Comparison of air change rates obtained by different ventilation measurement techniques in five Danish homes

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1 Introduction

The outdoor ventilation rate is an important parameter in the field of indoor air quality. Building ventilation rates have been measured by a number of different methods in studies conducted during the past decades. Active tracer gas measurement using constant concentration method is believed to be the most accurate ventilation measurement method available in buildings where multizone effects are important (Sherman, 1990). On the other hand, the method is complicated and requires expensive instrumentation. Other methods to determine ventilation rates, such as the one using the concentration of occupant-generated CO_2 (ASTM, 2002) or long-term passive tracer gas methods (Dietz et al., 1982) are more feasible in large scale studies. The reliability of these methods is however often questioned (Persily, 2005). This study compares the air change rates (ACR) calculated from occupant-generated CO_2 with those obtained from continuous tracer gas measurements.

2 Materials/Methods

The air change rate in the bedrooms of five Danish homes was measured with two different methods. Single zone mass balance of occupant generated CO_2 was used to calculate the ventilation rate during 4 to 5 nights in each bedroom. Data from night periods was used in order to avoid noise in data from unknown activities and occupancy in the room. At the same time the air change rates were measured using Freon® as tracer gas. Constant concentration of the tracer gas was maintained throughout the dwellings, with a tracer gas dosing and sampling point in up to six rooms in each home, including the bedrooms. With this method, in contrast to the CO_2 method, only the outdoor air delivery into the rooms was measured. The air change rates obtained from the build-up of the CO_2 concentration in the bedrooms during the nights was compared to the air change rates obtained from the tracer gas (TG) measurement in the time period 00:00 – 06:00 of the respective nights. The measurements were conducted in the spring, summer and fall. Another set of measurements are being conducted during winter. The results will be reported in the future.

3 Results

The total ventilation rates (influenced by airflows both from outdoors and adjacent spaces) determined by the CO_2 method were several times larger than the outdoor air ventilation rates obtained by the tracer gas measurement in the same space during the same nights. Occasionally the difference was more than an order of magnitude (Table 1).

Table 1. Examples of ACRs obtained in the same bedrooms by different methods

Home-bedroom	Night	ACR TG	ACR CO_2	CO_2/TG ratio
A-Bedroom 1 (spring)	1	0.02	0.04	2.1
	2	0.02	0.10	5.8
A-Bedroom 2 (spring)	1	0.04	0.74	19.9
	2	0.03	0.45	17.1
E-Bedroom 1 (fall)	1	1.53	3.60	2.4
	2	2.37	3.60	1.5
	3	1.90	3.60	1.9

The average ACR(CO_2) / ACR(TG) ratio for all bedrooms, nights and seasons was 8.5. Only two

(2.6%) out of the total 77 compared nights demonstrated lower ACR with the CO_2 method compared to the TG method and only 7 nights (9%) showed a ACR(CO_2) / ACR(TG) ratio between 1.0-1.5. It is important to note that a high ratio does not necessarily indicate a large absolute difference between the ACRs obtained by the two methods. For example in Home A – Bedroom 1 (Table 1), the ACR determined from the CO_2 concentration is 5.8 times larger than from the TG method, however, both methods clearly indicate that the ventilation rate in the room is extremely low. Better agreement between the two methods is achieved when comparing average ACRs over several nights and rooms within a given home (see Table 2).

Table 2. ACRs for each home (average of all days and bedrooms) for the three seasons and three measurement methods

Home-Season	**ACR TG**	**ACR CO_2**	**CO_2/TG ratio**	**PFT***
A-Spring	0.03	0.33	11.0	NA
A-Summer	0.49	1.07	2.18	0.47
A-Fall	0.06	0.38	6.33	0.30
B-Spring	0.19	0.69	3.63	0.84
B-Summer	1.15	3.20	2.78	1.55
B-Fall	0.32	1.04	3.25	1.26
C-Spring	0.59	1.26	2.14	0.29
C-Summer	1.47	2.80	1.90	0.53
C-Fall	0.92	1.60	1.74	0.28
D-Spring	0.02	0.10	5.00	0.27
D-Summer	1.36	2.51	1.85	0.81
D-Fall	0.03	0.34	11.3	0.31
E-Spring	2.49	3.85	1.55	1.13
E-Summer	2.66	7.97	3.00	1.75
E-Fall	1.93	3.60	1.87	1.02
Average	0.91	2.05	3.97	0.77

*Value for entire home and entire month - corresponding to the month during which the other two methods were applied.

We have also conducted measurements of the average monthly-ACR in the five homes using the passive tracer gas method (PFT). Although not perfectly comparable, the PFT method provided similarly inconsistent ACRs, mainly lower than the CO_2 method and more comparable to the TG method (Table 2). This may further indicate that the ventilation rate determined from the CO_2 concentrations may overestimate the true outdoor ventilation rate in spaces, as it reflects the total ventilation rate in the space (Bekö et al., 2010). Better controlled experiments allowing a more straightforward comparison of the PFT method with the other two techniques are currently being conducted.

Further details on the ACRs and their seasonal variations determined by TG and PFT in the five homes can be found in Gustavsen et al. (2011) and Frederiksen et al. (2011).

4 Conclusions

All three ventilation measurement techniques may have significant uncertainties, especially when applied in multi-zone settings. The uncertainties are stemming from interzonal airflows and insufficient mixing of air. In order to minimize the errors, measurements should be conducted over a longer period of time and the building should be considered as a single zone. Air change measurements in a single room may be relatively precise when interzonal flows are avoided by e.g. closing the doors to adjacent spaces.

5 References

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