Ventilation Requirements, Historical Overview and Background

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ABSTRACT
This paper describes the history and back ground of the ventilation requirements. The paper starts with an overview of existing international requirements. An analysis is made about the reasons and goals for ventilation. Ventilation strategies are discussed .The advised strategy is to ventilate only for unavoidable sources such as people in rooms and their unavoidable activities, for instance cleaning, maintenance and personal care like cooking, bathing and showering. The history is of the requirements as well as the underlying studies are described an discussed. Human effluents such as odours and smells seem to play the most important roles for our existing ventilation requirements. Suggestions are given to investigate the role of masking odour or odourizing the air. In that case it might be possible to reduce air flow rates to rooms and hence save energy.

1. INTRODUCTION

1.1 Aim of the study

The aim of this paper is to describe the history of the ventilation requirements and its background. Since the Air Infiltration and Ventilation Centre (AIVC) is part of the International Energy Agency (IEA) program Energy Conservation in Buildings and Community Systems (ECBCS) a huge amount of research has been carried out over the last decade on the reduction of ventilation and infiltration during the heating season in buildings. The reduction of infiltration has made significant progress. The reduction of ventilation is almost always discussed in relation to the health of people who are present in buildings.

1.2 Ventilation, energy and health

From the energy point of view, during the heating season, reduction of the ventilation flow rate is proportional to the energy savings. Minimizing the ventilation flow rate can be reached by using demand controlled ventilation systems. Discussions on the reduction of the required flow rate turns up from time to time. The requirements on ventilation flow rates through out the world vary at least a factor of three to four.
One might ask several questions:

- Why are there such big differences in ventilation requirements between countries?
- Are people so different in the different countries?
- Are there any indications that due to the difference in ventilation requirements between countries, the health of the population is negatively affected?

Answers on these questions can not easily be given.
Nevertheless in terms of energy a factor of three to four difference in requirements means a lot.

2. REASONS FOR VENTILATION

2.1 Goals for ventilation

There can be a variety of reasons to control ventilation in buildings. The three most important ones are:

- Ventilation for control of indoor air quality purposes
- Ventilation for control of temperature
- Ventilation for control of moisture

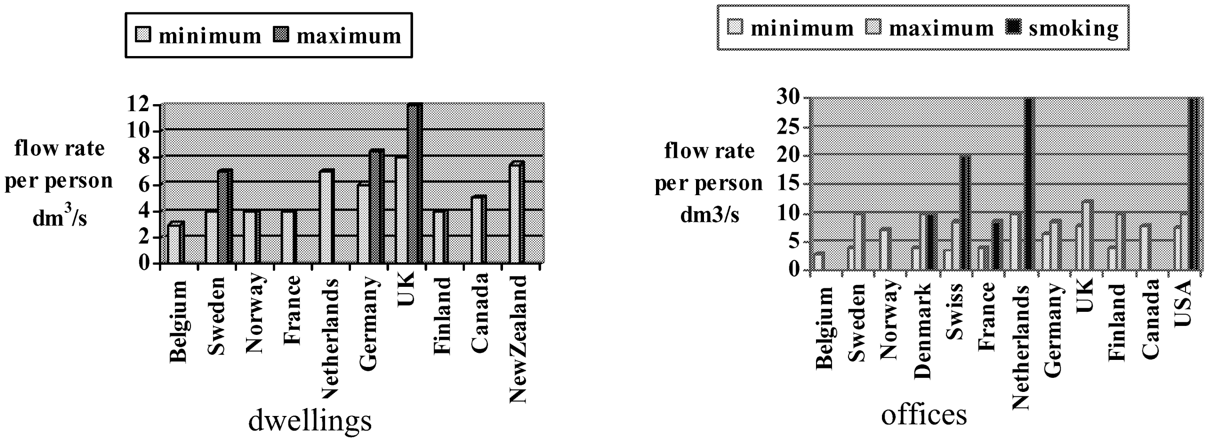

Figure 1 Overview of ventilation requirements in building for several countries. (TIPVENT, 2000) [1]

This paper mainly focuses on the aspects of indoor air quality control. There is an aim to minimize ventilation during heating periods to reduce energy consumption in the built environment.

The reasons in relation to indoor air quality are twofold:

- Control the concentrations of pollutants produced inside the building through mixing and dilution or displacement
- Control the pressure difference between rooms in buildings to prevent dispersion of pollutants to rooms to be protected

2.2 Effects of ventilation

Ventilation has several effects. In the first place: Air supply to a room normally gives air movement and air circulation in that room. Cold air supply might cause draught and hence comfort complains of people in the room.

In case there is a temperature difference between inside and outside, the air will be heated to room temperature and hence there is an energy penalty.

The challenge always is to respect indoor and quality and comfort at the minimum level of energy consumption. The whole program of IEA ECBCS is focusing on the optimization of the three parameters IAQ, comfort and energy consumption.

2.3 For whom or what is ventilation necessary

An interesting next question might be for whom or what is ventilation necessary.

Normally air is supplied to rooms for the breathing of persons and or animals. Air extraction is applied for the removal of stale air. A number of pollutants might be the reason. The most important pollutant sources indoor air:

- Human effluents
- Moisture
- Heat
- Emissions from building- , furniture- wall and floor covering- materials
- Emissions produced by the ventilation system itself

The removal of excessive heat or excessive warm air during spring, summer and autumn will not be covered in this paper.

2.4 Strategies for ventilation requirements

Emissions from all other sources then persons and their inherent activities in buildings are considered as avoidable. The ventilation required for the persons in the room should be enough to prevent problems with emissions from all other sources. This means that there must be a policy for control on the maximum emissions of the avoidable sources of pollutants. Not all countries follow this approach. In practice it is also not very easy to apply. But it should be the ultimate goal, because otherwise one accept that ventilation and hence energy consumption is needed for a phenomenon which can be avoided.

This strategy for requirements is described in the European Collaborative Action; ”Ventilation, Good Indoor Air Quality and Rational Use of Energy”.. [2]

3. HISTORICAL OVERVIEW

3.1 First requirements

The first ventilation requirements found in literature presented by Max Sherman [3] on the AIVC Workshop “ Trends in national building ventilation markets and drivers for change” are presented below.
The first requirement on ventilation start in 1631 by King Charles in England. He required at least windows for ventilation in buildings. The first flow rate requirement is from the English parliament (1836) with a flow rate of 4 cfm per person which equals to about 2 dm^3/s per person. The remark was made that this fow rate could rise over time because of new research.
In the USA, in 1895,. the American Society of Ventilation Engineers (ASVE) advised much larger flow rates 30 cfm per person or about 15 dm^3/s per person, based on contagion. In 1927 the United Building Code required windows with at least 1/8 th of the floor area of rooms.

3.2 Von Pettenkofer

Von Pettenkofer [4] was the inventor of using CO_2 as indicator for the air quality in rooms. He recognized that CO_2 was harmless at normal indoor levels and not detectable by person. From his studies he proposed the so called “PettekoferZahl” of 1000 ppm as a maximum level to overcome hindrance of odours from human effluents. He assumed an outside concentration of about 500 ppm. So in fact he advised not to have a larger ΔCO_2 between inside and outside than 500 ppm. This equals to a flow rate for an adult of about 10 dm^3/s per person.
This is the number which is nowadays still used as the basis for ventilation requirements in many countries.

3.3 Yaglou

Yaglou [5] studied the indoor air quality in rooms using olfactometry as a mean to determine the indoor air quality. He found big differences in persons who are in the room under investigation and persons who are entering this room. He concluded that CO_2 was not the right marker for indoor air quality in rooms. The reason for the big difference between occupants and visitors he explained as the adaptation of the noses of persons in the room.. This adaptation has a typical time frame of a few minutes. He developed from his experiments a sensory intensity scale from 0 to 5. The level 0 means no perceptible odour and 5 was a nauseating level. The level 2 was moderate where people were neither pleasant nor disagreeable. From his studies he advised an outdoor air flow rate for adults af about 7 - 8 dm^3/s.

3.4 Bouwman

Bouwman [6] a Dutch researcher studied in 1980 the required level of outside air for persons in offices. In total 25 persons were asked to score about their perception of odour. He concluded that with 5% unacceptable odour score of people in the room about 10 dm^3/s was a necessity. For visitors to the room for the same 5 % unacceptable level equals to a flow rate of about 15 dm^3/s.

3.5 Cain

Around the same time as Bouwman, Cain et al.[7] carried out a quite extensive study on the odour perception of human effluents and tobacco smoke. In total 165 persons were included in his study. The ventilation during his study varied from 9 to 36 m^3/h. The result given in table 1 are the average values he found during his study with three different occupation rates.

Table 1 The percentage acceptable against flow rate per person

ventilation rate per persoon	% of odour acceptance	
m^3/h	visitors	occupants
9	68	96
18	75	96
27	79	92
36	81	95

The results suggest that for the occupants in the room there is almost no relation with the air flow rate while for the visitors it seems that the relation with flow rate is evident.

3.6 Fanger

Ole Fanger started his studies on the perceived indoor air quality around 1985. He defined after a quite extensive study the Olf as the unit for source strength of human effluents.
One sedentary person represents 1 Olf and a heavy smoker for instance 25 Olf. One decipol (dp) is the perceived air quality in a room with a load of one Olf (standard person) ventilated by 10 dm^3/s.The approach has lead to CEN standard 15251with classes of CO_2 levels related to flow rates.

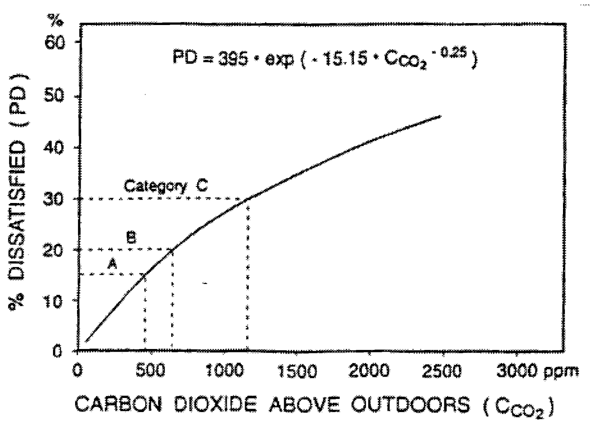

Figure 2 Relation between ΔCO_2 and the percentage of people in the room dissatisfied by the odour concentration.

The flow rate relation and classes of CO_2 are given in Table 2

Tabel 2 Classes used in CEN standard 15251 with the relation between CO_2 percentage dissatisfied and flowrate.

Category	CO_2 above outdoors in ppm	Expected Percentage Dissatisfied in %	Air Flow per person in dm3/s
I	350	15	10
II	500	20	7
III	800	30	4
IV	>800	>30	< 4

4. BACKGROUND

4.1 From pollutants to health effects

The role that ventilation plays between pollutant sources and health effect is crucial. But ventilation is in no way a solution for everything. Minimizing the pollutant source has to be considered first. The exposure to a certain pollutant is determined by many factors:

- type of pollutant
    - building materials
    - furnishing
    - household chemicals
    - human effluents
- release mechanism
- distribution in the room by ventilation
- transport of the pollutant from room to room
- pattern of a person over the rooms in the building
- use of ventilation provisions
- breathing
- doses

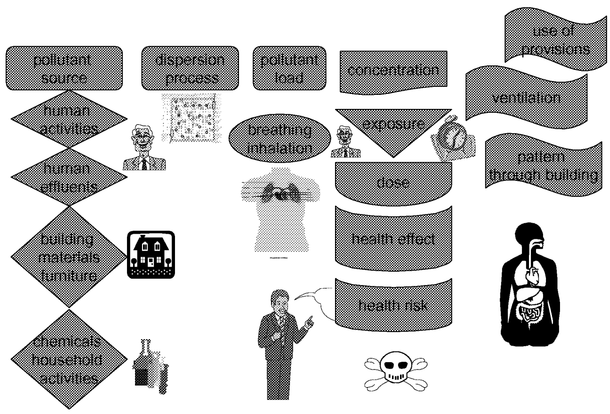

Figure 3. Schematical overview from pollutant to health risk and the role of ventilation

4.2 Human effluents

Human effluents seem to play a very important role in the discussion about required air flow rate. What are the human effluents and what does it consist. Humans are at the same time producers of pollutants as well as receivers. The main effluents produced by persons and their origin are:

- Breathing air
  - CO_2
  - Odours
- Skin
  - Sweat
  - Urea
  - Odours
- Penis or vulva
  - Urine
- Anus
  - Feaces
  - Gases

The main body odour source for indoor air quality seems to be produced trough sweating under the armpit.

4.3 CO_2 and advised levels

There are many concentration levels of CO2 for different applications. (see table 3)

Table 3 A list of CO_2 levels (source [9])

	CO_2
Outside (+1 ppm/a)	0.038% 380 ppm
Comfort level	0.12% 1200 ppm
Mortality level	10% 100 000 ppm
Bom shelters max	2% 20 000 ppm
Submarines max	3% 30 000 ppm

4.4 Minimum ventilation

For the breathing a very low flow is required in relation to the ventilation flow required in standards and regulations.

Assume a sedentary person with a breathing frequency of 14 per minute. The flow per breath is about 6 dm^3/minute.The flow rate for inhalation is therefore 0.1 dm^3/s. For someone who is very active in doing sports, for instance a running person, the breathing frequency is about 30 per minute. The flow rate is about 15 dm^3/minute or about 0.25 dm^3/s. This is at least a factor of 20 lower than the ventilation levels required in standards and regulations. So to save energy the breathing of humans is not a determining factor.

4.5 Odourising and masking

The odour or smell produced by human beings seems to be the most important factor. If odour reduction is possible,.probably the ventilation rate can be decreased. If we assume that ventilation is responsible for about 40 % of the energy consumption of buildings, a reduction of 10% of the flow saves also 10 % in terms of energy. A study to investigate the role and possibilities of odourizing and masking fits perfectly in the program of IEA-ECBCS .

5. CONCLUSIONS

- There is about a factor of four difference in ventilation requirements in different countries. The reason for it is not quite clear nor logic.
- The advised strategy for ventilation is to ventilate for the unavoidable sources such as human beings in buildings and not for emissions of building- and furnishing materials. These sources should be dealt with by source control.
- All studies in the past for the determining of ventilation rates are based and carried out on the perceived indoor air quality through odours.
- The ventilation rate required by breathing is at least a factor of twenty lower than the existing ventilation levels required in regulations and standards.

6. RECOMMANDATION

- Investigate the possibility of carrying out a study about masking and/or odourizing air in rooms in order to study the health effects of decreasing the ventilation rate.

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