

Use of mechanical ventilation in Finnish houses

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ABSTRACT

This study reports ventilation measurement and occupant questionnaire results from newly built 102 Finnish detached houses. The results show that ventilation units were used constantly and the fan speed setting was changed very seldom. There was a slight tendency to use higher speed in the summer than in winter. Ventilation units provide an average actual air change rate of about 0.4 ach (13 L/s,pers) both in winter and summer which is less than the code value of 0.5 ach. Airflow measurements at design fan speed show that only 57% of houses comply with regulations. Low actual air change rates were caused by low fan speeds used by occupants as 52% of houses in the winter and 47% in the summer used the lowest possible fan speed. Correspondingly, actual supply airflow rates in bedrooms were low, in average 4 L/s. Occupant complaints about ventilation noise correlated with noise level in bedrooms. It is concluded that ventilation noise is an important factor affecting the use of ventilation units. Inspection of drawings and ventilation systems showed that in houses not complying with ventilation regulations either ventilation units were undersized or sound attenuation was poor.

KEYWORDS: mechanical ventilation, ventilation rate, PFT, dwellings, complaints

INTRODUCTION

In Finnish houses, mechanical supply and exhaust ventilation with heat recovery has been a most common solution during last 20 years. In apartment buildings, centralized mechanical exhaust system has been the prevailing system since 1970s (Palonen et al. 2001). The situation changed in 2003, when the building code began to require at least 30% heat recovery from the exhaust air (D2 2003). Due to this requirement, practically all new residential buildings are today equipped with mechanical supply and exhaust ventilation.

The code requirement for the ventilation is 0.5 ach in general, and the code gives guideline values for outdoor and exhaust airflow rates for common rooms. These Finnish values follow quite well the second category specified in (prEN 15251). The guideline value for outdoor air flow rate is 6 L/s per person (4 L/s,pers before 2003) or 0.5 L/s,m² (0.35 L/s,m² before 2003) for the bedrooms and living rooms.

Occupancy by two persons is a common design assumption for bedrooms; giving 12 l/s design supply airflow rate.

The system sizing is easy for the designer when following design airflow rates. More actual question is how well the drawings are followed during construction, are the sound attenuation installed and systems balanced, and how the design values are met in practice. This study provides some answers based on actual air change measurements in houses. Another important question is how the occupants are using ventilation units. When switched off, they definitely became useless. User behavior is studied through the inspections and questionnaire of the occupants.

Previous indoor climate studies in homes in Nordic countries have shown that air change below 0.5 ach can increase the rate of infestation of house dust mites. This was concluded by the EUROVEN group (Wargocki et al. 2002) in a comprehensive review, examining whether health and comfort problems are more likely if the outdoor air supply rate is below a certain level. Bornehag et al. (2005) has shown that the prevalence of asthma and allergy is higher for children having lower ventilation rate at home. More symptoms were reported when ventilation rate was below 0.5 ach compared to higher ventilation rate (the highest studied group had ventilation rate of 0.64 ach). These results show that 0.5 ach requirement is justified and should be expected to be met in practice when actual air change rates are measured.

This study reports actual ventilation rate measurement and occupant questionnaire results from newly built 102 Finnish detached houses. The performance of mechanical and natural ventilation systems is compared. The compliance with code requirements is determined and factors affecting the use of ventilation units are identified.

METHODS

The sample of the 102 houses was selected according to ventilation system so that natural ventilation and mechanical ventilation were represented in the study. As mechanical supply and exhaust ventilation has been a standard solution in Finland during last decades, the sample included more natural and mechanical exhaust ventilation than it is in newly built houses (natural ventilation means here passive stack ventilation). It was impossible to find newly built houses with natural ventilation and older houses (up to 24 years) were included in the study. Other houses were less than five years old. Half of the houses were located in Tampere and other half in Helsinki metropolitan area with a maximum distance of about 200 km between houses and a similar cold climate for all houses. The houses were selected from databases of companies that manufacture and build houses. In the areas close to the universities in Helsinki and Tampere, announcements were published in local newspapers to get homeowners involved in the study. In the subgroups according to ventilation system the selection was random. The sample of 102 houses (from which 74 houses in PFT measurement) was according to ventilation system:

- 10% (11%) natural ventilation (passive stack ventilation)
- 29% (28%) mechanical exhaust
- 61% (61%) mechanical supply and exhaust.

An average size of houses was 156 m² of heated area and 386 m³ volume (medians) and average age of houses was 3 years (except the houses with natural ventilation). An average number of occupants were 3.6 and average building leakage value 3.9 ach at 50 Pa (the range between 0.5 to 8.9 ach at 50 Pa). All the houses were one or two storey houses with wooden frame construction.

The measurements were conducted between 2002 and 2004. Air change rate was measured during 2-3 week period in winter with passive tracer gas technique, which allowed to determine average overall air change and master bedroom outdoor airflow rate. In summer, exhaust flow rates were measured from outlets. In master bedrooms, also supply flow rates and sound pressure levels were measured. Occupants were asked to fill questionnaire about perception of indoor climate and the

use of ventilation units. Actual use of ventilation units is analyzed based on air change rate and bedroom sound level measurements as well as occupant complaints and comparison of actual ventilation unit fan speed to design one.

RESULTS

Actual ventilation rates in summer and winter

Summer time air change rates measured as the sum of exhaust airflows are shown in Figure 1, left. These measurements were performed at the fan speed of ventilation units occupants commonly used (i.e. fan speed setting was not changed to attain design flow rates). Occupants were asked to change the filters and the filter condition was also checked before measurements. In total, 92 mechanically ventilated houses were measured; median was 0.39 ach, average 0.39 ach and standard deviation 0.16 ach. Exhaust flows in naturally ventilated houses were not measured.

Winter time three week period average air change rates measured with passive tracer gas technique (PFT) in 74 houses are shown in Figure 1, right. This sample includes also houses with natural ventilation (NV in Fig. 1). For 74 houses median is 0.36 ach, average 0.38 ach and std 0.14 ach.

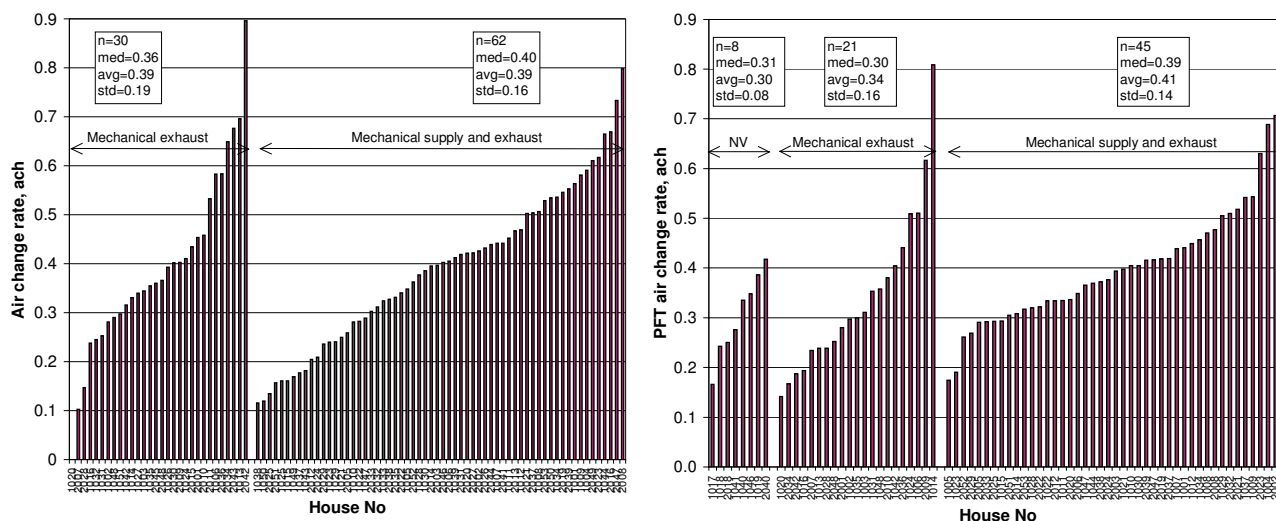


Figure 1. Summer time air change rates of each house (left) and winter time three week average air change rates (right).

Outdoor air ventilation rates per person (calculated from total air change rates) are shown in Figure 2. Median airflow rate for summer and winter time was 10.8 vs. 10.7

L/s,pers (i.e. calculated from exhaust flow vs. PFT results), the average 12.5 vs. 12.0 and standard deviation 9.2 vs. 6.0 L/s,pers.

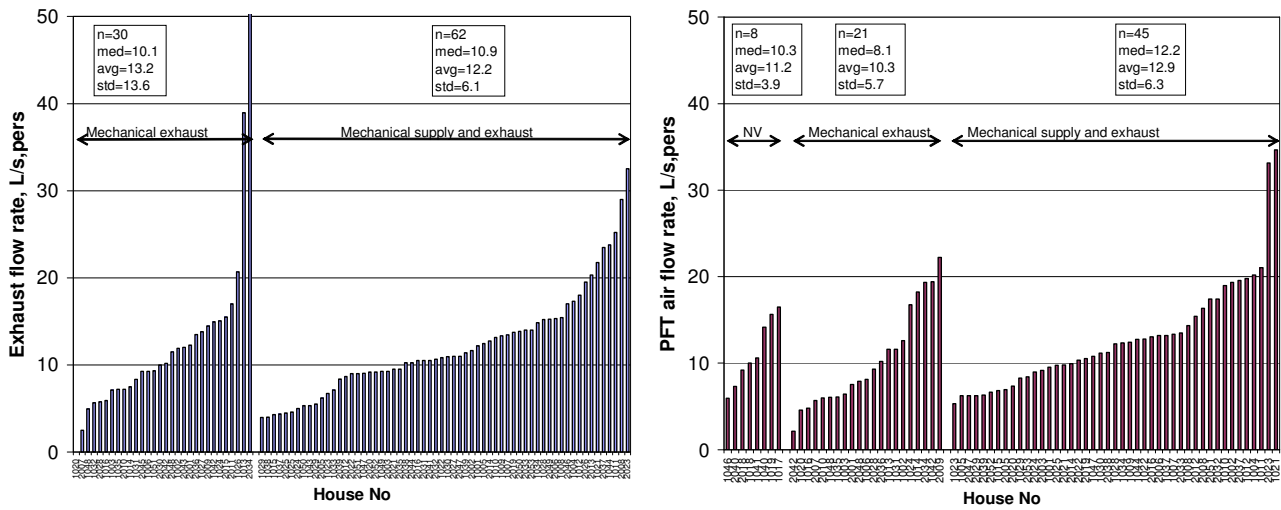


Figure 2. Outdoor air flow rates per person for the summer time (left) and for the winter time three week period (right).

Master bedrooms' outdoor airflow rates were possible to determine from PFT-measurement results. In the summer time master bedrooms' supply airflows were also measured from supply air terminals at actual fan speed, Figure 3. PFT-results analyses showed good air mixing between the master bedrooms and the rest of the rooms in houses. This is in the line with the questionnaire result, that 75 % of bedroom doors were kept open during nights.

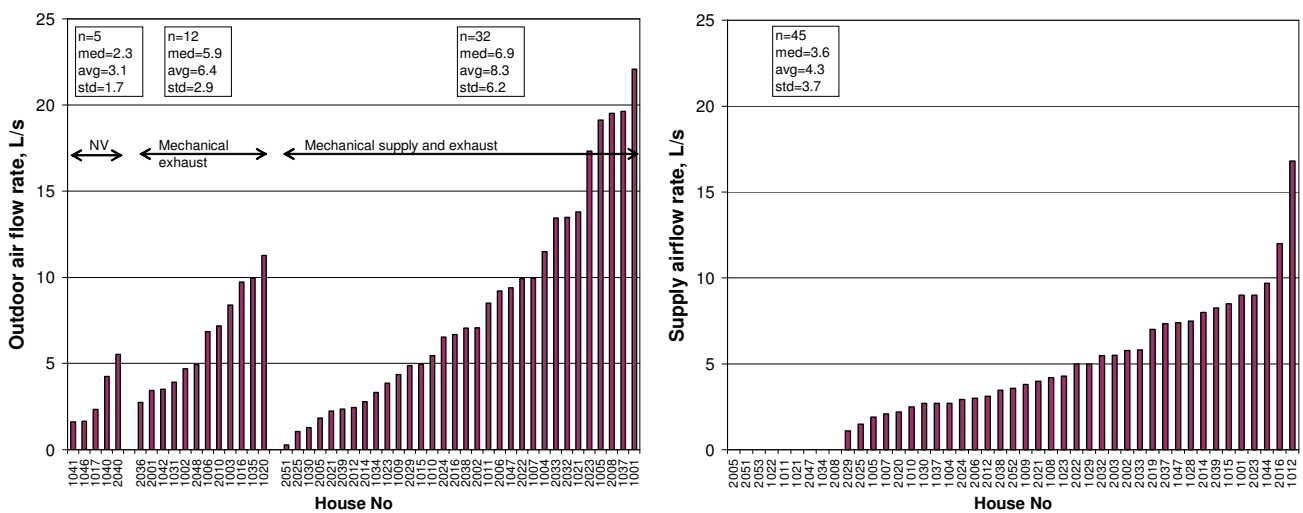


Figure 3. Average outdoor air flow rates in master bedrooms in three week period in winter (left) and supply airflow rates in summer (right)

The use of ventilation units

The use of ventilation units were studied by asking the fan speed setting in summer and winter in the occupant questionnaire. For that question the response rate was only 45%, whereby, the settings were checked during winter measurements in all houses. Ventilation units and exhaust fans had 3 to 8 speeds, and all the units there scaled to 4 point-scale so that 1 is min speed and 4 max speed. 13% of the occupants reported that they use two speeds (e.g. 1 and 2 or 2 and 3). In these cases, the speed checked in the winter measurements is used for reported winter speed. A lower reported speed for summer was used, if the lower reported speed in the winter corresponded to checked speed and if not then higher reported speed was used. 2 units with continuous speed control and 2 units with one speed were excluded.

In Figure 4, left the distribution is shown for mechanical supply and exhaust ventilation and for mechanical exhaust ventilation. There was no significant difference between these ventilation systems. Checked and reported speeds were the same in 96% of cases, which indicates that the differences in Figure 4, left should be mainly due to different samples of houses.

When compared to design fan speeds which varied between 3/4 and 2/4, the actual speeds were typically by one point lower. Airflow measurements at design fan speed showed that only 57% of houses comply with regulations. Compliance with regulations is determined here so that the ventilation unit should be capable to provide 0.5 ach air change rate with noise level in living rooms and bedrooms not exceeding 28 dB(A) (D2 2003). Many ventilation units failed the criteria due to poor sound attenuation.

Actual fan speeds gave generally low air change rates compared to the capacity of ventilation units and exhaust fans at full speed as shown in Figure 4, right, where min, max and actual air change values are calculated based on exhaust flows.

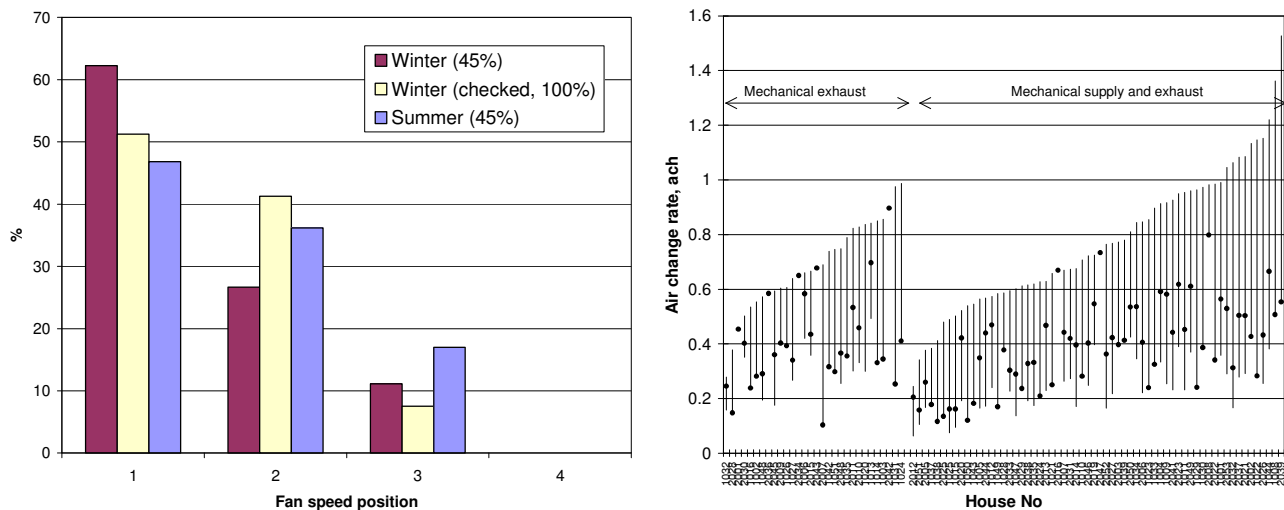


Figure 4. Use of ventilation units and exhaust fans: actual fan speeds (all units scaled to 4 speeds) in left and the full range of the units in right, where air change at actual speed is marked with dot.

One possible reason for the use of ventilation units at low speed can be the noise generation of ventilation system. Noise levels were measured in bedrooms at actual fan speed and maximum fan speed. As ventilation units were used at low speeds, an average sound pressure level was as low as 22 dB(A), Figure 5, left. Sound pressure values include background noise, but as measurements were done in houses located in relatively quiet areas, the measurement periods with background noise level below 20 dB(A) were available in all houses. The questionnaire results were used to find dependency between noise and the use of ventilation. Only significant dependency was found between ventilation noise complaints and sound pressure in bedrooms at maximum fan speed of the ventilation unit, Figure 5, right. No dependency was found for actual fan speed.

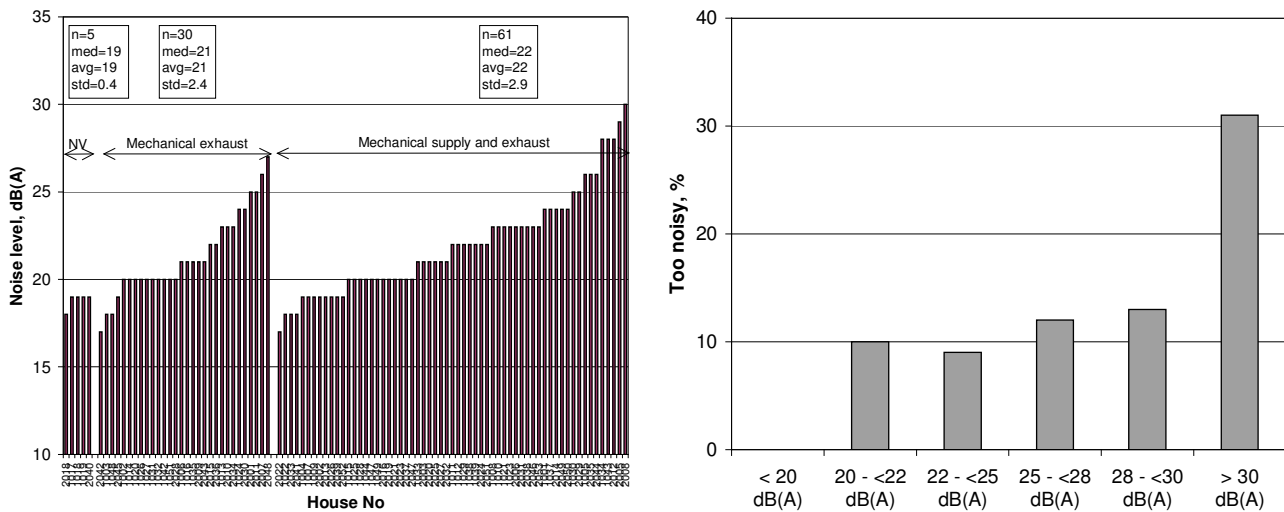


Figure 5. Sound pressure levels in master bedrooms at actual fan speed (left) and the dependency between maximum noise level in bedrooms and ventilation noise complaints.

The effect of building leakage

The building leakage rate does not only affect the heat energy demand and total ventilation rate, but it may affect thermal comfort as well. This was the fact at high leakage rates. The prevalence of cold floor and fluctuating room temperature complaints was significantly higher for building leakage values higher than 6 ach at 50 Pa compared to lower leakage values, Figure 6.

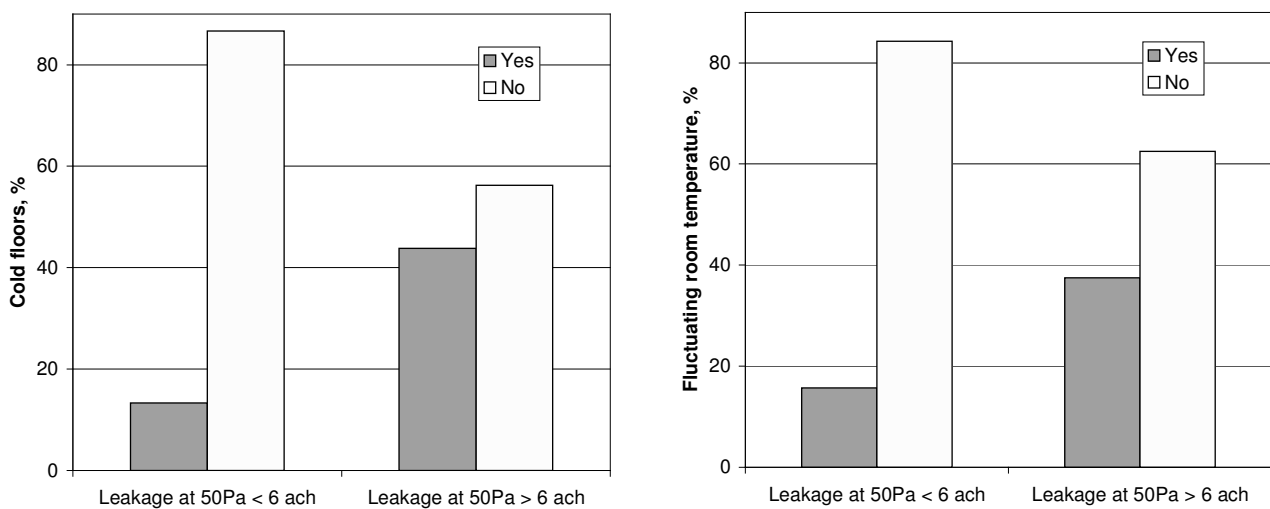


Figure 6. The effect of building leakage value on complaints related to thermal environment.

CONCLUSIONS

The results show that ventilation units were used constantly and the fan speed setting was changed very seldom. There was a slight tendency to use higher speed in the summer than in winter. In the majority of houses no more fan speed adjustments were done as only 13% of houses reported that they adjust fan speed in winter or summer.

Ventilation units provide an average actual air change rate of about 0.4 ach (13 L/s,pers) both in winter and summer which is less than the code value of 0.5 ach. Air change rates were lower than measured in similar indoor climate study in 1995 by Ruotsalainen, where average air change rates were 0.41, 0.46 and 0.49 ach for natural, mechanical exhaust and mechanical supply and exhaust ventilation respectively.

Airflow measurements at design fan speed show that only 57% of houses comply with ventilation regulations [i.e. that the ventilation unit is capable to provide 0.5 ach air change rate with noise level in living rooms and bedrooms not exceeding 28 dB(A)]. Many ventilation units failed due to poor sound attenuation.

Actual air change rate was equal or higher than the code value of 0.5 ach only in 18% of houses in the winter and 26% of houses in the summer. Low air change rates were caused by low fan speeds used by occupants as 52% of houses in the winter and 47% in the summer used the lowest possible fan speed. Correspondingly, actual supply airflow rates in bedrooms were low, in average 4 l/s measured from supply air terminals. Bedrooms' outdoor airflows measured with passive tracer gas were in average 8 l/s and these values include infiltration and possible window airing.

Occupant complaints about ventilation noise correlated with maximum noise level in bedrooms, which is sound pressure at maximum fan speed of the ventilation unit, and not with the noise level at actual fan speed. It is concluded that ventilation noise is an important factor affecting the use of ventilation units.

Inspection of drawings and ventilation systems showed that in houses not complying with ventilation regulations either ventilation units were under-dimensioned or sound attenuation was poor. As expected, larger ventilation units resulted as higher air change rate at lower noise level.

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