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Title: **Indoor Air Quality in Dwellings - A Comparison of the Performance of Different Ventilation Systems. IEA Annex 27 Evaluation of Ventilation Systems**

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INTRODUCTION

The main goal of IEA Annex 27 "Evaluation of ventilation systems" is to develop tools to evaluate ventilation systems in an objective way in terms of indoor air quality, energy, comfort, noise, life cycle costs, reliability and other building related parameters.
To check the developed tools some measurements in real dwellings are necessary. The development of the tools is in its final stage. During the AIVC conference some of these tools will be presented. The indoor air quality tool is not yet ready. The results reported in this paper are investigations carried out in three groups of 10 dwellings with practically the same floor plan. Each group had a different ventilation system.
The ventilation systems are:

- Natural supply and passive stacks (natural)
- Natural supply with mechanical exhaust (mech. exhaust)
- Mechanical supply and exhaust (balanced)

This paper is the first analysis of the results. In a later stage the measurement results will be compared with the results of the tools developed within IEA Annex 27.

MEASUREMENTS

The measurements took place during the heating season 95/96 in Roermond, in the South East of the Netherlands.
The measurements carried out are:

- temperature and relative humidity
- PFT measurements to determine the total flow
- constant concentration tracer gas measurements to determine flow rates at room level
- IAQ measurements, CO_2, CO and TVOC's
- Air leakage tests
- system flow

During the measurements the occupants of the dwellings were asked to fill out a questionnaire form to determine their use of the ventilation provisions, such as the use of grids and vents and the switching of the mechanical system.
An overview of all measurements is given in figure 1.

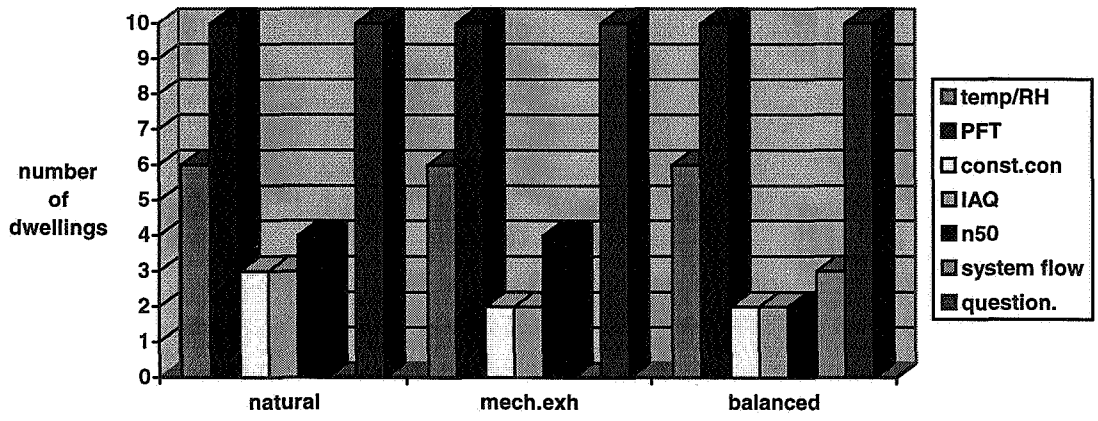

Figure 1 Overview of all measurements

DWELLING DATA

The dwellings are two storey single family houses with warm water heating systems.
The dwellings have a flat roof. All windows are double glazed.
The ground floor has an entrance hall, toilet and living with open kitchen.
The first floor has three bedrooms and a bathroom.

Ventilation systems

Due to building regulations a ventilation system in the Netherlands consists of:

Natural ventilation:	grids and openable windows in all habitable rooms, passive stacks in toilet, bathroom and kitchen.
Mechanical exhaust:	vents and openable windows in all habitable rooms, mechanical exhaust in toilet, bathroom and kitchen
Balanced system:	mechanical supply to all habitable rooms openable windows in all habitable rooms mechanical exhaust in toilet, bathroom and kitchen

Not all these provisions were found in the dwelling which were investigated.
In case of natural ventilation the grids were not in the bedrooms and living, but only in the kitchen. In the dwellings with balanced systems the grids were in living room and kitchen. According to the building regulations they are not required there.

Air leakage data

The measured air leakage of the dwellings can be seen in figure 2.

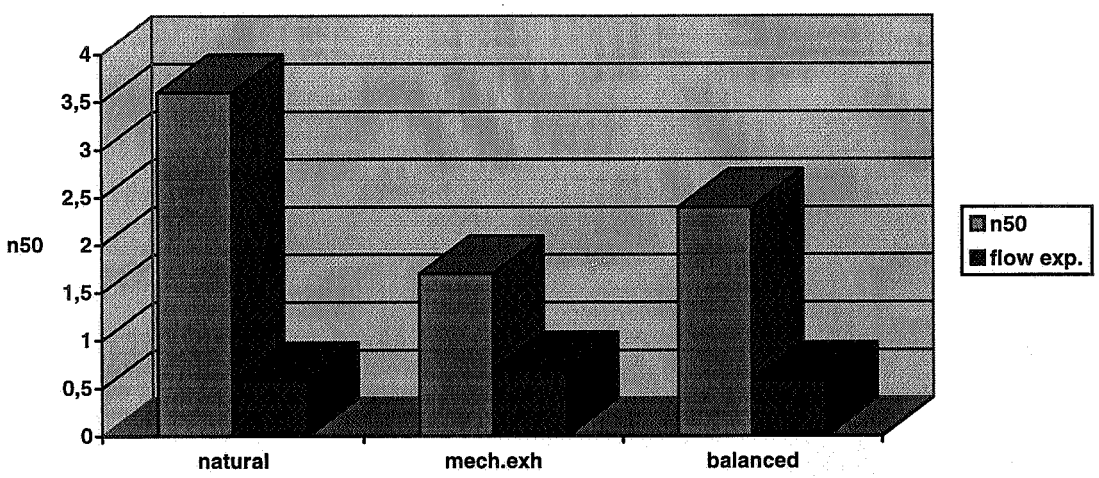

Figure 2 Results from pressurisation measurements

The air tightness of these dwellings can be considered as quite good. The differences between the three systems are however considerable.

Number of occupants per dwelling

The average number of occupants in the dwelling may be important for the intensity of the use of the dwelling. Data can be found in figure 3.

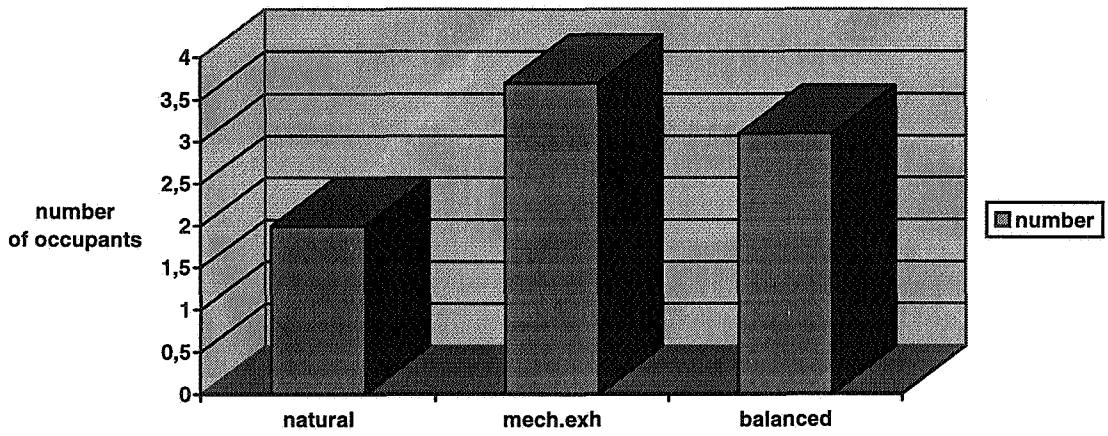

Figure 3 Average number of occupants grouped per ventilation system

The average number of occupants for all dwellings is about 2,9, which is a quite normal level. However the differences between the three groups are big. The natural ventilation system dwellings have about half of the occupancy than the two others.

MEASUREMENTS RESULTS

Temperature

Figure 4 shows the measured data.

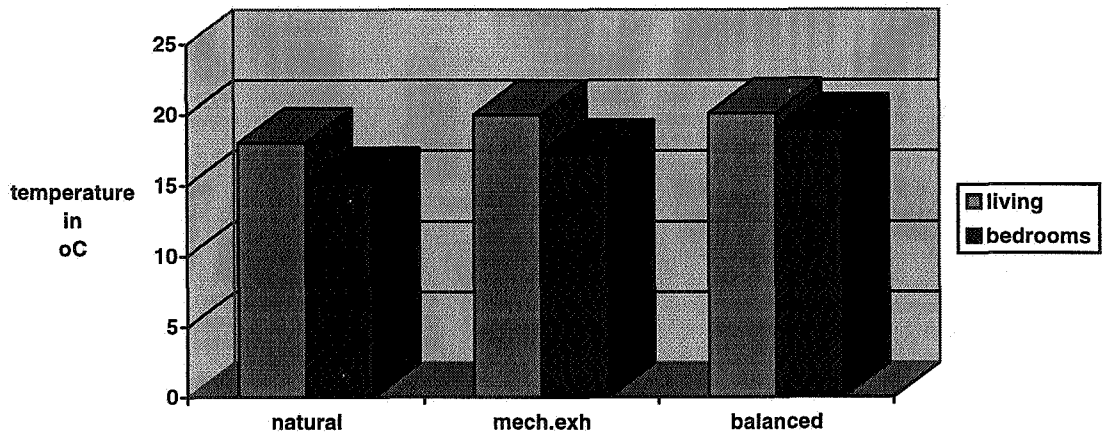

Figure 4 Temperatures in the dwellings

The following remarks can be made.

The temperature in the living is almost the same in the dwellings with mechanical exhaust and the balanced systems.
The naturally ventilated dwellings have the lowest temperature in the living as well as in the bedrooms. In the dwellings with balanced ventilation the difference between living and bedroom temperatures is as expected very low.

Moisture level

The results of the moisture level is presented in figure 5.

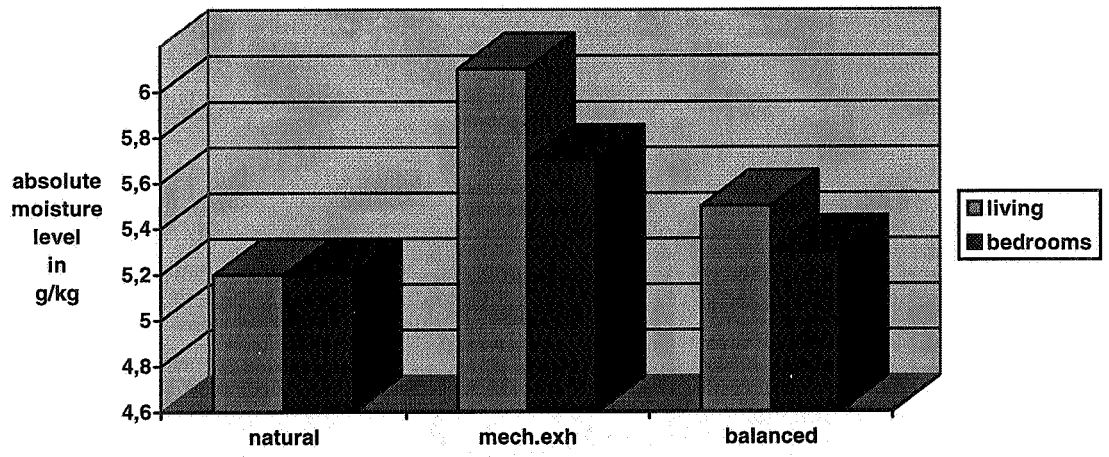

Figure 5 Absolute moisture level in the air

As can be seen the differences between the ventilation systems are considerable.
An important effect can be the occupancy. But also differences in ventilation rate may have their effect. The natural ventilated dwellings again are much lower than the dwellings of the two other systems.

Air Flow Rates

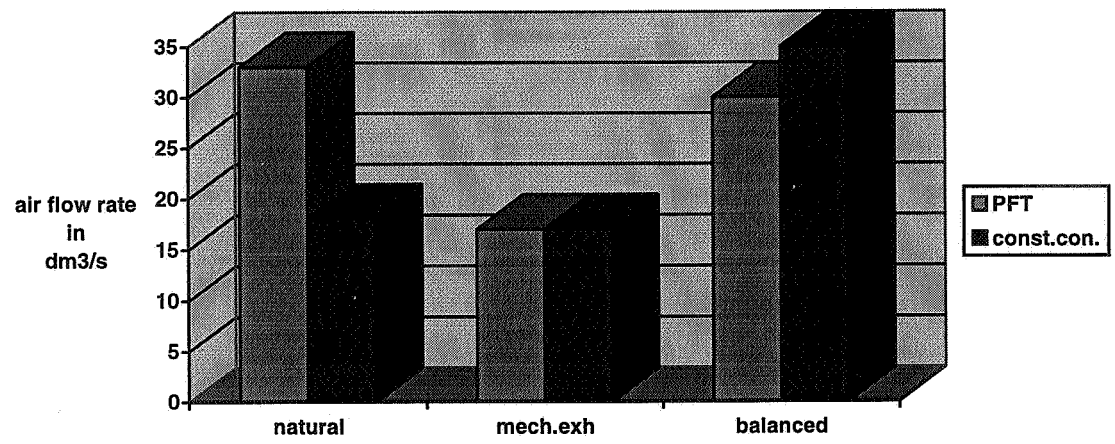

Figure 6 Measured air flow rates

There is a good correlation between the PFT measurements and the constant concentration measurements in case of mechanical exhaust and balanced systems.
The natural ventilated dwellings give a enormous difference between PFT and constant concentration results. Many checks have been carried out on the data analysis but no explanation can be given.

Indoor air quality

The indoor air quality is measured in terms of CO_2 , CO and TVOC concentrations.
The CO_2 data can be found in figure 7.
Again considerable differences between the groups of dwellings with different ventilation systems. The CO_2 concentration in the dwellings with the mechanical exhaust system is much higher than in the two other systems. This is partly due to the higher occupancy.
But this can not explain the whole effect. There must be an effect of the air flow rate.

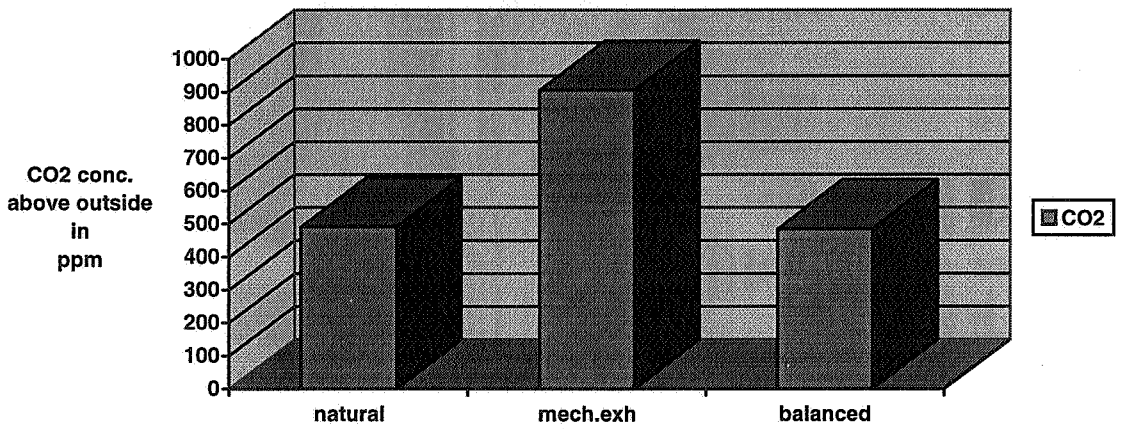

Figure 7 Measured CO_2 levels in dwellings

The measured data for CO and TVOC are shown in figure 8.

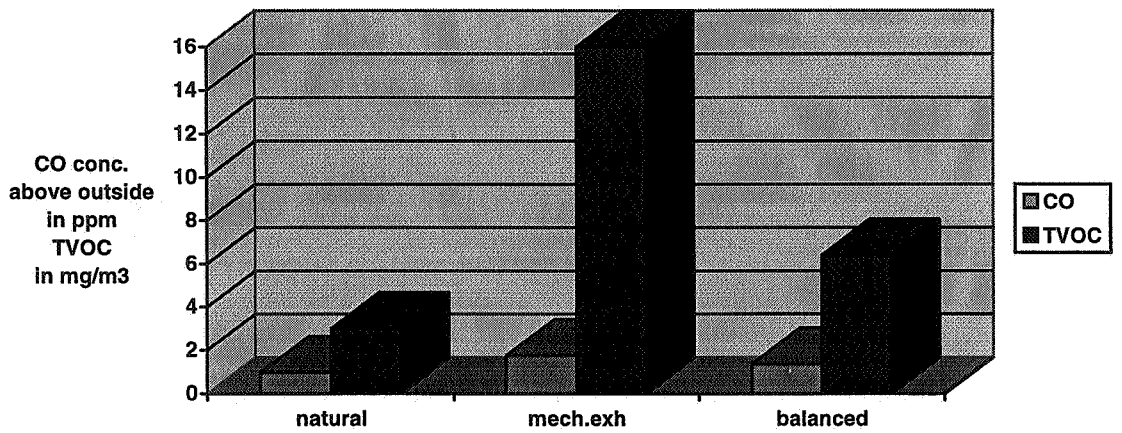

Figure 8 Other measured indoor air quality results.

The differences can't be explained on the bases of number of occupants. The habits of the occupants must be the risen for it.

Use of ventilation provisions

Grids

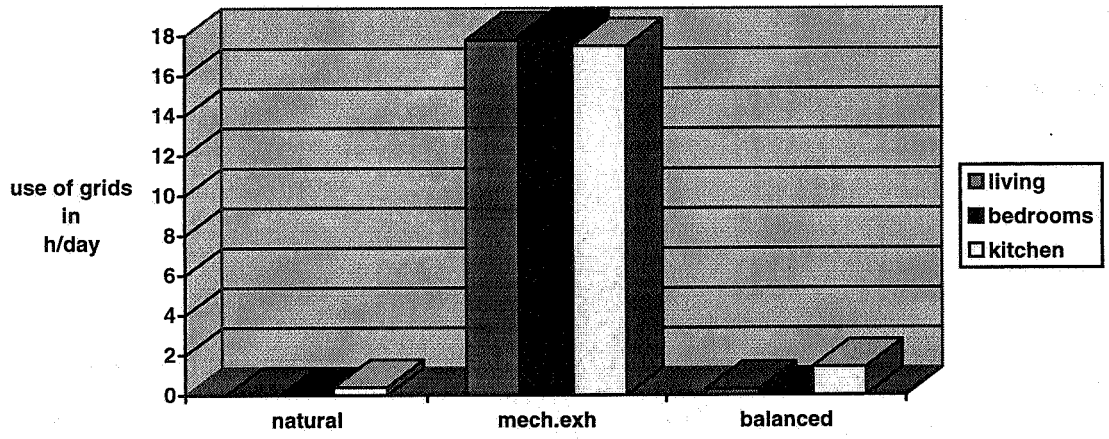

Figure 9 The use of grids by the occupants in hours per day.

Some remarks are necessary to understand these figures.
In the dwellings with natural ventilation system the grids are only present in the kitchen.
In the dwellings with balanced systems the grids, which are not a necessity at all, are only present in living room and kitchen.
The frequent use of these grids at average about 18 hours a day is remarkable. There effect on the flow rates are not very big. The sizing of the grids have to be checked.

Airing

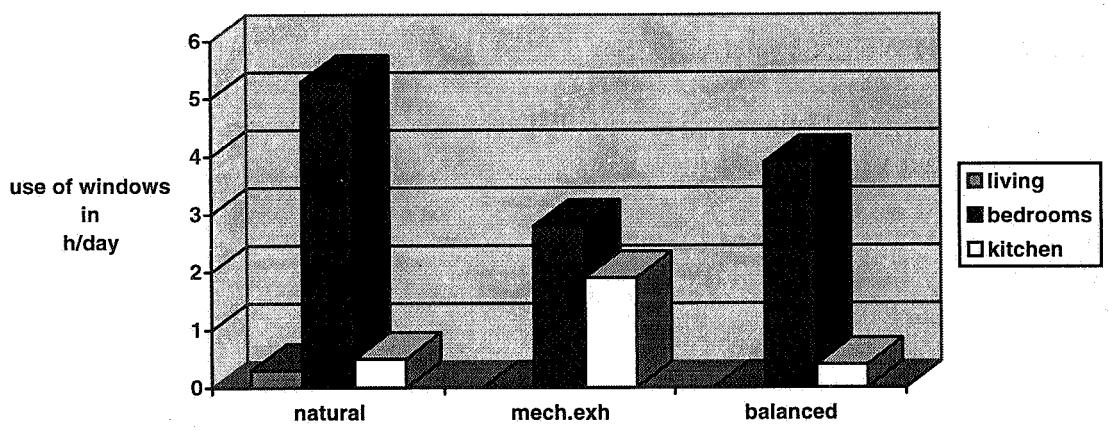

Figure 10 Use of windows for airing

The use of openable windows for airing give a more coherent picture. The result are shown in figure 10.
In the living the use is at minimal level. The use of openable windows in the kitchen is limited to less than two hours, which can be explained by the cooking periods.
In the bedrooms the lowest use is in the dwellings with mechanical exhaust which have the maximum use of the grids. (see figure 9)
The results are in agreement with earlier research of IEA annex 8 "Inhabitants behaviour with regard to ventilation".

Switch on time of balanced systems

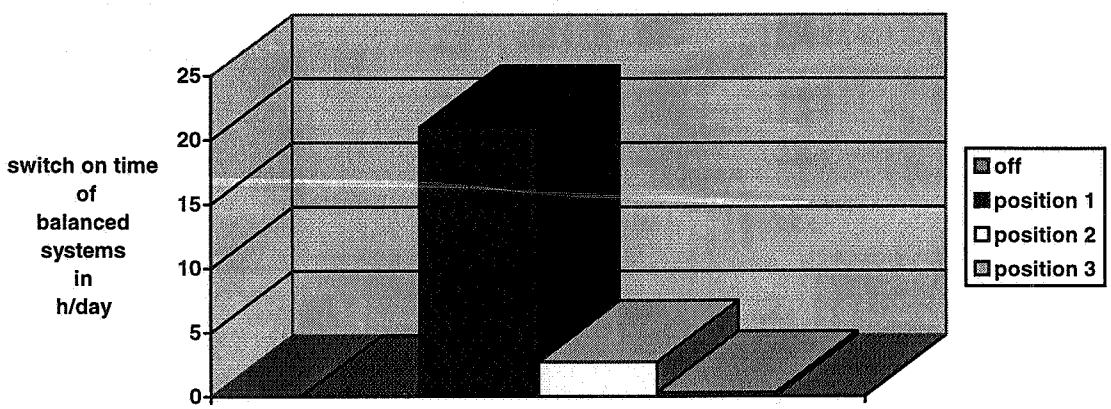

Figure 11 Switch on time of the balanced systems

As can be seen the balanced system are switched in position 1 for more than 20 hours. The are flow rate at that position 1 is aboutd16 dm^3/s. The air flow rate in position 2 is about 26 dm^3/s and in position 3 about 33 dm^3/s.
So a few hours per day, normally during cooking and washing, the air flow rate for the whole dwelling is at a level around 30 dm^3/s.

RELATION BETWEEN VARIABLES

As can be seen in figure 12 there is a relation between some of the variables of this study.
The most important variables are:

- CO_2 level
- air flow rate
- air leakage
- number of occupants

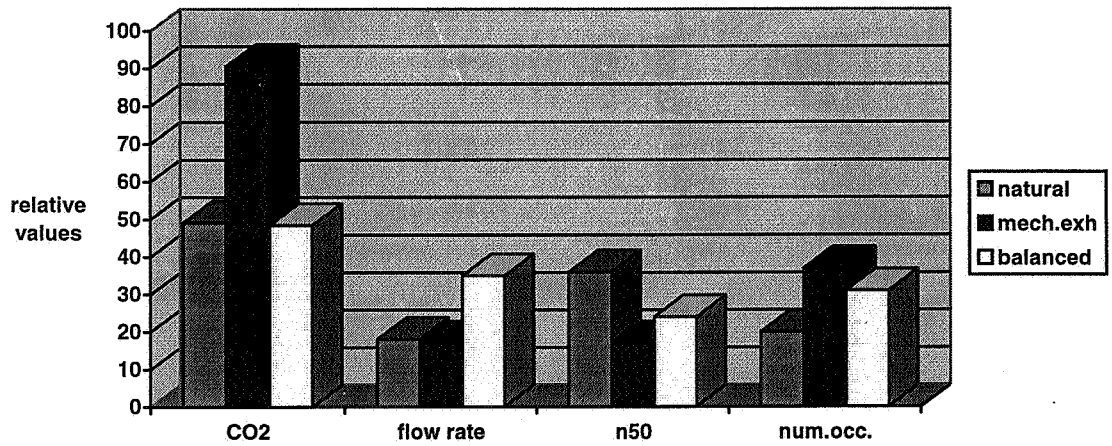

Figure 12 Relation between CO_2 , air flow rate, air leakage and the number of occupants

The mechanical exhaust systems have the highest CO_2 concentration in the most air tight dwellings with the highest occupancy. The air low rate is about the same as in case of the natural ventilated dwellings.
The CO_2 concentrations in the balanced ventilated dwellings is half of that of the mechanical exhaust systems. The flow rate in the balanced systems is about twice that of those in the mechanical exhausted dwellings, with about the same occupancy.

CONCLUSIONS

The measurement results show that the main parameter for the indoor air quality in these dwellings is not the ventilation system it self, but the use of the ventilation provisions in the dwellings by the occupants. Window airing can't be neglected in evaluating the indoor air quality in dwellings.

Other important parameters are:

- number of occupants
- air leakage level of the dwelling

For other pollutants such as CO and TVOC the main parameter is probably the activities by the occupant and not the ventilation system.

A tool to evaluate ventilation systems which don't take into account the inhabitants behaviour will not be very successful in predicting the right indoor air quality.

A conclusion that one of the ventilation systems is better that the other is difficult to draw. Natural and balanced systems had about the same CO_2 level . The air flow rate of the balanced system was twice as high as the natural one, but the number of occupants was also higher.