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Preliminary comparison of air change rates measured in Quebec City homes using SF_6 and perfluorocarbon tracer gases and blower door test results during the winter season of 2008-09

Daniel Aubin[1,*], Denis Gauvin[2], Doyun Won[1], Hans Schleibinger[1] and Don Fugler[3]
[1] Institute for Research in Construction, National Research Council of Canada
[2] Institut National de Santé Publique du Québec
[3] Canada Mortgage Housing Corporation

[*] *Corresponding email: Daniel.Aubin@nrc.ca*

SUMMARY
This paper provides a comparison of the air change rates measured by perflurocarbon tracer gas (PFT) and SF_6 tracer gas decay, and the house airtightness measured by a blower door during the winter season of 2008-09 in 68 homes in Québec City, Canada. The average air change rates for all the homes were similar for SF_6 and PFT, however the individual measurements did not correlate well. A better inverse correlation was obtained between measured formaldehyde concentrations and the air change rates based on PFT measurements than those based on SF_6 measurements. Using on the PFT measurements, 83% of the homes did not achieve the nominal guideline of 0.35 air changes per hour for residential buildings.

KEYWORDS
ventilation, SF_6, blower door, perfluorcarbon tracer gas, air change rate

INTRODUCTION
This paper describes the preliminary results obtained from a field study investigating the impact of ventilation rate on indoor air quality (IAQ) and the respiratory health of asthmatic children in Québec City, Canada. The objective of this study is to determine if increased ventilation will lead to a corresponding decrease in the number of asthmatic symptoms in children, to correlate ventilation rates with IAQ, and to support research for determining health-based ventilation rates.

The first phase (ongoing) of the study involves a series of three residential home visits spread out over a year (two winter visits and one summer visit) where a number of IAQ relevant chemical, biological and physical parameters are measured over a 6-8 day period. A series of questionnaires capturing information related to housing characteristics and occupant behaviour are also administered during the residential home visits. This paper focuses only on the physical parameters relating to ventilation measured for the first phase in 68 of the participating homes. Over 100 homes are expected to be tested upon completion of the first phase. At the end of this phase, each house will have 3 tracer gas tests by PFT (two winters and one summer) and 2 tests by SF_6 (two winters). Each house will have a blower door test in winter conditions and in summer conditions.

The second phase involves an intervention where half the homes identified as having inadequate ventilation will have their ventilation rates increased by the installation and use of a heat recovery ventilator or a modification of the existing ventilation system. The monitoring in the third phase will be identical to the first phase and will be used to assess the effectiveness of the intervention on improving the indoor air quality.

METHODS

The average air change rates measured in the child's bedroom over a 6-8 day period were determined using the perfluorocarbon tracer (PFT) technique developed by the Tracer Technology Group at Brookhaven National Laboratory (Dietz and Cote, 1982). Three PFT emitters were placed throughout the house (except for the child's bedroom) while one capillary adsorption tube, used to sample the PFT, was placed in the child's bedroom. Analysis of triplicate CATS placed side by side showed a standard deviation of less than 6%. In all cases the homes were treated as a single zone. This paper reports on a single PFT tracer gas test result, taken in winter, which is available for 37 of the 68 houses.

The air change rate was also measured over a 3-5 hour period in the child's bedroom using SF_6 tracer gas decay according to the ASTM test method E 741-00 (ASTM, 2006) using an Innova 1312 or 1412 photoaccoustic field gas monitor. The test results below represent one SF_6 test for 64 houses and two SF_6 test for 13 houses, taken during winter conditions.

The air tightness measurements were performed with an orifice blower door (Minneapolis Blower Door Model 3 with DG-700 digital pressure and flow gauge from The Energy Conservatory) and the results were analyzed with the TECTITE Ver. 3.2 building air tightness test analysis software. The test results on 63 houses are from the winter series of tests.

House characteristics, such as the year of construction, heating systems and recent painting, were documented through a questionnaire administered to the occupants. Formaldehyde was measured in the child's bedroom over a 6-8 day period using duplicate Waters Sep-Pak ® ExPosure cartridges between 28 November 2008 and 15 April, 2009. The cartridges were subsequently analyzed for formaldehyde using high performance liquid chromatography (HPLC) according the American Society for Testing Materials (ASTM) test method D 5197-03 (ASTM, 1997).

RESULTS

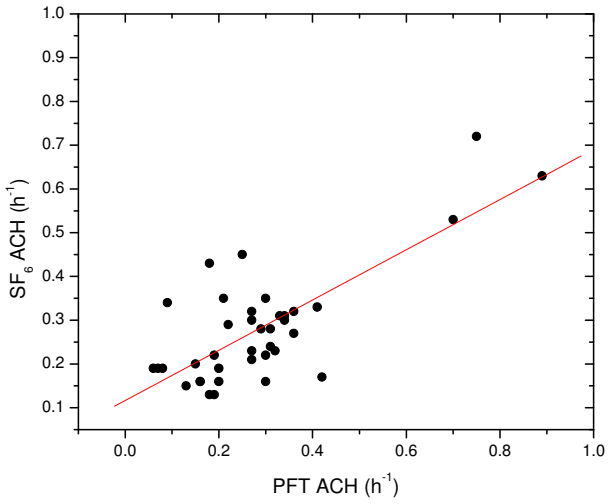

Figure 1. Correlation in between the PFT and SF_6 derived air change rates. The slope of the linear fit is 0.57 ± 0.08 and $R^2 = 0.76$ (n=37).

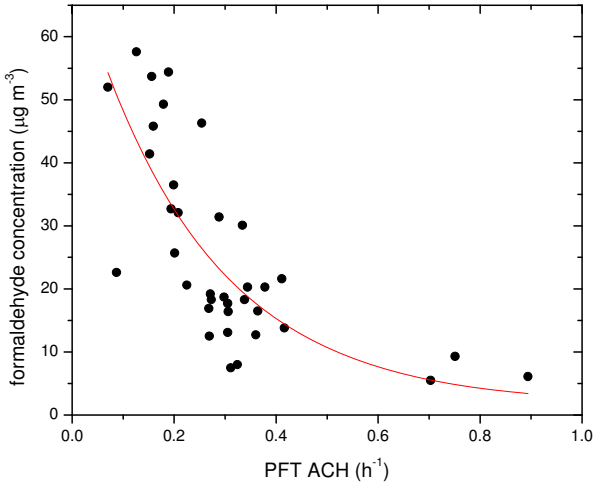

Figure 2: Correlation in between the PFT air change rates and formaldehyde concentration measured in the child's bedroom over a 6-8 day period. Data is fit to a first order exponential decay ($R^2 = 0.57$, n=36)

Table 1. Summary of the air changes rates measured during the winter 2009-10 season in Quebec City

Method	ACH (h^{-1})	ACH standard deviation (h^{-1})	number of measurements
SF_6 tracer decay	0.27	0.12	77
perflurocarbon tracer	0.32	0.22	37
blower door at 50 Pa	4.16	2.64	63

DISCUSSION

A comparison of the average air change rates obtained from all house using the PFT and SF_6 tracer gas indicates that the measured ACHs are similar however individual measurements do not correlate very well as seen in Figure 1. No correlation was observed between tracer gas based air change rates (SF_6 or PFT) and blower door test results. These two types of measurements are not expected to be correlated since the blower door test relies on air leakage rates obtained when the home is depressurized and cannot be interpreted as a direct measurement of natural air change rates that would occur under natural conditions (ASTM, 2007).

The SF_6 measurement provides a measure of the air change rate over the 3-5 hour sampling period. As a result it can be easily influenced by the occupant's behavior or anomalous conditions present during the measurement period. In many cases the quality of the fit to the exponential decay used to determine the air change rate was quite poor, with an R^2 value ranging from 0.43 to 0.99, with the average R^2 of all measurements being 0.87. The SF_6 measurements taken twice at the same house at different times during the same season were found to vary by 35% on average (n = 13). Air infiltration is very weather dependent and this variation is expected (Sherman, 1998).

The PFT air change rates measured in this study are also similar those measured by Gilbert *et al.* (2008) where 80% of the homes in Quebec City (n = 96) had an air change rate below 0.23

h^{-1}. The PFT measurement is more representative of the air change rate experienced over the entire sampling period because it spans several days rather than a few hours as in the case of SF_6. This may explain why a better correlation was obtained in between the measured formaldehyde concentrations and the PFT measurements, $R^2 = 0.57$ (Figure 2), rather than with the SF_6 measurement ($R^2 = 0.10$, not shown). As formaldehyde is generally emitted in the home by a variety of off-gassing sources (Gilbert et *al.*, 2008) its concentration is expected to be higher in homes with lower air change rates as observed in Figure 2.

Our preliminary data for phase 1 of the field study indicates that on average the homes do not meet the ASHRAE standard of 0.35 ACH for residential buildings (ASHRAE, 1989). Based on the PFT measurements, 83% of the homes do not achieve this rate of ventilation.

CONCLUSIONS

Once all first phase houses have been thoroughly tested, we will be able to better compare the relative utility of the two tracer gas tests and the blower door results. The results so far indicate that the PFT air change measurements correlate better with the limited air quality measurements taken up to this point.

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