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COMPARISON OF IAQ PERFORMANCES OF FRENCH VENTILATION SYSTEMS IN RESIDENTIAL BUILDINGS

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ABSTRACT

Until now, there is no widely accepted way to express any index for this purpose and taking into account the large variety of possible pollutants. Things can be simplified is the aim is more to compare different systems and strategies than to give an absolute value of quality.

For the study of a pollutant source, the main important point for comparison is the pattern of its production, whatever this pollutant is. For human feeling and health we defined 5 main generic pollutants: constant emission related to the room area; human metabolism (using CO_2 as a tracer); emission due to cooking activities; passive smoking; indoor humidity related to the dryness feeling.

The detailed data is for each inhabitant the curve of the number of hours above a pollutant level concentration Ci : Nh (Ci). A condensed one is calculated as the cumulated value above a threshold limit Cimax. This is the basis for the results presented here. Other parameters are also calculated as pressure difference between outdoor and indoor, room related parameters (humidity, condensation hazards), and energy parameters (heat needs and fan energy). This methodology was defined and used in the framework of IEA annex 27 "domestic ventilation".

The main ventilation systems used in France have been described based on the Ann27 approach, applied by using the ventilation code SIREN, developed by CSTB. The sensitivity analysis presented in the paper takes into account different climates, dwelling types, air airtightnesses, dwelling occupancies, water vapour production.

KEYWORDS

ventilation system, IAQ index, ventilation heat losses, ventilation codes,

INTRODUCTION

The IEA Ann 27 "domestic ventilation" developed a methodology making it possible to compare different ventilation systems and strategies on the same international approved basis. We first present this approach

THE IEA ANNEX 27 METHODOLOGY

In the IEA annex 27 project ventilation systems are study: nine dwellings (3 plans and 3 airthightness), three occupancy (spacious, average, crowded), three climates (cold, mild, warm). [1]

Results are given in term of indoor air quality (pollutant exposure for each inhabitant) condensation risks and energy.

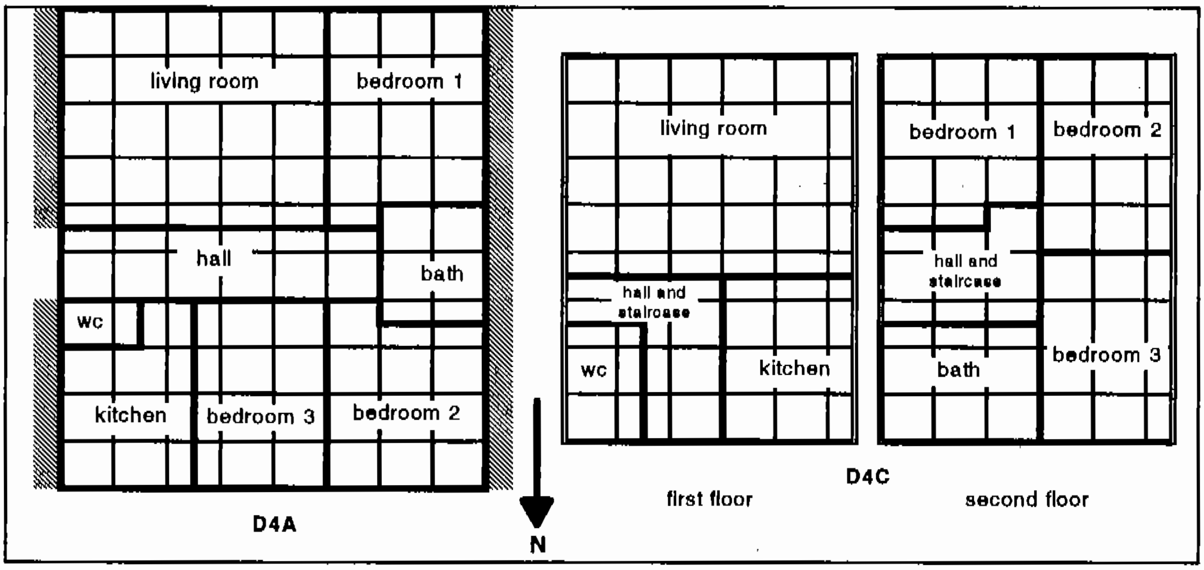
Dwellings: three dwellings have been considered:

- D4A : four rooms flat located on ground floor in a four-storey building.
- D4B : four rooms flat located on top floor in a four-storey building.
- 4C : 4 rooms single family house

Leakage values are given hereafter :

	n50 (ach)		
D4A	1	2.5	5
D4C	2.5	5	10

Half of the cracks are located at 0.625 m from the floor and the other half 1.875 m from the floor for the leakage 1 , 2.5 and 5. For leakage 10, the additional cracks are located at the floor and at the ceiling.



The climates are related to meteorological data from :

- cold : Ottawa (Canada).
- mild : London (United Kingdom).
- warm : Nice (France).

Four ventilation systems are designed :

- natural airing
- passive stack
- mechanical exhaust
- mechanical exhaust and supply

Dimensioning make use of inlets or outlets size and airflows (extract and supply)

For each system an alternative consists in additional fans in kitchen and bathroom, opening windows in bedrooms.

Indoor air quality for people

For the study of a pollutant source, it can be noticed that the main important point for comparison is the pattern of its production (level versus time and place), whatever this pollutant is. Therefore, it is possible to define some generic pollutants, which will be defined only by their pattern.

For human feeling and health we propose at first to base the comparisons on five main generic pollutants :

- Plt1 : constant emission related to the room area. It could be related to pollutant emission by the rooms themselves.
- Plt2 : human metabolism. It is based on the CO_2 production.

- Plt3 : cooking activities. It is based to the water evaporated during cooking and could be related to odours production, as to CO or NOx production in case of gas appliance.
- Plt4 : passive smoking . It is based on a production of pollutant for the hours and place when and where people are smoking (production 20 U4/h in the living when woman is present between 13 - 24 o'clock).
- Indoor humidity : this one is here only related to the dryness feeling. It is not a generic pollutant as it can be expressed directly in terms of indoor relative humidity.

A weekly schedule of the dwelling occupancy has been defined by IEA annex 27 [1].

Results :For each inhabitant we give the curve of the number of hours above a pollutant level concentration Ci : Nh (Ci). These results are also given in a condensed form based on the calculation of the cumulated value above a threshold limit. For CO2, the limits are 700 and 1400 ppm : the condensed outputs are expressed in ppm.h above these two levels.

The energy needs must be split into heat needs and electrical needs for fan.

The heat needs is calculated knowing the airflows to the outdoor and the temperature difference between outdoor and indoor. The airflows are separated into three parts :

- air exhausted by the ventilation system,
- air exfiltred through the envelope,
- airing by opening windows.

The average air flow and air change per hour is the direct averages during the heating season of the overall air dwelling airflow. It is not of direct interest because it is neither related to indoor air quality nor to heating needs. For example with the same average airflow, the heat needs will be increased if the ventilation in winter is higher (passive stack systems) and decreased if the ventilation is lower (humidity controlled systems).

We calculate **heat needs equivalent air flow rate** and air change rate which are the constant airflow (or air change rate) which would lead to the same heat needs as the ones calculated. It is simply calculated by :

$$\mathrm{Qave} = \frac{\int 0.34 \times Q(t) \times (Ti - Te(t)) \times dt}{\int 0.34 \times (Ti - Te(t)) \times dt}$$

The electrical needs are calculated on the whole year if this corresponds to the system running: the power is considered 40 W for a dwelling : the annual consumption is 350 kWh.

THE COMPUTER CODE *SIREN95*

The computer code SIREN95 is an evolution SIREN ("SImulation du RENouvellement d'air") developed in C.S.T.B [2]. It is used to calculate the airflow throughout the entire heating season (about seven months) in a dwelling (with a maximum of 15 rooms).

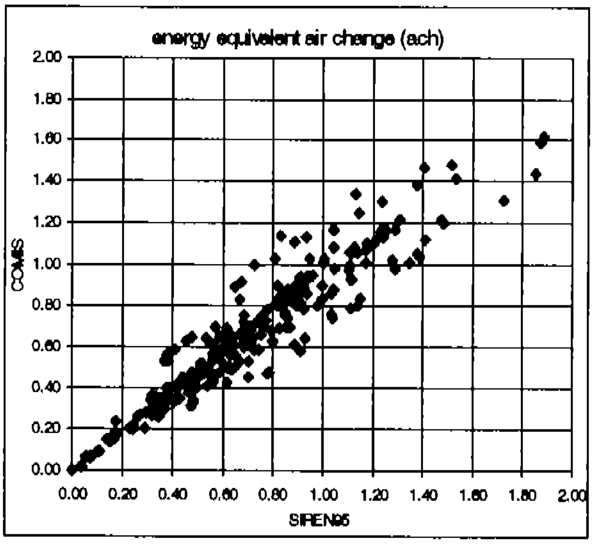
The code uses hourly meteorological data (temperature, relative humidity, wind speed and orientation) ; occupancy and pollutants production (CO_2 H_2O ...) are defined with a half an hour step ; actually four pollutant, plus water vapour can be taken into account ; for water vapour hygroscopic inertia an be adjusted. Pollutants and humidity concentrations are assumed uniform in each room.

In SIREN95 internal pressures are assumed a hydrostatic field ; the inside temperature is considered constant in a horizontal plane (only vertical gradient : stack effect is taken into account).

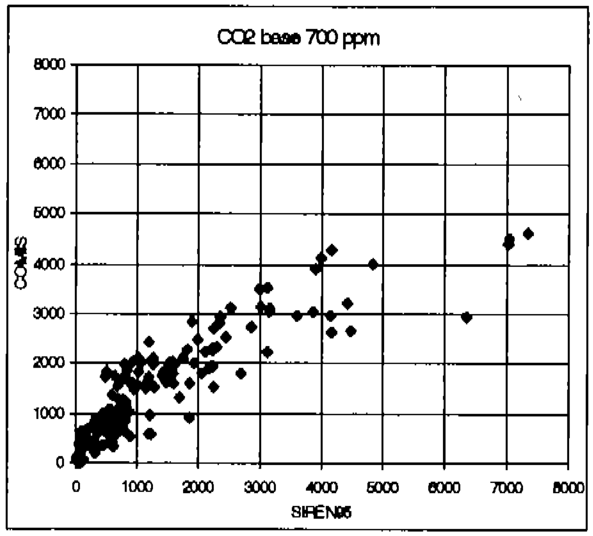
Each component (air inlets, outlets, cracks, fans, windows, ...) is characterised by its flow rate curve as a function of the pressure difference and also when relevant, of the temperature, pollutant concentration or relative humidity. The curves of components can be given by functions (not necessary smooth) or tables : a possible hysteresis can be taken into account.

SIREN95 is written in FORTRAN 77 ; it runs an entire heating season in roughly four minutes (PC Pentium 150 MHz or more)

We compared COMIS and SIREN95 on the results of 174 simulations with changes in dwellings, ventilation system, climates, occupancy, ...



Results of equivalent air change are in good accordance : for natural airing, SIREN95 (which don't take into account pressure losses due to internal doors) gives a higher level than COMIS



Four cases corresponding to natural windows airing and passive stack ventilation systems are quite different (values calculated with SIREN95 above 6000 ppm.h).
For mechanical ventilation systems (exhaust only and balanced results are in good accordance.

PERFORMANCES OF VENTILATION SYSTEMS

With SIREN95 we have run 990 simulations with changes in dwellings, ventilation system and climates.

For the most important parameters (IAQ, condensation, energy) the results are given in five classes (++ - - approach). The class limits are not directly reproducing the 20% values, as the curves are not linear (which means that doing so would not make it possible to appreciate well the - - class).

We give hereafter the classes limit for three pollutants and equivalent air change rate :

	IAQ			
	CO2 700ppm	cooking	passive smoking	energy
unit	kppm.h	U3.h	U4.h	ach
++ to +	500	600	400	0.4
+ to 0	1000	1000	600	0.6
0 to -	2000	1500	1000	0.8
- to --	4000	4000	1600	1.0

Results are given in tables as follows :

- indoor air quality : we calculated for each case the - - to ++ classes for CO2, cooking products, and passive smoking ; the final result is the worst value.
- condensation : we calculated for each case the - - to ++ classes for the habitable rooms and the wet rooms ; the final result is the worst value.
- energy (equivalent air change rate).

APPLICATION TO VENTILATION SYSTEM IN USE IN FRANCE

Cases studied

We used the typical D4a and D4c dwellings for three typical French climate :. Nancy, Trappes and Nice. We took into account the 3 typical families with an additional sensitivity study based on different schedules of water vapour production

The different ventilation system are as follows :

Mechanical exhaust only

It is based on available products according to French regulation

	Dwelling D4A	Dwelling D4C
Kitchen outlet	45 / 120 m^3/h	45 / 120 m^3/h
WC outlet	30 m^3/h	30 m^3/h
Bathroom outlet	30 m^3/h	30 m^3/h
Living-room inlet	module 30	module 22
Bedroom inlet	module 45	module 45
Fan power	45 W	45 W

The air inlet module is the airflow under 20 Pa

Humidity controlled mechanical exhaust only system

These systems were designed and dimensioned according to the manufacturer specifications. Two kinds of system are taken into account :

- Humidity controlled type 1 : humidity controlled kitchen air outlet only
- Humidity controlled type 2 : humidity controlled air inlets and kitchen outlet

The fan power is 60 W.

Balanced ventilation system

The exhaust part is the same as the mechanical only one. The supply part is taken equal to 21 m^3/h in the bedrooms and 42 m^3/h in the living room.

The fan power is 60 W for the supply part and 55 W for the exhaust part.

Passive stack

This system is taken into account for the detached house only, based on available guidance document "Solutions techniques pour le respect du règlement thermique en maison individuelle"

- kitchen :	exhaust device ("grilles"), 400 cm² circular duct with the sizes: 200 mm diameter ; length 5.6 m cowl 200 mm diameter ζ=1,5 C=-0,5
- bathroom :	exhaust device ("grilles"), 100 cm² circular duct with the sizes: 160 mm diameter ; length 2.8 m cowl 160 mm diameter ζ=1,5 C=-0,5
- WC :	exhaust device ("grilles"), 100 cm² circular duct with the sizes: 125 mm diameter ; length 5.6 m cowl 160 mm diameter ζ=1,5 C=-0,5

Mechanical supply in the hall

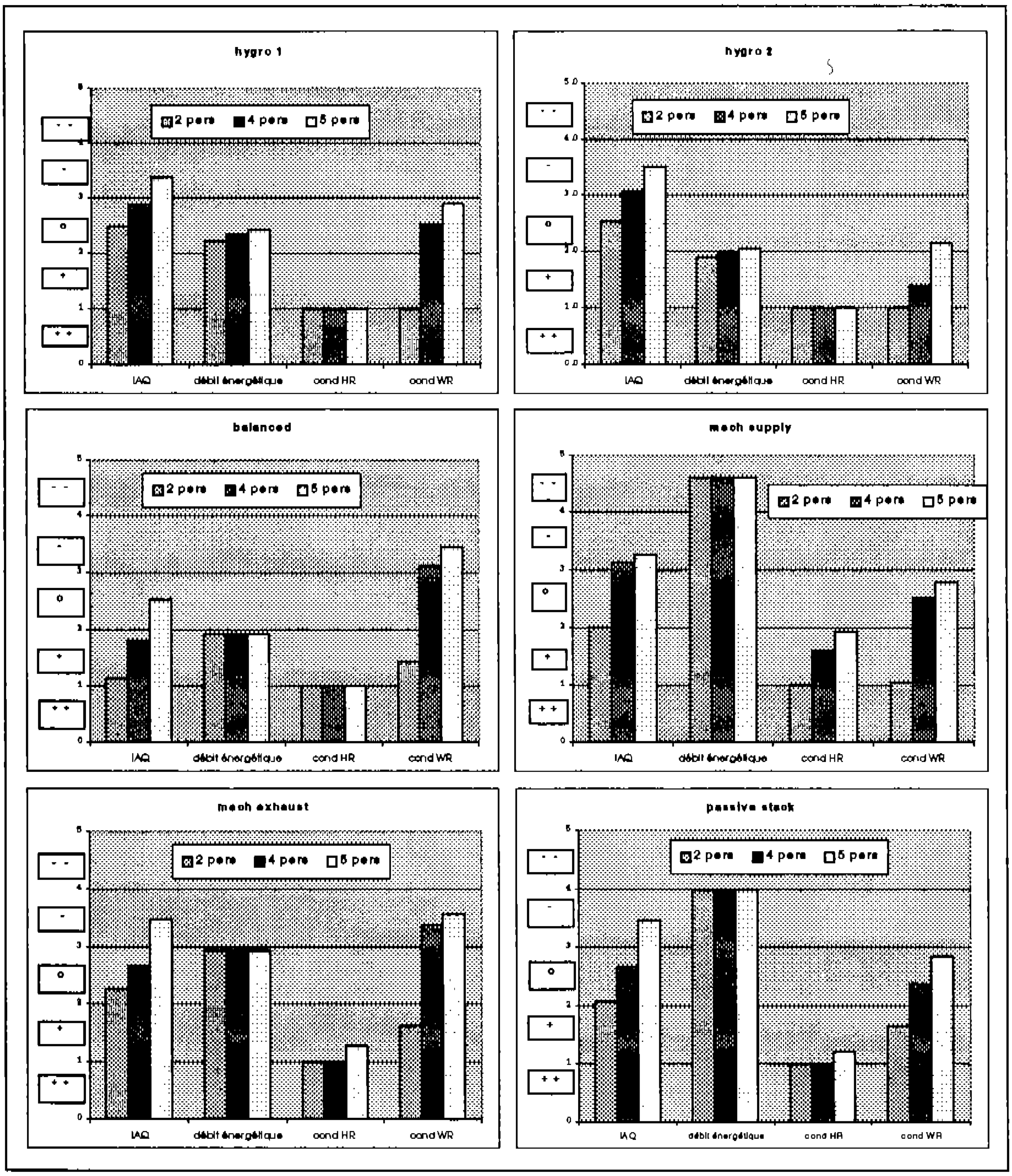
This system is available on the French market and is mainly used for retrofitting. It has been taken into account for the detached house only starting from a situation corresponding to existing buildings (grilles in the wet rooms according to sanitary regulation).

- Supply air in the upper part of the hall with an air flow of 169 m^3/h ,
- grilles in all main rooms (area 30 cm² corresponding to a module 45)
- grilles in the upper part of all wet rooms (100 cm²),
- one grille in the lower part of kitchen (100 cm²).

The fan power is 75 W.

Results

In order to facility the comparison, it is possible to present a quality profile for each system and occupation. For each case of quality index, the note is given as a 1 to 5 index corresponding to the + + to - - quoting.



The main results can be described as follows :

	IAQ		
occupants/dwelling->	2	4	5
Humcontrolled 1	+	o	o
humcontrolled 2	o	o	-
balanced	++	+	o
mech supp	+	o	o
mech ex	+	o	o
passive stack	+	o	o

All systems give an acceptable air quality, except for HC2 for over occupied dwellings.

	energy equiv. air change rate		
occupants/dwelling->	2	4	5
Humcontrolled 1	+	+	+
humcontrolled 2	+	+	+
balanced	+	+	+
mech supp	--	--	--
mech ex	o	o	o
passive stack	-	-	-

H.C. and balanced systems are the most efficient ones. PSV is less efficient due to the sensitivity of airflows to outer conditions. Central mechanical system is the less efficient one because each room is ventilated separately.

	condensation in wet rooms		
occupants/dwelling->	2	4	5
Humcontrolled 1	++	++	++
humcontrolled 2	++	++	++
balanced	++	++	++
mech supp	++	+	+
mech ex	++	++	++
passive stack	++	++	++

All systems are quite efficient. The Hall mechanical supply is + as the exhaust air is poorer controlled in wet rooms.

	condensation in habitable rooms		
occupants/dwelling->	2	4	5
Humcontrolled 1	++	o	o
humcontrolled 2	++	++	+
balanced	++	o	o
mech supp	++	o	o
mech ex	+	o	-
passive stack	+	+	o

The efficiency depends highly on the number of occupants.

CONCLUSION

The choice of a ventilation system is always based at least on a balance between indoor air quality for people, condensation risks and energy needs for heating and fan. The methodology developed within Ann 27 proved to be useable for other system than the one taken into account within this group, ending with a multiparameter comparison. This makes it possible to give advices for the choice of existing systems, and the development of new ones by quantifying the impact of the system design and dimensioning.

ACKNOWLEDGEMENTS

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