

Room Airflow Rates in Finnish Houses

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SUMMARY

Airflow rates were measured in one hundred and two newly built single-family houses during 2002-2004. Of the measured houses, 10 % used natural ventilation, 28 % used mechanical exhaust and 61 % used mechanical supply and exhaust. Exhaust airflow rates were measured during the summer period from terminals. Supply airflow rates and sound pressure levels were measured in master bedrooms. During a 2-3 week period in winter, air change rates were measured with a passive tracer gas technique to determine the overall air change rate.

An average actual air change rate in the summer period was 0,40 1/h in houses with mechanical supply and exhaust ventilation and 0,37 1/h in houses with mechanical exhaust ventilation. Winter period values were respectively 0,41 1/h, 0,34 1/h and 0,3 1/h in naturally ventilated houses. All these values are below the code value of 0,5 1/h. Similarly, the average supply airflow rates in bedrooms were lower than the recommended value in the building code. Both exhaust and supply airflow rates will be reported.

Actual air change rates, room airflow rates together with sound pressure levels compared to airflow rates at the design speed of the ventilation units show possible improvements needed in the ventilation of houses.

INTRODUCTION

In Finnish houses, mechanical supply and exhaust ventilation with heat recovery has been the most common solution during the last 20 years. In apartment buildings, the centralized mechanical exhaust system has been the prevailing system since the 1970s [1]. The situation changed in 2003, when the national 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 building code requirement for the ventilation is 0.5 ach in general; the code also 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 [2]. The guideline value for an outdoor airflow rate is 6 l/s per person (4 l/s, per person 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 a 12 l/s design supply airflow rate.

In this study, airflow rates were measured in 102 single-family houses in Helsinki and Tampere area. Most of the measured houses were equipped with mechanical supply (28%) or mechanical supply and exhaust (61%) ventilation. Of the measured houses, 10 % were built

with natural ventilation. Only a few houses were older than 5 years in this study. In this article, we concentrate on room airflow rates.

METHODS

The sample of 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 few decades, the sample included more natural and mechanical exhaust ventilation than there is in newly built houses (natural ventilation means here passive stack ventilation). As it was impossible to find newly built houses with natural ventilation, 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 the other half in the 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. Also, newsletters were delivered to areas with newly build houses.

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.

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

Dust from outside air can rise filters pressure drop and significantly reduce airflows of the ventilation unit within a few months. To try to avoid that, tenants were asked to change filters before measurements were taken. In a few cases, measurements had to be repeated because the filters were not changed and there was no airflow to measure.

Exhaust airflow rates were measured in kitchens, bathrooms and saunas during the summer period from terminals. Exhaust airflow rates were measured in the minimum, maximum and normally used fan speed position. The sums of the exhaust airflows were used to calculate the air change rate of the houses. Supply airflow rates to bedrooms were measured with pressure difference from terminals. These air exchange rates were close to the air change rates that were measured in wintertime with tracer gas [3].

Occupants were asked to fill a questionnaire about their 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, in order to design one.

RESULTS

Air exchange rates of the houses were measured from terminals at different fan speeds of the ventilation units. In Figure 1, the air change rates of mechanically ventilated houses can be seen. In the building code, the air change rate is 0,5 change per hour is recommended [4]. The measurements (Figure 1 b) shows that this recommended value can be attained in 90 % of the houses.

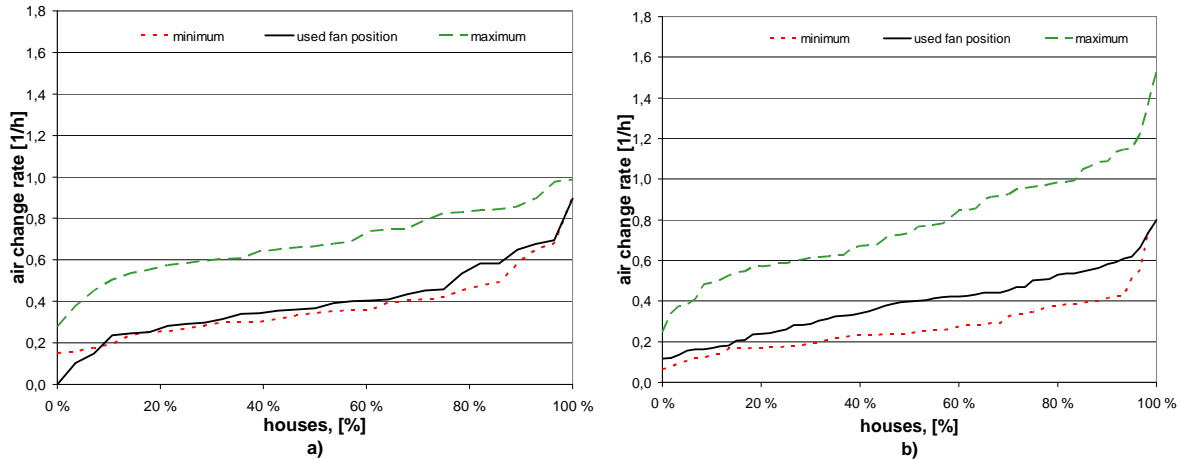


Figure 1 Air change rates in mechanically ventilated houses: a) mechanical exhaust (29) and b) mechanical supply and exhaust (61).

In reality, only 20 % of mechanically ventilated houses exceed the building code value in the normally used fan speed position. With the mechanical exhaust and supply ventilation unit, about 25 % of the measured houses had an air change rate of over 0,5 change per hour.

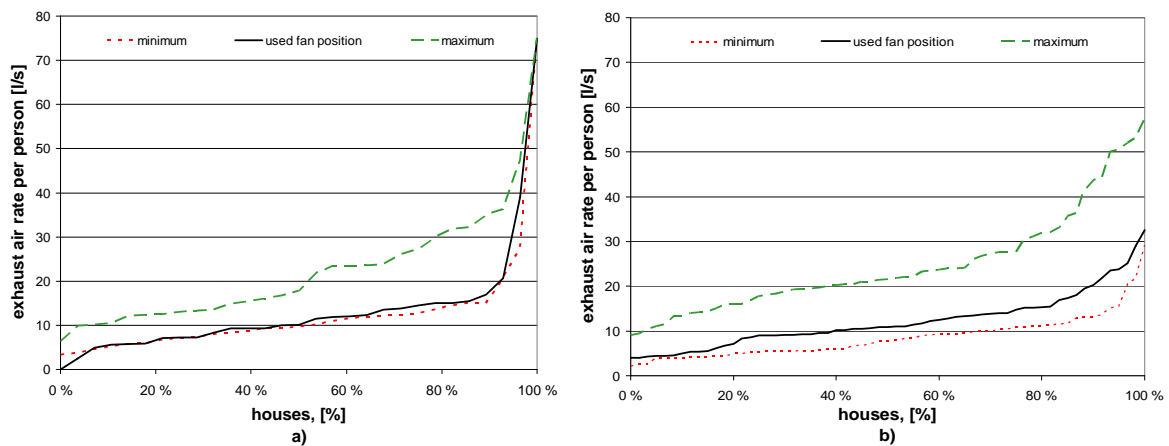


Figure 2 Exhaust air flow rates in litres per person. Overall exhaust air in mechanically ventilated houses a) mechanical exhaust, b) mechanical supply and exhaust.

In Figure 2, we have a graph of the exhaust air rate per occupant. We can see that the average in both systems was near 12 l/s.

Exhaust air rate in kitchens

Finnish building code (D2) recommends a range-hood exhaust air rate of 8 l/s, with a 25 l/s boost if fan speed can be controlled. Without the fan speed control, the airflow rate should be 20 l/s, with 25 l/s boost [4].

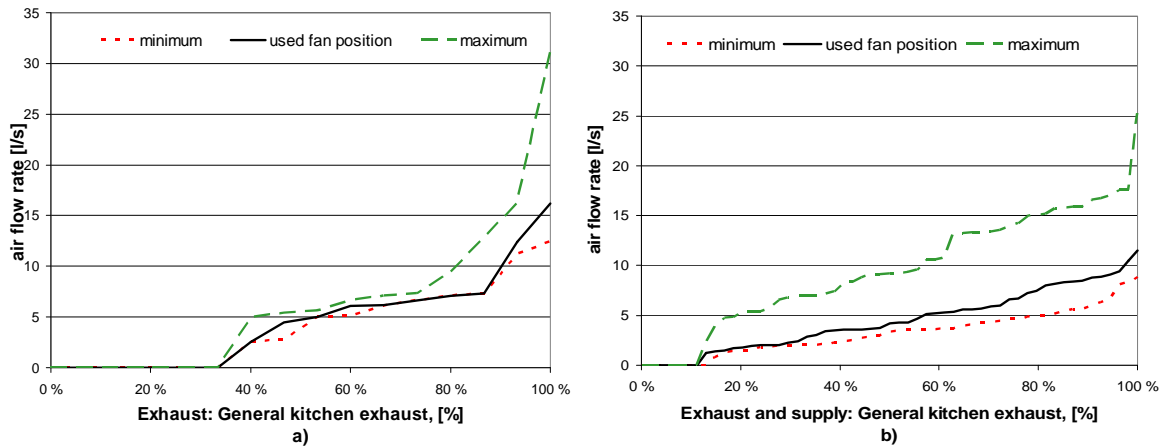


Figure 3 Exhaust airflow rate in kitchens (general ventilation). A) mechanical exhaust (29 kitchens) and b) mechanical supply and exhaust (61 kitchens). Airflow rates in minimum, maximum and normally used fan speed position.

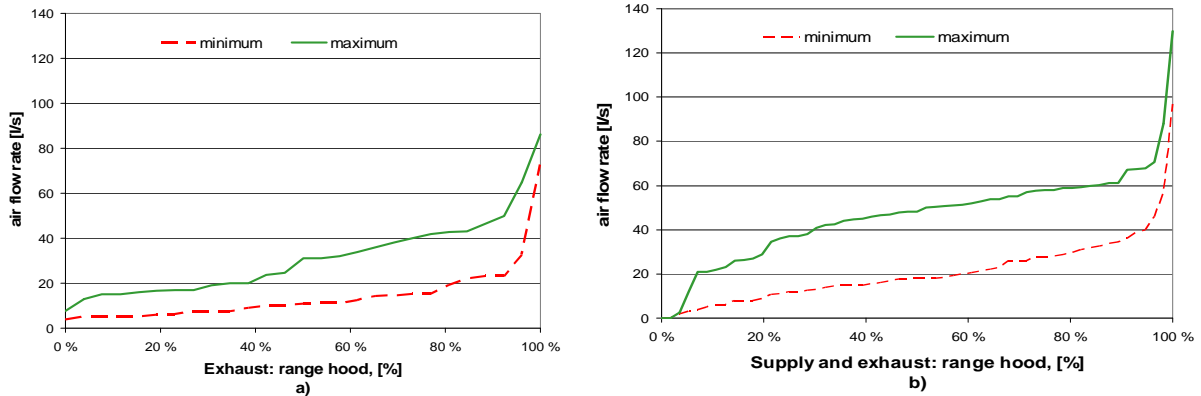


Figure 4 Exhaust airflow in kitchen range hood. A) Mechanical exhaust (27 hoods) and b) mechanical supply and exhaust (57 hoods).

Table 1 General kitchen exhaust and kitchen range hood airflow rates average, median and standard deviation. Mechanical exhaust, and mechanical supply and exhaust.

Mechanical exhaust 29 houses	min	Used fan position	max	Mechanical supply and exhaust 61 houses	min	Used fan position	max
General exhaust 16 kitchens				General exhaust 55 kitchens			
average [l/s]	4	5	7	average [l/s]	3	4	10
median	4	5	6	median	3	4	9
standard deviation	4,1	4,8	8,2	standard deviation	2,2	3,1	5,8
27 range hoods				57 range hoods			
average [l/s]	14		31	average [l/s]	21		47
median	11		31	median	18		48
standard deviation	13,6		17,6	standard deviation	15,7		21,0

In many houses, the measured airflow was under the 1 l/s (Fig. 3). In mechanical exhaust houses, the 50 l/s was possible to achieve in 10 % of kitchen-range hoods with boost, and in mechanical supply and exhaust houses, in 50 %.

Bathroom and sauna

The Finnish building code recommendation for bathroom exhaust is 10 l/s and for boosted exhaust 15 l/s. In mechanical exhaust ventilated houses, 65 % and in mechanical supply and exhaust ventilated houses, 70 % could have achieved the recommended value of 10 l/s at fan speed normally used.

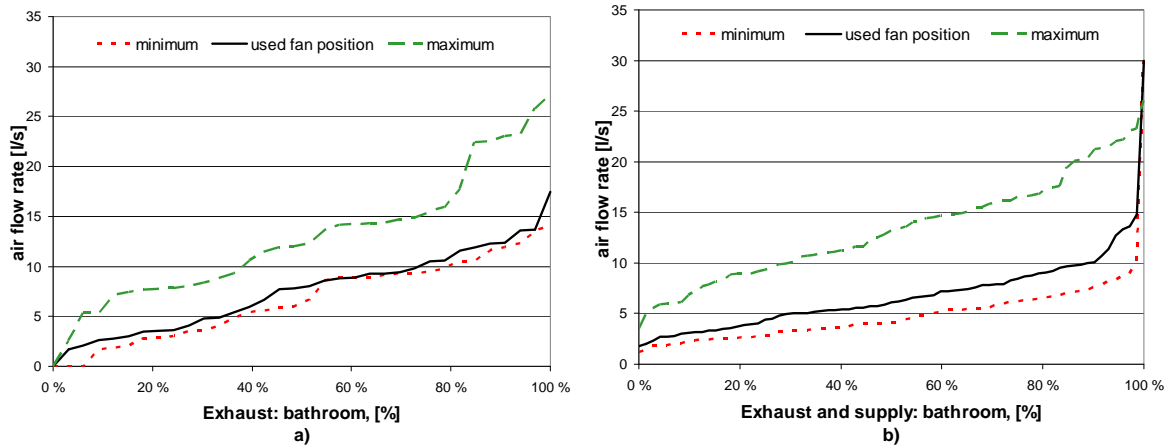


Figure 5 Bathroom exhaust airflow rate. A) mechanical exhaust (34 bathrooms), b) mechanical supply and exhaust (73 bathrooms).

In the sauna, the exhaust should be at least 6 l/s. That was achieved in 70 % of the measured houses using the normally used fan speed position.

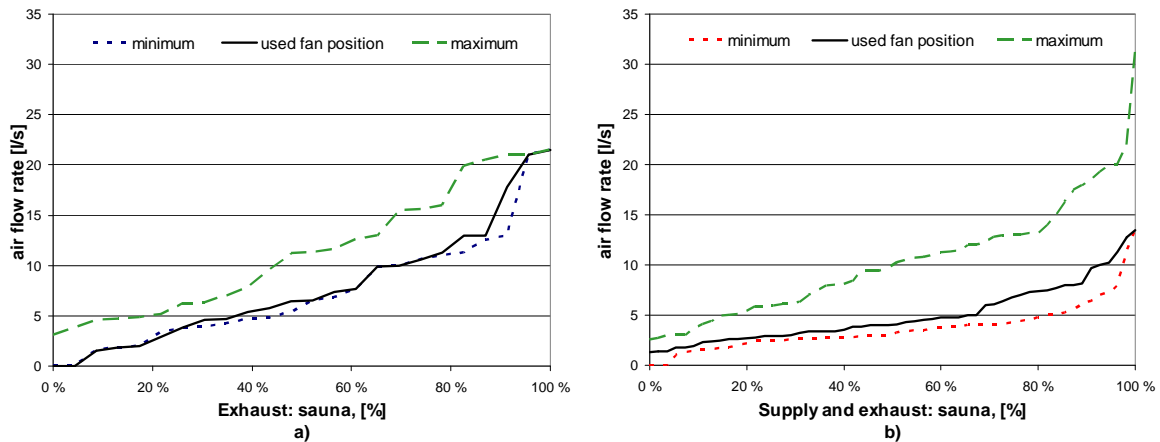


Figure 6 Exhaust air rates in sauna: a) mechanical exhaust (21 saunas), b) mechanical supply and exhaust (56 saunas).

Table 2 Characteristics of mechanical exhaust and mechanical supply and exhaust: bathroom, average, median, standard deviation.

Mechanical exhaust 29 houses	min	Used fan position	max	Mechanical supply and exhaust 61 houses	min	Used fan position	max
34 bathroom				73 bathroom			
average [l/s]	7	8	13	average [l/s]	5	7	13
median	6	8	12	median	4	6	13
standard deviation	4,1	4,1	6,6	standard deviation	3,6	4,0	5,1

Table 3 Characteristics of mechanical exhaust and mechanical supply and exhaust: sauna average, median, standard deviation.

Mechanical exhaust 29 houses	min	Used fan position	max	Mechanical supply and exhaust 61 houses	min	Used fan position	max
24 saunas				56 saunas			
average [l/s]	7	8	11	average [l/s]	4	5	10
median	6	6	11	median	3	4	10
standard deviation	5,8	6,1	6,2	standard deviation	2,4	2,9	5,8

Exhaust airflow rates in toilets

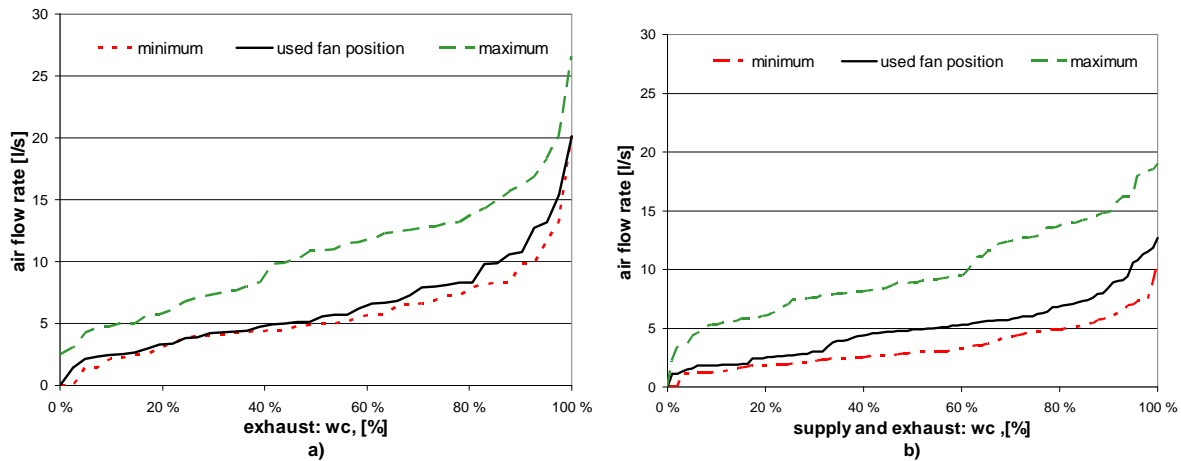


Figure 7 Exhaust airflow rates in toilets. A) Mechanical exhaust 42, normal use position average 6 l/s, median 5 l/s and standard deviation 4,0 at normally used fan speed position. B) Mechanical supply and exhaust 99, normal use position average 5 l/s, median 5 l/s and standard deviation 2,7 at normally used fan speed position.

The Finnish building code recommendation for a toilets exhaust air rate is 10 l/s. In mechanically ventilated houses, this is reached in 15 % of mechanical exhaust and in 5 % of houses with mechanical supply and exhaust ventilation at normally used fan speed position.

Bedrooms

In two-person bedrooms, both supply and exhaust were measured. Normally there is only supply airflow to bedrooms, but, in some cases, there were also exhaust terminal. There were nine houses (3 with mechanical exhaust and 6 with mechanical supply and exhaust) with an exhaust airflow rate of between 2 to 10 l/s.

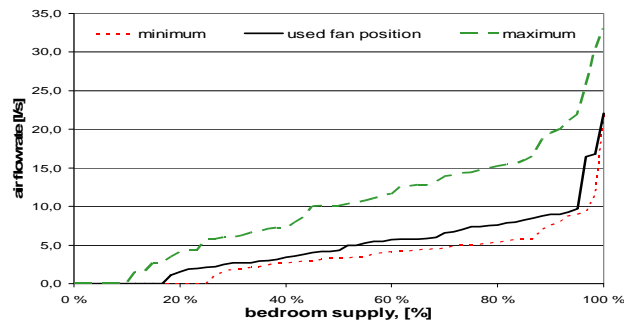


Figure 8 Supply airflow rates in bedrooms (61). Average 5 l/s, median 4 l/s and standard deviation 4,3 at normally used fan speed position.

The recommendation for minimum supply air rate in the Finnish building code is 6 l/s per person. The measured bedrooms were two-person bedrooms, so the minimum recommended supply air rate was 12 l/s.

Figure 8 (right) shows that, in 60 % of the houses, the recommended supply airflow rate could be achieved at some fan speed. It is possible to have a better air change rate for bedrooms with wardrobes (exhaust included). The measured exhaust air rates in wardrobes in Figure 9 shows that 27 % of the measured terminals have over 12 l/s exhaust in the operating range.

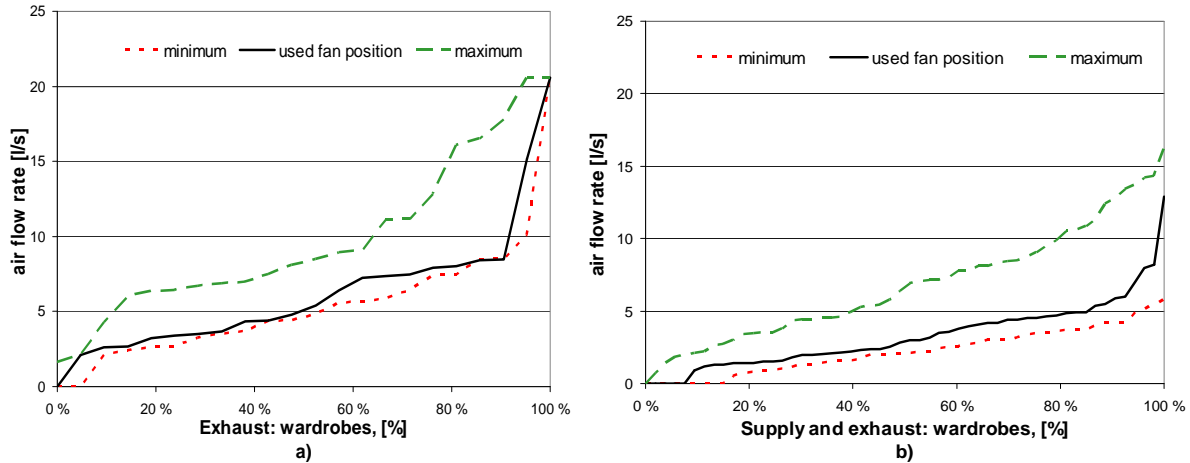


Figure 9 Wardrobe exhaust air rates. A) mechanical exhaust n= 22, normal use position average 6 l/s, median 6 l/s and standard deviation 4,5 at normally used fan speed position. B) mechanical supply and exhaust 54, normal use position average 3 l/s, median 3 l/s and standard deviation 2,4 at normally used fan speed position.

The building code recommended exhaust air rate is only 3 l/s. In mechanically ventilated houses, this value was achieved in exhaust in 77 % of the houses and in supply and exhaust in 48 %.

Sound levels in bedrooms

The sound level of the ventilation unit was also measured in the bedroom and living room. When interviewing the occupants during measurements, only a few of them mentioned the problems with noise from ventilation units.

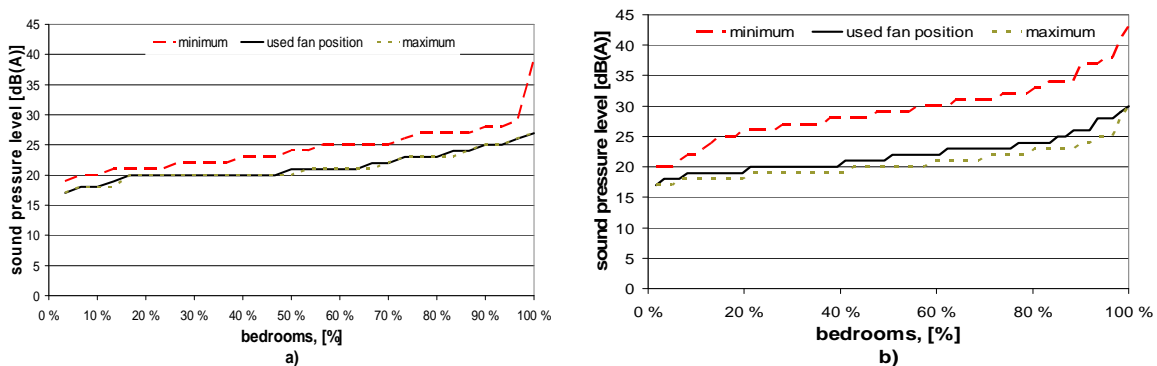


Figure 10 Bedroom sound pressure levels. A) mechanical exhaust, B) mechanical supply and exhaust.

From Figure 10, however, it can be seen that sound pressure levels were low compared to building code value 28 dB(A) [4]. This indicates that the sound pressure levels should be near 20 to 22 dB(A), which is acceptable at night.

DISCUSSION

At normally used fan speed position, room airflow rates were only half of the recommended values of the Finnish building code. Only in a few houses the airflow rate values were higher than 0.5 ach at normally used fan speed position. The recommended value was possible to reach in 90 % of the houses at some fan speed.

Measured exhaust air rates were slightly higher than 10 l/s per person in almost every house at normally used fan speed. In interviews, tenants did not complain about any odour problems, even if the airflow change rate was low.

In many cases, tenants did not have any knowledge about their ventilation system and its operation range. They did not know the best possible way to use it efficiently or how to maintain it properly.

It can be recommended that the design fan speed should be written on the ventilation unit and there should also be instructions how to change the filters and how often that should be done. It would also be useful to provide a guideline with ventilation unit given information about the general principle of the ventilation system, its operation and maintenance.

ACKNOWLEDGEMENT

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