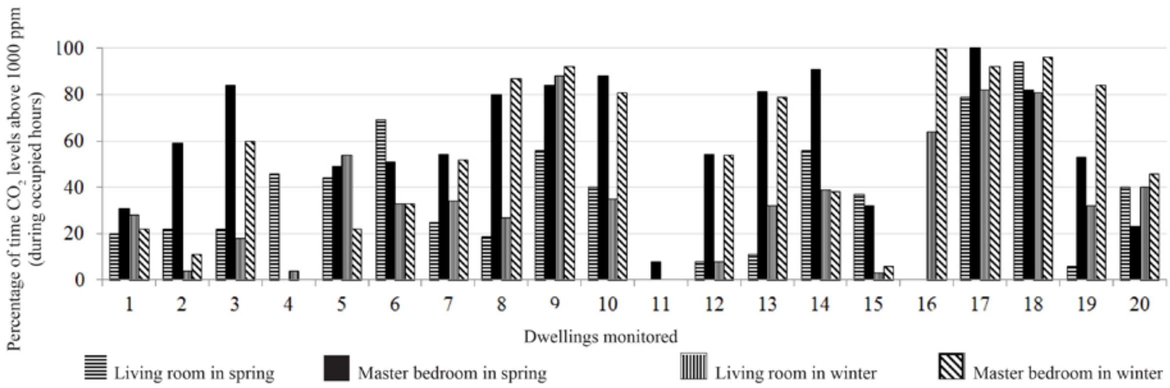


Figure 1. Percentage of time > 1000ppm for occupied spaces in living rooms and master bedrooms during monitoring periods in spring and winter.

## RESULTS AND DISCUSSION

In this study $CO_2$ is being used as a proxy indicator for ventilation. There is a general acceptance that $CO_2$ keeps 'bad company' and that levels above 1000 ppm are indicative of poor ventilation rates (Porteous 2011) and corresponds well with a ventilation rate of 8 l/s per person (Appleby 1990). A study by Batterman and Peng (1995) identified associations between $CO_2$ levels and total volatile organic compounds (TVOCs). A paper by (Wargoki

2013) identified associations between $CO_2$ levels and health and concluded “The ventilation rates above 0.4 h-1 or $CO_2$ below 900 ppm in homes seem to be the minimum level to protect against health risks based on the studies reported in the scientific literature”.

Figure 1 shows the percentage of occupied time (using the occupancy information) that $CO_2$ levels exceed the 1000ppm threshold is shown in Figure 1. It is apparent from the results that high levels of $CO_2$ are endemic in the properties, despite the use of MVHR and MEV ventilation systems. The examination of the houses and interviews with occupants identified a series of common problems and these are summarized below:

| **Design** | **Construction** | **Operation** |
|---|---|---|
| • Individual flow rates to rooms inadequate for a delivery of 8 l/s per person, and below Building Standards requirements<br>• External Inlet and outlet vents are located too close together and near boiler flue, leading to a risk of gases entering the system, and complaints of smells from the flat below entering the flat above causing the system to be turned off.<br>• Duct runs are complex, duct sizes are small (100 – 125mm dia.) and flexible ducting is frequently used.<br>• The system are not sized or designed for actual loads in terms of IAQ (e.g. room occupancy, peak occupancy, household size) | • Unbalanced flows in all the dwellings<br>• Bedrooms with missing supply vents<br>• Poorly placed vents, e.g. too close to the bedroom door<br>• Use of flexible ductwork (where rigid ducting has been specified)and poor installation leading to constricted ducts<br>• Lack of sealing of the system during construction and lack of cleaning before handover leading to construction dust in the system. | • Units located above bedrooms, lack of acoustic separation and insolation causing noise leading to units being turned off.<br>• Unit located in the loft leading to lack of maintenance and clogging of filters<br>• Lack of occupant guidance on the use of the system – system being turned off<br>• User maintenance of the filters – lack of access and understanding<br>• ‘Cold’ air perceived as draught<br>• Use of windows over MVHR system |


Figure 2a), close location of inlet, outlet and boiler flue; 2b) dirty filter; 2c) constricted flexible duct

High $CO_2$ levels were also observed in the houses which used dMEV. Causes included: Reliance on the use of trickle vents for make up air. Trickle vents are frequently closed and there is lack of clear air-flow paths due to curtains and blinds. Windows are trickle vents are closed at night due to issues of noise and security. The window design in one scheme incorporates a trickle vent which is occluded by the window frame itself. The boost switch for the dMEV system is not main connected and does not when the battery is flat. Use of windows is preferred to trickle vents – they are more accessible and the effects are more immediate. However this adaptive behavior does not occur at night when occupants are asleep. There are some incidences of high occupancy (2 adults and 2 children in a bedroom).

## CONCLUSIONS

The fact that such poor conditions were so common is a cause for concern. Taking this sample as being broadly representative of contemporary construction in London suggests that the proportion of housing with poor ventilation may be very high indeed and this could have important implications for occupants' health. The study found gaps in knowledge at design, construction and occupancy. Designers are generally designing to the regulation, rather than performance standards and are not thinking holistically about what levels of ventilation may be required, and how they may be achieved; there was evidence of poor construction and workmanship on site, with a lack of appreciation of the implications of this; and there was little handover or occupant guidance on how the ventilation should be used. Further work is needed to examine the actual impacts of poor ventilation and to develop systems and approaches that can deliver good IAQ in the context of reduced energy consumption.

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