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Ventilation rates and IAQ in national regulations

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Summary

This paper presents some results from the HealthVent project supported by the European Commission DG Sanco. One of the objectives of the project has been to review and critically evaluate the existing requirements on ventilation and IAQ defined in national building codes and European standards. This paper presents a summary of the values given in European ventilation regulations, and results of a comparison. The up-to-date data in national legislation and codes were collected from 16 European countries with questionnaires, which were sent to project partners and trusted experts on ventilation. The requirements on ventilation rates were found to be given in different units, therefore test cases of real-life design situations were introduced to compare the data on a basis of a common unit. The results show that the ventilation rates given in the regulations are inconsistent and very heterogeneous. The ventilation rates in test cases range from 0.23 to 1.21 h^{-1} in dwellings and from 4.2 to 41.7 l/s for local exhaust rates. The ventilation rates per person in test cases of classroom, playroom, and office range from 4 to 25 l/s. Big differences were also found in pollutant levels. Limit CO levels range from 3.0 to 12.5 mg/m^3 and formaldehyde levels from 10 to 100 µg/m^3. In conclusion, the evaluation of the data showed that values in the European local regulations, standards, and those practised locally, are very inconsistent. Moreover, several values in regulations were found to be looser than the recommended values published in European standards and WHO guidelines, thus allowing lower ventilation rates and higher pollutant levels than recommended. Results indicate that there is a considerable need on the European level to harmonize the ventilation and IAQ regulations and adjust them to the values provided in standards and guidelines.

Introduction

Considering the amount of time people spent inside and the concentrations of indoor pollutants, the buildings are the most important factor in air pollution exposure and associated health effects. Ventilation is used to bring outdoor air to the occupied indoor zone and to remove or dilute indoor-generated pollutants. Ventilation rate, as the flow of outdoor air to a space, is one of the most important factors affecting indoor air quality.

In this article some of the results from the work performed in the HealthVent project[2], supported by the European Commission. The objective of the HealthVent project is to develop health-based ventilation guidelines for the EU. Members of the project group are experts from different disciplines from 9 European countries. One of the objectives of the project was to review and critically evaluate the existing requirements on ventilation and IAQ defined in building codes and European standards. The project's focus was set on ventilation rates, pollutants, noise, temperature and relative air movement in dwellings, offices, schools and kindergartens.

Methods

The work focused on national regulations and practice in European countries. The data was collected with a special questionnaire, which was sent to project partners and trusted experts on ventilation in several European countries. The questionnaire comprised of 10 questions

2 HealthVent project website: www.healthvent.eu

and sub-questions. The respondents were asked to provide values of ventilation rates, pollutant limits, noise levels, etc., which can be found in the national regulations. In case if no such values existed in the regulations, they were asked to provide values which are most widely used in practice (from standards, guidelines, etc.). In the responses they had to mark if the provided value is mandatory or voluntary to use. Respondents in 16 countries supplied the requested data (**Table 1**).

The returned questionnaires revealed that the ventilation rate criteria are given using various units depending on a country, which do not allow direct comparisons. Criteria are expressed as flow rate per number of persons, flow rate per floor area, flow rate per number of rooms, fixed flow rate per room type, number of air changes per hour, or combination of different units. In order to compare ventilation rates criteria, we developed several test cases, which represent real-world situations.

Test cases were developed for two different dwellings, a kitchen, a toilet, a bathroom, a school classroom, a kindergarten playroom, and an office. The details of the test dwellings are shown in **Table 2 and 3**. Using this data we compared the ventilation rates in dwellings on the base of air changes per hour, ventilation of kitchens, bathroom, and toilet as ventilation rate per room, and ventilation of classroom, playroom, and office as air flow rate per person.

Table 1. Countries included in the summary and abbreviations used in charts below.

BG	Bulgaria	**LT**	Lithuania
CZ	Czech Republic	**NL**	Netherlands
DE	Germany	**NO**	Norway
FI	Finland	**PL**	Poland
FR	France	**PT**	Portugal
GR	Greece	**RO**	Romania
HU	Hungary	**SI**	Slovenia
IT	Italy	**UK**	United Kingdom

Comparison of ventilation rates

The results show that values are very inconsistent among European countries. **Figures 1 and 2** show ventilation rates[3], which were calculated using the input data from **Tables 2 and 3**. The lowest ventilation rate in dwellings is 0.23 h^{-1} and the highest 1.21 h^{-1}. Large differences can also be seen in the cases of local exhaust rates, where the highest rates can be up to five times higher than the lowest rates. The ratio is therefore similar to the one of air changes in dwellings, where it is almost 1 to 6. Observing ventilation rates in the cases of classroom and playroom, one can distinguish two groups of countries with similar values. The first group has ventilation rates of around 10 l/s per person. It is formed by the following countries: Finland, Germany, Hungary,

3 Ventilation rate is the flow of outdoor air to a space

Table 2. Properties of the test dwellings.

Properties	Dwelling case 1	Dwelling case 2
floor area	50 m^2	90 m^2
ceiling height	2.5 m	2.5 m
main rooms	2: 1 living, 1 sleeping	4: 1 living, 1 sleeping, 2 children
kitchen	1 x 10 m^2 with window and electric stove	1 x 15 m^2 with window and electric stove
toilet	1 x 2 m^2	1 x 2 m^2
bathroom	1 x 5 m^2	1 x 5 m^2
persons	2	4

Table 3. Properties of the test rooms.

Properties	Kitchen	Toilet	Bathroom	Classroom	Playroom	Office
area	10 m^2	2 m^2	5 m^2	50 m^2	50 m^2	12 m^2
ceiling height	2.5 m	2.5 m	2.5 m	2.8 m	2.8 m	2.8 m
persons	1	1	1	25	25	1

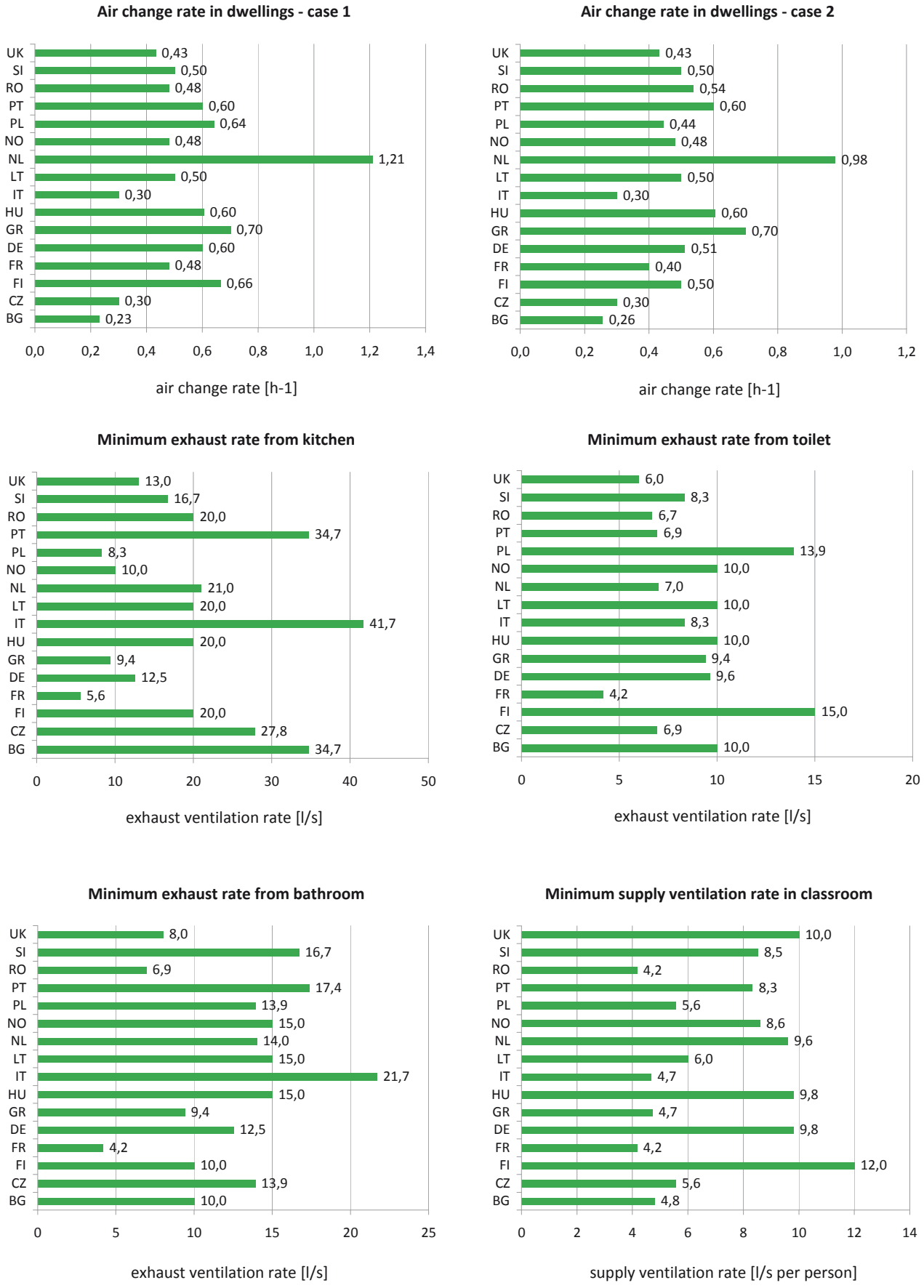

Figure 1. Comparison of ventilation rates in the test cases of dwellings, kitchen, toilet, bathroom and classroom.

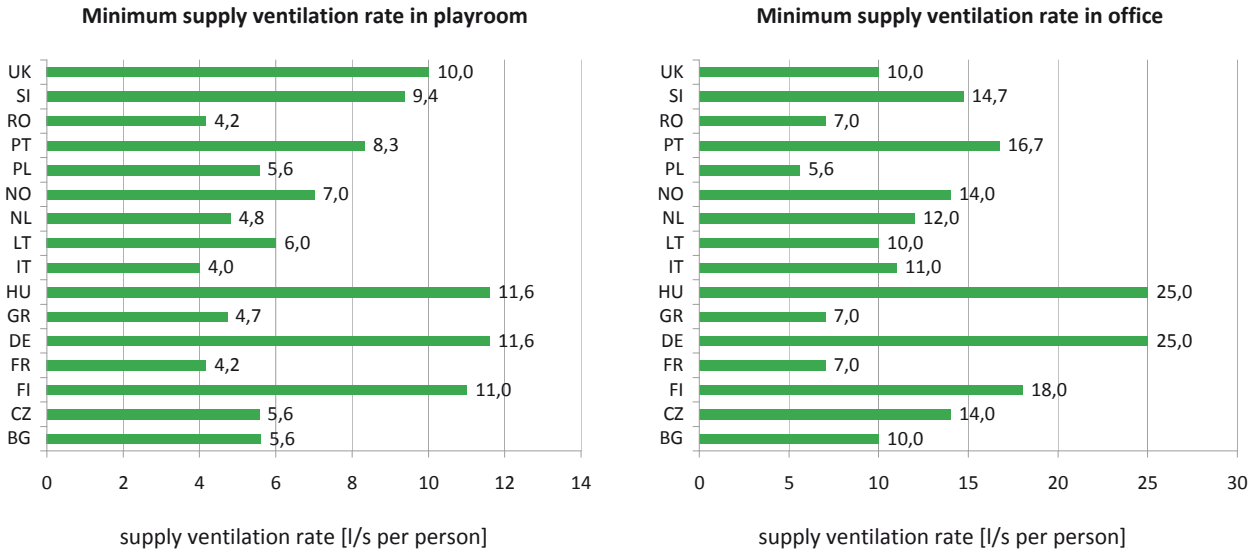

Figure 2. Comparison of ventilation rates in the test cases of kindergarten playroom and office

the Netherlands, Norway, Slovenia and UK. The second group has rates of around 4 l/s per person and is formed by the following countries: Bulgaria, Czech Republic, France, Greece, Italy, Lithuania, Poland and Romania. Both Nordic countries are in the group with higher ventilation rates, which is predominantly formed by the countries from the North and West of Europe. No countries from the Southern Europe are in that group. The ventilation rates in offices cannot be so obviously divided into two groups, because rates are much more scattered. Two ventilation rates that stand out are from Germany and Hungary, which are calculated according to EN 15251. The region-based conclusions are therefore not possible in the office case.

Indoor pollutants

The required limit levels of selected pollutants are shown in **Table 4**. The table also includes the WHO suggested values to serve as a comparison [2, 3]. The comparison of all values is difficult, because the limits are given as a maximum or average concentration in a given time. Only 6 out of 16 countries have requirements on limit indoor pollutant levels in non-industrial buildings. Limit levels of only two pollutants are found in the regulations of all the 6 countries: carbon monoxide (CO) and formaldehyde (HCOH). The range of CO limit levels is wide, from 3 to 12.5 mg/m³. The WHO recommended limit is 7 mg/m³, therefore the limit of 4 countries exceeds that value. Formaldehyde limit values range from 10 to 100 µg/m³ and all values are equal to or below the WHO recommended value of 100 µg/m³. Limit values of other pollutants are not included in the regulations of all countries and their ranges are also wide.

Discussion

The data was collected from 16 countries from all parts of Europe, thus giving a good coverage of regions with different building practice and climate. Although the respondents are experts on ventilation, a certain measure of uncertainty exists regarding the accuracy of the data in the received questionnaires. Due to limited resources, all data could not be verified. The data presented in this article are informative and should not be used for the design of ventilation.

Different boundary conditions, which are used to calculate the ventilation rates, show that countries have taken different approaches to define ventilation in the regulations. Approximately one third of countries have requirements for the ventilation of dwellings, which result in air change rate lower than 0.5 h^{-1}.That is in contrast with the health-based recommendations of minimum air change rate of 0.5 h^{-1} [5]. The ventilation rates in classrooms, playrooms and offices are also in contrast with health-based recommendations, because the resulting ventilation rates are often below 10 l/s per person. In the extensive review of studies that investigated the association of ventilation rates with human responses, Seppänen et al. [5] and Sundell et al. [6].

Table 4. Indoor pollutant limit levels.

	WHO	FI	LT	NO	PT	RO	SI
Ammonia[µg/m^3]	-	20	40	-	-	-	50
Asbestos	-	0 fb/cm	0.1 mg/m^3	0.1 fb/cm	-	-	-
CO[mg/m^3]	7[#2]	8	3	10[#5]	12.5	6[#3]	10
CO_2[ppm]	-	1200	-	1000	1000	-	1670
Formaldehyde[µg/m^3]	100	50	10	100[#3]	100	35[#3]	100
NO_2[µg/m^3]	40	-	40	100[#4]	-	-	
Ozone[mg/m^3]	0.1[#5]	-	0.03	-	0.2	-	0.1
PM_{10}[µg/m^3]	20	50	50	-	150	-	100
Radon[Bq/m^3]	-	200[#1]	-	100	400	140[#6]	400
Styrene[µg/m^3]	-	1	2	-	-	-	-

[#1] annual average, [#2] daily maximum, [#3] 30 min average, [#4] 1 h average, [#5] 8 h average, [#6] instant max, fb – fibre

The limit levels of pollutants are often higher than those recommended by the WHO, and missing in the regulations of several countries. The ranges of values are wide, which indicates that the countries do not use common theoretical background to determine the limit values. Minimum requirements for pollutant levels in non-industrial buildings should be included into the regulations of all European countries.

Conclusion

A review of the European regulations for ventilation rates and indoor air quality showed that the values in regulations are inconsistent and vary greatly according to country. Almost all of the regulated parameters included in the review are already defined in European Standards, which were accepted in the CEN voting process by national bodies. Nevertheless, the values found in the standards and those in the regulations are not harmonized. The inconsistency on the national level between the EN standards and regulations, as well as on the European level from country to country, causes problems to designers and industry, and increases the construction cost. Besides that, the current practice is in contrast with the efforts of unification and standardization of the European common market. Clearly, a common European guideline is needed, which would serve as a basis for national European regulations. The guideline should include ventilation rates, technical properties, and other parameters related to the performance of ventilation.

Acknowledgements

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