IAQ in working environments in Belgium: alternative approaches to CO_2 requirement

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ABSTRACT

In March 2016 a new regulation came into force in Belgium regarding the wellbeing at work, with specific requirements on the indoor air quality (IAQ). The requirement is expressed as a maximum absolute CO2 concentration of 800 ppm in all working spaces. Compared to the previous requirement, i.e. 30 m³/h per worker, this new requirement corresponds to at least a doubling of the required ventilation flowrate.

Although the advantage of this new requirement is its performance based approach (final result, in terms of CO2), this raises the question of the responsibility of the different involved persons, such as the designer, contractor and owner of the building, the employer but also the employee as end user of the building. Moreover, the stricter requirement remains an economical and technical challenge, especially for existing building without a complete ventilation system.

Our work aimed to identify alternative approaches for the expression of IAQ requirements for working environments in order to maximise the final IAQ improvement for the workers while assuring an effective implementation in practice thanks to a robust compliance framework.

Beside an absolute CO2 requirement, different alternatives exist to consider also the impact of material emissions on the IAQ in working environments. The new standard FprEN16798-1:2016 has been used as a basis to identify alternative approaches.

The advantages of the CO2 requirement are to be performance based and easily measurable on site. However, the CO2 requirement focuses only on the persons as source of pollutants and do not consider the possibility to control the other sources of pollutants, such as emissions from materials, by limiting them at the source (for example choosing low emitting materials).
One of the alternative approaches is to consider the ventilation needed for the persons and that needed for material emissions separately in accordance with method 2 described in the standard. An alternative approach could be different CO2 requirements depending on the level of emission of the materials.

The proposed requirements could encourage the choice of (very) low emission materials, leading to effective IAQ improvement in practice. The challenge for the future remains the characterisation of the emission levels for the building materials, but also for all other materials, products and activities in the workspace, as well as using those datapoints effectively in a robust compliance framework.

KEYWORDS

IAQ requirement, working environment, material emission, CO_2 concentration.

1 INTRODUCTION

In March 2016 a new regulation came into force in Belgium [1] regarding the wellbeing at work, with specific requirements on the indoor air quality (IAQ). The requirement is performance based and expressed as a maximum absolute CO_2 concentration of 800 ppm in all working spaces. Compared to the previous requirement, i.e. 30 m³/h (8,3 l/s) per worker, this new requirement corresponds to at least a doubling of the required ventilation flowrate.

Although the advantage of this new requirement is its performance based approach (final result, in terms of CO_2), this raises the question of the responsibility of the different involved persons, such as the designer, contractor and owner of the building, the employer but also the employee as end user of the building. Moreover, the stricter requirement remains an economical and technical challenge, especially for existing building without a complete ventilation system. Finally, this higher flow rate is maybe not necessary in all cases, especially if the sources of pollutants from the material have been limited and the persons are the main pollutant source. For example, the results of the Healthvent project [3] [4] recommends a minimum flow rate, for health, of 4 l/s.pers if the non-human pollutants are limited; and FprEN16798-1:2016 [2] recommends flow rates from 10 l/s.pers to 4 l/s.pers depending on the perceived IAQ foreseen.

Our work aimed to identify alternative approaches for the expression of IAQ requirements for working environments in order to maximise the final IAQ improvement for the workers while assuring an effective implementation in practice thanks to a robust compliance framework.

These different approaches have been applied to three typical building types to compare the required flow rates in different situations. Then, pros and cons of the different approaches have been identified.

2 ALTERNATIVE APPROACHES

Beside an absolute CO_2 requirement, different alternatives exist to consider also the impact of material emissions on the IAQ in working environments. The draft standard FprEN16798-1:2016 has been used as a basis to identify alternative approaches.

The advantages of the CO_2 requirement are to be performance based and easily measurable on site. However, the CO_2 requirement focuses only on the persons as source of pollutants and do not consider the possibility to control the other sources of pollutants, such as emissions from materials, by limiting them at the source (for example choosing low emitting materials).

The alternative approaches could then consider the emissions from the material to determine the flow rate required in the working spaces.

A second (alternative) approach could be two different CO_2 requirements (of flow rate requirements) depending on the level of emission of the materials. In case no attention has been paid to limit the non-human pollutant sources (such as emissions from materials), the higher flow rate is required, e.g. minimum 14 l/s.pers or maximum 400 ppm of CO_2 concentration above outdoor (= 800 ppm if outdoor concentration is 400 ppm). On the other hand, if it can be proved that the emissions from the materials are limited by choosing (very) low emitting materials, a less strict requirement applies, e.g. minimum 7 l/s.pers or maximum 800 ppm of CO_2 concentration above outside (= 1200 ppm absolute if outdoor concentration is 400 ppm).

A third (alternative) approach is to consider the ventilation needed for the persons and that needed for material emissions separately in accordance with method 2 described in the standard FprEN16798-1:2016. A first flow rate is calculated for the persons, e.g. 7 l/s.pers (according to class II for the perceived IAQ in the standard). A second flow rate is calculated for the pollutant emissions from the materials, based on different flow rates per m² depending on the level of emission of the building, e.g. 0.35 l/s.m² for very low emissions, 0.7 l/s.m² for low emissions

and 1.4 l/s.m² for non-low emissions. Both of these flow rates are calculated for each space and the highest of the them is the flow rate to consider as requirement.
Note that for this approach, it is possible to convert the requirement per space expressed in flow rate toward a requirement expressed as a maximum CO_2 concentration (possibly different for different spaces) in order to facilitate the conformity check of the requirement.

For these two alternative approaches, a framework is necessary to classify the type of emissions in a building between very low emissions, low emissions and non-low emissions. For example, this framework could be based on existing framework to classify the emissions from the building materials used for the floor covering, paintings and materials for the ceiling and walls, etc. Such a framework exists for example in France [5], with an emission label (with several classes from A+ to C); and in Belgium [6], for floor materials only, with a pass/fail approach.

3 APPLICATION OF THE APPROACHES TO TYPICAL BUILDINGS

3.1 Methodology

The three approaches described above have been applied to three types of building spaces with different occupation rates: an office with 15 m²/pers, a meeting room with 3.5 m²/pers, and an intermediate space with 10 m²/pers. For each type of space, three different levels of material emissions have been considered: very low emitting, low emitting, non-low emitting.

In these 9 configurations, the flow have been calculated according the 3 approaches described above and the results are presented in the form of : flow rate per surface area (l/s.m²), flow rate per person (l/s.pers) and absolute CO_2 concentrations (for outdoor concentration of 400 ppm). These values are equilibrium values for nominal occupation of the spaces, i.e. design occupation and design flow rate. These results are presented in Table 1.

3.2 Results and discussion

For the first approach with an absolute CO_2 requirement of 800 ppm, the flow rate per person are the same for all types of spaces and all emission levels. However, because the occupation is different, the flow rate per surface area is lower for the office and higher for the meeting room.
For the second approach with 2 levels of CO_2 requirements of 1200 ppm for (very) low emitting buildings and 800 ppm for non-low polluting buildings, the design flow rate per person depends on the emission level of the building.
For the third approach with a flow rate for the persons and a flow rate for material emissions, the final design flow rate of the space depends on the design number of persons in the space and on the surface area of the space and level of emission of the building.

With the third approach, based on the standard FprEN16798-1:2016, the design flow rate of a space is determined based on the most limiting pollutant source of this specific room. If the occupation rate of the space is low and the emission level of the building is high, then the limiting factor is the emission and the design flow rate depends on the surface area of the space and on the flow rate per m² for non-low emitting buildings. In contrast, if the occupation rate of the space is high and the emission level of the building is low, then the limiting factor is the presence of the persons (bio effluents) and the design flow rate depends only on the number of persons in the room. The design flow rate is thus adapted, case to case, according to the most limiting factor for IAQ.

In contrast to this third approach, the first one (with absolute CO_2 requirement of 800 ppm), can lead to different levels of IAQ for the pollutants from material emissions. In the office, the lower flow rate per surface area could sometimes be too low to control the pollutants from emissions, with possibly too low IAQ. In our example, the design flow rates in an office are lower with this approach compared to the third one. In contrast, in the meeting room, the flow rate per person are higher than the third approach. Especially when low emission materials are used, these higher flow rates are probably unnecessary, causing also unnecessary energy consumption.

For the second approach (with 2 levels of CO_2 requirements), the design flow rate of the spaces depends partly on the emission level of the building. In case low emitting material have been used, the flow rate per person can be lower while assuring equivalent IAQ and decreasing energy consumption. This is the main advantage of the second approach compared to the first one. However, in case of non-low emitting buildings, the same problems occur for the meeting room: higher design flow rate compared to the third approach based on the standard FprEN16798-1:2016.

Table 1: Application of the 3 approaches on 3 typical building spaces and for 3 levels of emissions from materials. The results are expressed as flow rate per surfac area, flow rate per person and CO_2 concentration.

Type of space / building				**Debiet or [CO2]**		
Space	**Area per person (m²/pers)**	**Building emission level**		**Approach 1**	**Approach 2**	**Approach 3**
Office	**15**	**Very low**	l/s.m²	0,9	0,5	0,5
			l/s.pers	14	7	7
			ppm	800	1200	1200
	15	**Low**	l/s.m²	0,9	-	0,7
			l/s.pers	14	-	10,5
			ppm	800	-	933
	15	**High/unknow**	l/s.m²	0,9	0,9	**1,4**
			l/s.pers	14	14	**21**
			ppm	800	800	**667**
Intermediate	**10**	**Very low**	l/s.m²	1,4	0,7	0,7
			l/s.pers	14	7	7
			ppm	800	1200	1200
	10	**Low**	l/s.m²	1,4	-	0,7
			l/s.pers	14	-	7
			ppm	800	-	1200
	10	**High/unknow**	l/s.m²	1,4	1,4	1,4
			l/s.pers	14	14	14
			ppm	800	800	800
Meeting room /	**3,5**	**Very low**	l/s.m²	4,0	2,0	**2,0**
			l/s.pers	14	7	**7**
			ppm	800	1200	**1200**
	3,5	**Low**	l/s.m²	4,0	-	**2,0**
			l/s.pers	14	-	**7**
			ppm	800	-	**1200**
	3,5	**High/unknow**	l/s.m²	4,0	4,0	**2,0**
			l/s.pers	14	14	**7**
			ppm	800	800	**1200**

4 DISCUSSION OF PROS AND CONS OF THE APPROACHES

Some pros and cons of the different approaches have been identified and listed in Table 2.

First, the approaches can be compared about the expected impact on the real IAQ in the working environment and their incentives for a better ventilation system on one hand and a better source control on the other hand.
Because the first approach focuses only on a CO_2 requirement and not at all on the source control of material emissions, this approach has absolutely no incentives, for the employers and building designers and contractors, to limit the sources of pollutants by choosing (very) low emission materials. The high level of requirement in this first approach (800 ppm absolute CO_2 concentration) could in theory lead to high IAQ for bio-effluents as well as "indirectly" for other pollutant sources. However, because this higher flow rate has a huge economic impact for the employers as well as for the building owners, the true applicability of this first approach in practice is expected to be very poor.
On the other hand, the two alternative approaches allow an effective incentive to control the pollutant emissions at the source, by choosing (very) low emitting materials, and at the same time to adapt the required flow rate for ventilation accordingly to the emission sources. The ambition level of IAQ can then be similar to the first approach but adding 2 main advantages compared to the first approach: (1) a better incentive for source control, and (2) a better expected applicability of the requirement in practice because the flow rate can be lower in case of low emission.
Compared to the second approach, the third one presents an additional advantage: the design flow rate of a space can be fine-tuned in function of the design number of persons in the room and the amount (surface area) and the type of emitting materials in the room. In such way, the third approach is probably more appropriate for some specific cases such as meeting room where the occupation rate is high and consequently the flow rate for the person can be the limiting factor even if the emission level of the material is high or unknown. This is an important point for this type of space (meeting room, etc.) where the impact of higher flow rate can have high economic consequences.

The different approaches can also be compared according to the ease of control of the requirement conformity and to the ease of building design.
One of the main advantage of the first approach is the ease of conformity control related to the performance-based requirement expressed as a maximum CO_2 concentration. Nowadays CO_2 sensors are easily and economically available and can be easily used by the different involved to check the conformity on site. The same advantage can be attributed to the second approach where the requirement is also expressed as a CO_2 level (but using 2 different levels).
In contrast, the third approach is based on flow rate calculations to be carried out separately for each space rather than general CO_2 levels. This requires a bit more calculation at the design stage as well as for conformity check. Moreover, the measurement of a flow rate on site can be more difficult and expensive than a measurement of the CO_2 concentration in the room. However, one can imagine that the required flow rate per space can be converted to a required CO_2 concentration per space for easier measurement base on CO_2 on site.
Finally, because the 2 alternative approaches include also a part on the pollutant emission from material, they require also a framework in order to classify the emission level of a building (or a space) at the design stage as well as for the conformity check. Such an effective framework remains a challenge. On possible approach would be to use existing regulation and framework for material emission, such as the current Belgian regulation on pollutant emission for floor covering materials. Moreover, this framework for pollutant emission could also be evolving in time according to the development of regulations and frameworks in this field, for example first floor covering material, and later paintings and furniture for example.

The economic impact (for new building) of the different approaches and their applicability to existing building are also important parameters.
The first approach has the main disadvantage to lead to huge economic and very difficult applicability in existing buildings because the higher flow rate requirements implies much larger ventilation ductworks and technical rooms. Moreover, such higher flow rates have also consequences on the energy consumption of buildings and on the operational costs of buildings. In contrast, the 2 alternative approaches allow to make a more appropriate choice, case to case, between an effort on low emission material or an effort on higher ventilation flow rates. This can be particularly useful for existing building where the level of emissions can be proved to be low, for example in spaces using floor covering materials such as metal, stone or floor tiles, considered as low emitting materials, are used. This is probably the case for most of the existing schools where this new IAQ regulation remains a big challenge.
Compared to the second approach, the third one has an additional advantage to allow fine-tuned design flow rate in function of the design number of persons in the room and the amount (surface area) and the type of emitting materials in the room. This can be particularly useful for existing buildings and spaces where the occupation rate is high, such as meeting room. In such spaces with high occupation rate, the required flow rate for the persons in the third approach could be sufficient in some cases also to control the pollutant from emission even if the level of emission in this space is high or unknown.

Table 2: Comparison of the 3 approaches in terms of pros and cons.

Comparison Criteria	**Approach 1**	**Approach 2**	**Approach 3**
Expected impact on real IAQ	In theory high but difficult applicability in practice	High and better applicability expected	High and better applicability expected
Incentives for better source control	No	Yes, roughly	Yes, case to case
Incentives for better ventilation system	Yes but high flow rate	Yes, flow rate depends on emissions, but sometimes high flow rate (meeting room)	Yes, flow rate depends on emissions
Ease of conformity control	Easy: CO2 meting	Easy for CO2 meting + need framework for emissions	Flow meting more difficult but CO2 also meting possible + need framework for emissions
Ease of design and installation	Easy to calculate	Easy to calculate flow rates + need framework for emissions	Easy to calculate flow rates + need framework for emissions
Economic impact (for new building)	Very high (higher flow rates)	Choice between effort on materials or flow rates	Choice between effort on materials or flow rates
Applicability for existing buildings	Difficult (higher flow rates)	Ok if low emission, but sometimes high flow rate (high emission + meeting room)	Ok, flow rate depends on emissions

5 CONCLUSION

The new regulation for IAQ in working environment in Belgium is based on maximum CO_2 concentration of 800 ppm in absolute value, leading to design flow rate for ventilation two times higher. This has huge economic impact for new building as well as for existing ones. Consequently, the real application of this new regulation in practice could be very difficult and poor.

The proposed alternative approaches could encourage the choice of (very) low emission materials, leading to effective IAQ improvement in practice and better applicability of the whole regulation. The challenge for the future remains the characterisation of the emission levels for the building materials, but also for all other materials, products and activities in the workspace, as well as using those datapoints effectively in a robust compliance framework.

6 REFERENCES

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