A METHODOLOGY TO ASSESS THE IAQ PERFORMANCES 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. A condensed one is calculated as the cumulated value above a threshold limit. 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.

BASIS OF THE METHODOLOGY

The methodology is based on the calculation of different parameters by one simulation performed on a heating season. Conventionnal parameters are heat needs (defined here as the heat given to outdoor air without taking into account heat production efficiency) and condensation risks. Less commonly used ones are the occupant exposures to different kinds of pollutants, which makes it possible to make a comparison on IAQ performances. Detailed results can be expressed as a easy to use quality profile (- - to + + quoting for each of the parameter).

THE STUDIED PARAMETERS

Dwellings : three four rooms dwellings have been considered : two flats (D4A,D4B) situated on gound 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 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.
- 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 calculate 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.

The energy needs must be split into heat needs and electrical needs for fan. 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. 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 (CO_2 H_2O ...) are defined with a half an hour step .Internal pressures are assumed a hydrostatic field. 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.

COMPARISON BETWEEN COMIS & SIREN95

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

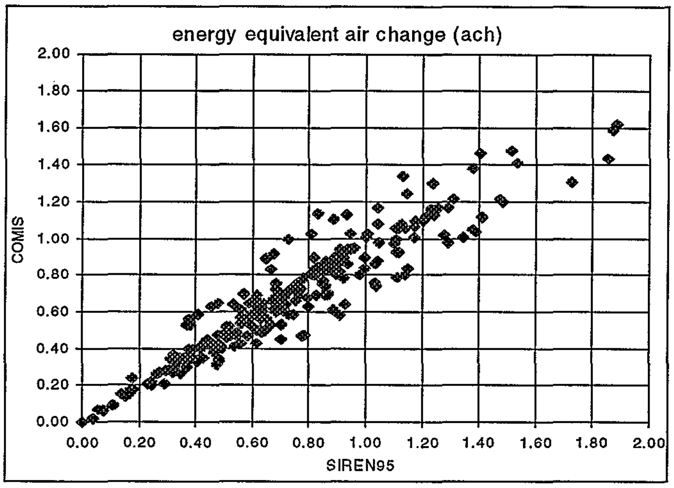

Fig 1 comparison between COMIS and SIREN for energy equivalent air change rate

Results differ of 0.4 a.c./h and 40 % at maximum: for natural airing, SIREN95 (which don't take into account pressure losses due to internal doors) gives a higher level than COMIS. Other differences can be due to the opened window modelling and the multiroots solving (physical approach in Siren, steady-state mathematical one in Comis)

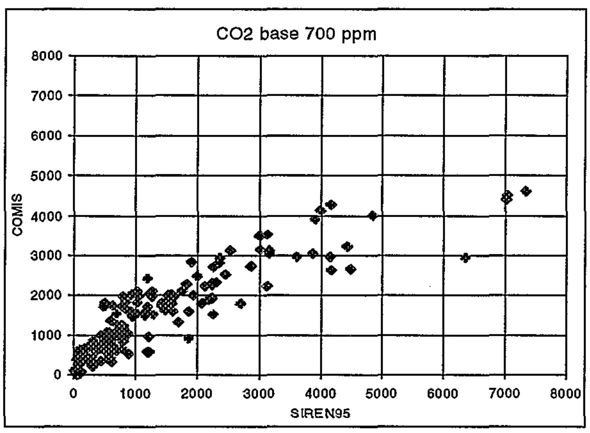

Fig 2 comparison between COMIS and SIREN for CO_2 (exposure above 700 ppm)

For cases corresponding to natural windows airing and passive stack ventilation systems are quite different (values calculated with SIREN95 above 6000 ppm.h).

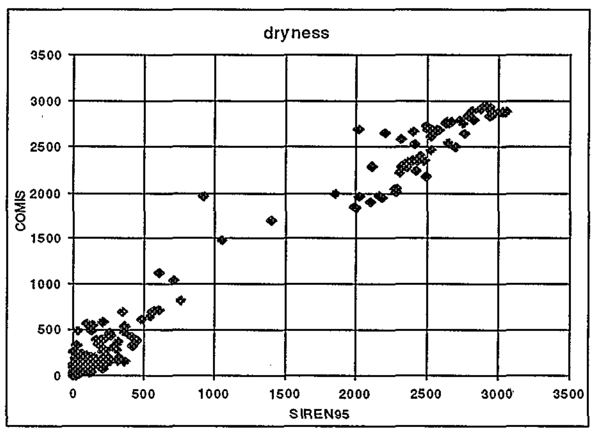

Fig 3 comparison between COMIS and SIREN for dryness feelin (hours)

Although COMIS use a post-processor to calculate indoor humidity the results differs less than 500 h.

The above results show that the methodology could be successfully applied with two different models. Even if the differences in the absolute values of the result are not neglictable, they make it possible to express them as a ranking, which one of the aim of the methodology.

PERFORMANCES OF VENTILATION SYSTEMS

In order to enable a first check, SIREN was run for 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 classes). 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).

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 tables1 and 2 give examples of results for Ottawa for air quality and heat needs only;

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).

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	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	o	+	+	-	-	o	+	+	++
	2.5	- -	-	-	o	- -	-	-	o	-	-	o	+	-	-	o	-	+	o	-	-	o	o	+	+	o	o	o	+	+	++
top	5	-	-	-	+	-	-	-	+	o	o	o	++	o	o	o	o	+	+	o	o	o	+	+	+	o	+	o	++	+	++
D4a	1	- -	- -	-	o	- -	- -	-	o	- -	- -	o	+	-	- -	o	-	+	o	-	-	o	o	+	+	-	-	o	+	+	++
	2.5	- -	-	-	o	- -	-	-	o	-	-	+	++	-	-	o	-	+	o	-	-	o	o	+	+	o	o	o	+	+	++
ground	5	-	-	-	+	-	-	-	+	+	+	+	++	o	o	o	o	+	+	o	o	o	+	+	+	o	+	o	++	+	++
D4c	1	- -	- -	o	o	- -	- -	o	o	- -	- -	+	+	-	- -	o	- -	+	-	-	-	o	-	+	o	-	-	o	+	+	++
	2.5	- -	- -	o	+	- -	- -	o	+	-	-	+	++	-	-	o	-	+	o	-	-	o	-	+	o	o	o	o	+	+	++
	5	-	-	o	+	-	-	o	+	-	-	+	++	-	-	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	o	+	++	+	++

table 1 : evaluation of indoor air quality vs ventilation system and dwelling characteristics for Ottawa climate

		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	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
top	5	++	+	o	-	++	+	o	-	o	-	--	--	+	o	o	o	-	--	+	o	o	-	-	--	++	+	+	o	o	o
D4a	1	++	++	+	o	++	++	+	o	+	-	--	--	++	+	+	o	-	-	++	+	+	o	-	-	++	++	++	+	++	+
	2.5	++	++	+	o	++	++	+	o	o	--	--	--	++	+	+	o	-	-	++	+	+	o	-	-	++	+	++	+	+	o
ground	5	++	+	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	-	--	--	--	--	--	--	o	-	-	--	--	--	-	--	--	--	--	--	o	-	-	--	-	--

table 2 : evaluation of heats needs vs ventilation system and dwelling characteristics for Ottawa climate

The input parameters of the table are as follows :

- Dwellings 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 *=0.05.

The equivalent area of the exhaust device ("grilles"), (Cd=0.6), is 70 % of the cross area of the duct (Kitchen: 200 cm^2 ; Bathroom and toilet:125 cm^2)

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) . Three mechanical exhaust flow rates are considered : 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.

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 (++) for heat needs, 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 enters 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, the habitable rooms are less ventilated (and the hall more), which leads to both high heat needs and low air quality.

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