

A METHODOLOGY TO ASSESS THE IAQ PERFORMANCE OF 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 if the aim is to compare different systems and strategies rather 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. The detailed data for each inhabitant is the curve of the number of hours above a pollutant level concentration C_i : $N_h(C_i)$. A condensed one is calculated as the cumulated value above a threshold limit C_{imax} . 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".

KEYWORDS

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

INTRODUCTION

A methodology to compare the performances of ventilation systems has been defined within the IEA annex 27 project. After a presentation of the different parameters taken into account, we describe the methodology and we compare the results given by the codes COMIS and SIREN95.

THE STUDIED PARAMETERS

In the IEA annex 27 project ventilation systems are study : nine dwellings (3 plans and 3 airtightness), three occupancy (spacious, average, crowded), three climates (cold, mild, warm). Results are given in term of indoor air quality (pollutant exposure for each inhabitant) condensation risks and energy.

Dwellings : three four rooms dwellings have been considered : two flats (D4A,D4B) situated on ground and top floor of a four-storey building and a single family house D4C

The climates are related to meteorological data : 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 makes 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 human feeling and health we based the comparisons on five main generic pollutants :

- Plt1 : constant emission related to the room area.
- Plt2 : human metabolism. It is based on the CO₂ production.
- Plt3 : cooking activities. It is based to the water evaporated during cooking and could be related to odours production, as to CO or NO_x 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.
- Indoor humidity : this one is here only related to the dryness feeling.

A weekly schedule of the dwelling occupancy has been defined by IEA annex 27 [1] including the production of pollutants by occupants metabolism. For each inhabitant we give the curve of the number of hours above a pollutant level concentration C_i : $N_h(C_i)$. These results are also given in a condensed form based on the calculation of the cumulated value above a threshold limit.

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; 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. **The electrical needs** are calculated on the whole year.

THE COMPUTER CODE COMIS

COMIS is a multi-zone flow model developed within Annex 23. The FORTRAN code was originally developed at the Lawrence Berkeley Laboratory in the framework of the COMIS one-year workshop. Significant further development of the model has taken place since that workshop. COMIS is programmed in FORTRAN 77. User interfaces for input and output processing are available for PC (for both DOS and MS-WINDOWS).

This program allows for sophisticated multi-zone airflow and contaminant transport simulations. Air flow component for natural as well as mechanical ventilation systems can be modelled. Various schedules can be defined for the outdoor climate, indoor rooms temperatures, pollutants sources and sinks, and airflow component operation schedule. The time evolution of flows and concentrations as well as integrated and mean values for the whole-simulated time period can be determined.

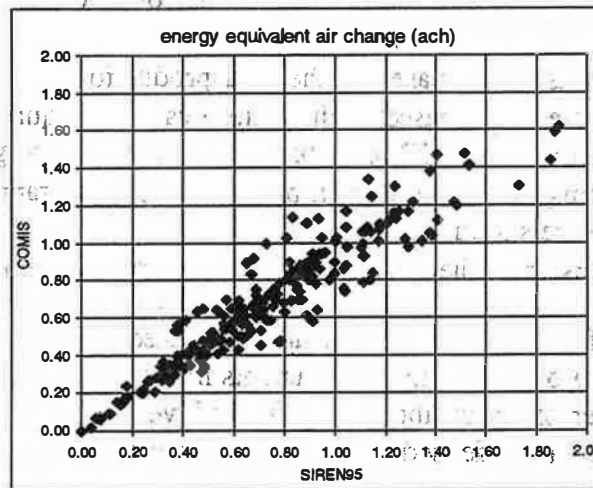
THE COMPUTER CODE SIREN95

The computer code SIREN95 is an evolution SIREN ("Simulation du RENouvellement d'air") developed in C.S.T.B [2]. The code uses hourly meteorological data (temperature, relative humidity, wind speed and orientation) ; occupancy and pollutants production (CO₂ H₂O ...) are defined with a half an hour step ; four pollutants, plus water vapour can be taken into account ; for water vapour hygroscopic inertia can be adjusted. Pollutants and humidity concentrations are assumed uniform in each room.

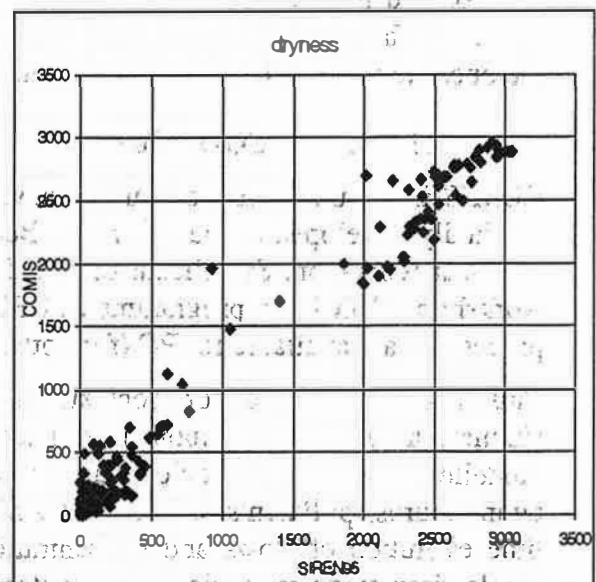
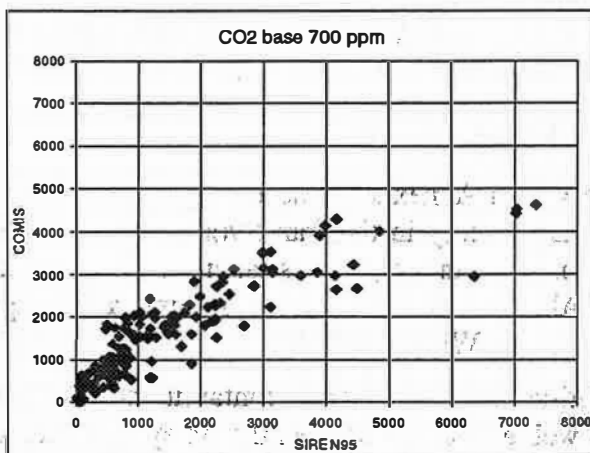
In SIREN95 internal pressures are assumed a hydrostatic field ; the inside temperature is considered constant in a horizontal plane (only vertical gradient ; stack effect is taken into account). Each component (air inlets, outlets, cracks, fans, windows, ...) is characterised by its flow rate curve as a function of the pressure difference and also when relevant, of the temperature, pollutant concentration or relative humidity. SIREN95 is written in FORTRAN 77; it runs an entire heating season in roughly four minutes (PC Pentium 150 MHz or more)

COMPARISON : COMIS & SIREN95

We compare 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.

Although COMIS use a post-processor to calculate indoor humidity the results are closely related.

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).

Results are given in tables as follow :

- 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).

		Indoor air quality																										
		nat. wind. airing				p. stack		mechanical exhaust						balanced														
airing ->		no		yes		no																						
supply ->		0	410	0	410	0	400	0						100														
flow rate ->								15	30	45	15	30	45	15	30	45												
add fan ->		no	yes	no	yes	no	yes	no	yes	no	yes	no	yes	no	yes	no	yes											
dwelling	n 50																											
D4a	1	-	-	-	o	-	-	-	o	o	-	-	o	-	o	o	+	+	-	-	o	+	+	+++				
	2.5	-	-	-	o	-	-	-	o	+	-	-	o	-	o	o	+	+	o	o	o	+	+	+++				
	5	-	-	-	+	-	-	+	o	o	o	o	+	+	o	o	o	+	+	+	o	+	o	+++	+++			
ground	1	-	-	-	o	-	-	-	o	+	-	-	o	-	o	o	+	+	-	-	o	+	+	+++				
	2.5	-	-	-	o	-	-	-	o	-	-	+	+++	-	-	o	-	+	o	-	-	o	o	+	+	+++		
	5	-	-	-	+	-	-	+	+	+	+	+	+++	o	o	o	o	+	+	o	o	o	+	+	+++	+++		
D4c	1	-	-	o	o	-	-	o	o	-	-	+	+	-	-	o	-	+	o	-	-	o	+	+	+++			
	2.5	-	-	o	+	-	-	o	+	-	-	+	+++	-	-	o	-	+	o	-	-	o	o	o	+	+	+++	
	5	-	-	o	+	-	-	o	+	-	-	+	+++	-	-	o	-	+	o	o	o	o	+	o	o	+	+++	+++
	10 case a	o	+	+	+++	o	+	+	+++	+	+	+	+++	o	+	+	+	+	+	+++	+	+++	+	+++	+	+++	+++	
	10 case b	-	-	+	+	-	-	+	+	-	-	+	+++	-	-	-	-	-	-	o	o	o	o	o	o	o	+	+++

		Heat needs																													
		nat. wind. airing				p. stack		mechanical exhaust						balanced																	
airing ->		no		yes		no																									
supply ->		0	410	0	410	0	400	0						100																	
flow rate ->								15	30	45	15	30	45	15	30	45															
add fan ->		no	yes	no	yes	no	yes	no	yes	no	yes	no	yes	no	yes	no	yes														
dwelling	n 50																														
D4a	1	+++	+	o	+++	+	o	+	+	-	-	+	+	+	o	-	-	+	+	+	o	-	-	+	+	+	+	+	+	+	
	2.5	+++	+	o	+++	+	o	+	o	-	-	+	+	+	o	-	-	+	+	+	o	-	-	+	+	+	+	+	o	o	
	5	+++	+	o	-	+++	+	o	-	o	-	-	-	+	o	o	o	-	-	+	o	o	-	-	-	+	+	+	o	o	o
ground	1	+++	+	o	+++	+	o	+	-	-	-	-	+	+	+	o	-	-	+	+	+	o	-	-	+	+	+	+	+	+	
	2.5	+++	+	o	+++	+	o	o	-	-	-	-	+	+	+	o	-	-	+	+	+	o	-	-	+	+	+	+	+	o	
	5	+++	+	o	-	+++	+	o	-	-	-	-	-	+	+	o	o	-	-	+	o	o	-	-	-	+	+	+	o	o	o
D4c	1	+++	+	o	+++	+	o	+	o	-	-	+	+	+	o	o	-	+	+	+	o	o	-	-	+	+	+	+	+	+	
	2.5	+++	o	o	+++	o	-	+	o	-	-	+	+	+	o	o	-	+	+	+	o	-	-	+	+	+	+	+	+	o	
	5	+++	+	o	-	+++	+	-	-	-	-	-	-	+	o	o	-	-	+	o	o	-	-	-	+	+	+	o	o	o	
	10 case a	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	10 case b	o	-	-	-	o	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

evaluation of indoor air quality and heats needs vs ventilation system and dwelling characteristics for Ottawa climate

These above tables give examples of results for Ottawa for air quality and heat needs only;

In addition to the +- approach related to principal parameters of IAQ, condensation and energy, additional parameters are qualified with warning flag on Dryness feeling, Pressure difference and Indoor humidity (house dust mite).

The input parameters of the table are as follows :

- Dwellings (D4A top, D4A ground, D4C) and n 50 value: (1; 2.5; 5; 10) are described in the studied parameters,
- The ventilation systems are identified by four base systems. Those systems can then be combined with local fans in bathroom/toilet and/or kitchen and window opening patterns (closed, or climate depending). Complete mixing is assumed in each room.

1. windows opening (airing)

Bedroom windows can be opened during weekdays from 8 h to 12 o'clock, depending on the weather conditions. Two cases of purpose provided openings are taken into account: 0 cm² and 410 cm² (80 cm² in each habitable room: 30 cm² in each of the toilet, bath, kitchen)

2. passive stack

Two cases of purpose provided openings are taken into account: 0 cm² and: 400 cm² (80 cm² in each bedroom and 160 cm² in the living-room)

The passive stack exhaust system is as follows:

Length of the ducts: Multifamily building. Building height to the top floor ceiling +1.5m;
Single family houses +2.5 m.

Ducts are circular sheet metal with the sizes: Ø150 mm bath and toilet, Ø200 mm kitchen.

The friction factor of the ducts is $\lambda=0.05$.

The equivalent area of the exhaust device ("grilles"), ($C_d=0.6$), is 70 % of the cross area of the duct

Kitchen: 200 cm²

Bathroom and toilet: 125 cm²

3. mechanical exhaust

Two cases of purpose provided openings are considered: 0 cm² and 100 cm² (20 cm² in each bedroom and 40 cm² in the living-room)

The mechanical exhaust flow rate is given for three levels: 15 l/s (7.5 l/s in the kitchen 5 l/s in the bath and 2.5 l/s in the toilet), 30 l/s 45 l/s (split as for 15 l/s)

4. balanced

Three cases of supply flow rates are considered: 15 l/s (3 l/s in each bedroom and 6 l/s in the living-room), 30 l/s, 45 l/s (split as for 15 l/s). The exhaust flow rates are the same as for the mechanical system, with a heat exchanger efficiency of 50 %

Local additional fans

For all systems additional fans can be used or not:

a) Kitchen hood: Running time 1 h/day, at 17.00 - 18.00 o'clock. Flow rate is 100 l/s

b) Bathroom fan: Running time is 2 h/day. Weekdays 6.00 - 8.00 o'clock and weekends at 9.00 - 11.00 o'clock. Flow rate is 25 l/s

The output parameters are the classes as described in the performances paragraph.

An IAQ ++ result indicate that the result is ++ for the CO₂; cooking and passive smoking pollutants. A - - value indicates that at least one of this pollutant leads to a - - value.

A - - value for energy indicates that the equivalent air change rate is higher than 1.0 a.c./h ; a ++ that it is less than 0.4 a.c./h

These tables makes it possible to evaluate the efficiency of a given ventilation system depending on the use of airing and additional fan in relationship with the dwelling characteristics (type of dwelling, situation, airtightness).

Some comments can be made regarding the produced values for Ottawa climate :

- it appears that a ventilation system can't be ++ both in air quality and energy needs. That is particularly true with natural windows airing and passive stack,
- For mechanical systems and providing that the dwelling is airtight enough, systems can be good (+) for IAQ and very good (++) , especially for balanced system with heat recovery,
- For mechanical exhaust system with no air inlets, the presence of an additional fan decrease the IAQ index if the dwelling is airtight : this is due to the fact that air enter through the fan hole when the fan is not running, which reduce the amount of air entering the habitable rooms,
- The location of unknown air leakages can have a strong impact on air quality for all systems but the balanced ones : this can be seen for the house D4c case a (equally split air leakages) and case b (half of air leakages in the hall). In this case, air is poorly entering through the habitable rooms, which leads to both high heat needs and low air quality.

ACKNOWLEDGEMENTS

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