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Evaluation of international ventilation and air cleaning guidance generated during the covid pandemic

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Abstract. The project aimed to make an inventory of hands-on ventilation and air cleaning advice that was shared with the general public and e.g. facility managers and building owners during the 2 years of the COVID pandemic. An online search resulted in 188 documents from 16 countries. Many documents addressed the importance of adequate ventilation but did not present concrete advice on how or how much to ventilate to make spaces 'covid safe enough'. Several documents mention the options of CO_2 monitoring but only as a rudimentary mean to estimate airborne infection risks. A substantial amount of documents explained that also air cleaning technology can help to decrease infection risks. But not as a substitute for regular fresh air supply, more as an addition to it. Some documents mentioned the effect of (increased) temperature and ditto humidity on virus survival rates but most do not give specific recommendations about setpoint changes. On the other hand, several documents do give concrete advice on other HVAC system settings related to e.g. operating hours, recirculation or pressure balances. The outcomes of this study will be used to help construct a new set of Dutch infographics and guidelines that should help non-technical decision makers to better understand how one can use ventilation and air cleaning technologies to decrease airborne infection risks inside.

1 Introduction

During the covid pandemic governments all over the world communicated to their citizens about how one could protect oneself from cross-infection. At the start of the pandemic the main focus was on advice like staying at home when ill and mask wearing when meeting others. At a later stage many organisations came up with additional advice on ventilation and air cleaning. This was further explored during a research project.

The project aimed to make an inventory of the hands-on ventilation and air cleaning advice that was shared with the general public and e.g. facility managers and building owners during the 2 years of the pandemic. The outcomes of this study will be used i. to identify general trends in technical advice given by the different countries and international authorities, and ii. to identify gaps in the material that was provided at the time.

2 Methods

The material was found directly by exploring the internet on websites from national and international governmental bodies, public health institutes, occupational health institutes, and engineering association. The main emphasis was on guidance material that (mid 2023 still) was available online in one of the following languages: English, Dutch, German, French, Spanish. The websites were examined either manually or by using the search bar, inserting keywords like "COVID" or "SARS-CoV-2", "ventilation", "air cleaning" and "infection". In addition, we approached co-authors of the Morawska, 2020 landmarkpaper on COVID and ventilation [1] and asked them for relevant input from their home-countries.

The study consisted of an analysis of relevant resources from 16 countries worldwide. Note that no guidance material from The Netherlands was analysed yet; this will be done at a later stage. The selection included the following countries: United States of America, United Kingdom, Canada, Germany, Austria, Switzerland, France, Japan, China, Singapore, India, Sweden, Denmark, Finland, Norway and Belgium. Also documents from international organisations like WHO, ECDC and REHVA were analysed. Documents that were not published originally in English, French, Dutch or German were translated by local experts or by Google Translate.

Only documents were included that the general publica had access to and that had a publication date between January 1st of 2020 and July 1st of 2023. Also, documents were only included if they had COVID transmission risk related recommendations on one or more of the following aspects: ventilation rates, application of air cleaners, HVAC system settings, CO_2 monitoring or temperature/humidity settings.

The webbased survey resulted (first stage) in 188 documents from 16 nations. We specifically looked at documents from public health institutes, occupational health institutes and engineering associations. An expert panel ranked the documents depending on the quality of the material provided. A distinction was made between i. documents with recommendations not supported by references, ii. documents with recommendations supported by references or expert panel judgements, iii. documents with recommendation supported by scientific journal papers and reports.

Based on the analysis described above, finally, 64 documents were selected that were further analysed during stage 2. The conclusions presented below are based on an analysis of those stage 2 documents.

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3 Results

3.1 Ventilation

A limited amount of the documents that were analysed recommend an increased ventilation rate or increased air exchange rate (in Air Change per Hour, ACH) to combat airborne transmission of SARS-CoV-2; we found this in documents from only 6 out of the 16 nations.

Some nations [2][3] recommended substantial increases compared to standard values (as e.g. included in building decrees), up to fresh air supply values of **40-80 m3/h** per person or minimum air exchange rates of 5 to 6 ACH. The latter often in the context of ventilation for health care buildings. In many documents from the other countries the authors used more general statements like 'fresh air supply should be in line with national building decree values'. Not one of the documents addressed the aspect of ventilation-efficiency.

3.2 CO_2 monitoring

In documents from 10 out of the 16 nations we found specific recommendations about CO_2 monitoring and recommended maximum CO_2 levels. Also, we found a general document from the European Centre of Disease Prevention and Control [4] that also recommend certain maximum CO_2 values that should not be exceeded when one wants to keep spaces 'safe' from infectious diseases. As upper limit most documents mention **1000 ppm**, sometimes (e.g. specifically for healthcare buildings) **800 ppm** is mentioned. Some of the documents have rudimentary explanations about where the values came from (with reference to scientific papers), often no direct 'proof' is given for the presented upper limits.

The general assumption presented in the documents is that there is a relation between the amount of viruses in the air (bio-aerosols) and the CO_2 concentration, in case one of the occupants in a space is infectious. However, multiple documents also point out that measured CO_2 concentration should be corrected for e.g. the number of people present and the level of activity (the latter as we know that when activity levels increase also breathing volume and aerosol production increases).

Some documents e.g. from Canada and Austria [5][6] state that in situations where people sing or speak loudly the assessment of the infection risk using CO_2 measurements fails. In those cases, people emit a factor of 100 much more aerosols, while their metabolism (and CO_2 production) hardly goes up. So, measuring CO_2 in a space that is used for singing or loud speaking (think e.g. of a church or nightclub) this leads to an underestimation of the airborne infection risk.

3.3 Air cleaning technologies

Not every nation included in this study accepted air cleaning as a mitigation strategy, but the majority does: 11 out of 16 nations mention air cleaning as a usefull (additional) measure to limit airborne infection risks. Als two international health institutes produced documents that recognize the (added) value of air cleaning sollutions [4][7].

The selected documents mention different technologies that can be used to clean indoor air from SARS-CoV-2 virusses, such as HEPA filters, UV light based technologies, electrostatic precipitators or electronic air filters (generated by plasma, charged needles, charged plates etc) and filter systems that use ozone or other chemicals as disinfectant. HEPA filters are accepted as an effective sollution by all of the studied nations (that accept air cleaning as mitigation strategy) but for the other technologies there are stark differences between nations. Some countries only accept traditional bag or flat pleated HEPA filter systems as a sollutions, other countries also allow the more 'exotic' sollutions.

Many of the documents gave additonal, more detailed advice on what to be aware of when selecting an air cleaning sollution. This is summarized in Table 1.

Table 1. Examples from the documents of aspects that should be addressed when deciding what kind of air cleaning technology to use.

Air cleaner selection criteria:
Intended use of the spaces (e.g. with activities that involve increased activity levels or talking loudly)
Volume and height of the spaces and expected maximum occupant density
Presence of sensitive occupants (e.g. elderly, young children, people with Asthma)*
HVAC context (characteristics and settings of ventilation system that is already in place)
Presence and intended use of operable windows
Needed system capacity (CADR)
Maximum system noise level that is accepted
Preferences for ceiling or duct mounted systems vs mobile units
Needs & wants in relation to operation and maintenance of the system
Preferences in relation to monitoring of the daily performance of the system

* *this could imply that certain technologies that generate harmful byproducts cannot be applied.*

3.4 HVAC system settings

In docments from 10 out of the 16 nations we found specific information that is relevant in this case. Many documents report about changing HVAC system settings as a quick response aiming to lower the risks of airborne transmission of pathogens. We found in several documents advice in relation to e.g. ventilation schemes. Often this reffered to extension of operating hours (e.g. to arrange for systems to be operational one or two hours before and after use) and avoidance of lower ventilation modes (e.g. with demand control systems present).

Another often mentioned intervention was related to avoiding or reducing recirculation at room level or centrally in Air Handling Units (AHU's). Avoiding recirculation means not bringing in secondairy air that might be polluted with virusses / bio-aerosols from other rooms. See Table 2 for a summary of the different kinds of HVAC setting interventions that were adressed.

Table 2. Examples of HVAC system interventions that were mentioned in the different documents.

Suggested interventions:
Extending operating hours
Avoiding or reducing central recirculation
Heat recovery section inspection
Changing temperature and humidity setpoints (see 3.5)
Disabling demand control ventilation (changing local air supply to maximum)
Checking possible air pathways (between rooms)
Introducing positive pressure regime
Create negative room pressure relative to corridor

3.5 Indoor Environmental Factors

Environmental factors such as increased indoor air temperature and increased relative humidity could affect the survival of viruses [8]. How indoor air temperature and relative humidity affects airborne transmission of SARS-CoV-2 is discussed in many documents studied. However, in most cases (documents from 12 out of the 16 countries) this did *not* lead to specific suggestions about ideal temperature or humidity setpoints. Probably mainly because changes - e.g. adjusting humidity setpoints to levels (> 80%) - that make sense from a virus-inactivation point of view - can have severe other consequences (like thermal comfort issues).

Having said this, in cold climates, in building without humification systems, low relative humidity indoors does affect mucociliary clearance. That probably explains why some of the documents (and e.g. ASHRAE guidelines, see [9]) recommend to keep the relative humidity in winter above a **minimum of 40%.** In the European documents that were studied lower minimum wither levels are recommend. For example one German document [10] recommends **20%** as lower limit for the relative humidity during the heating season.

4 Discussion

We found a lot of good examples of hands-on information for non-technical decision makers about the application of ventilation and air cleaning sollutions to decrease SARS-CoV-2 infection risks. However, recommendations often were linked to e.g. research reports and scientific papers that present 'proof' that the proposed intervention actually 'work'. Therefore, additional research is needed so more evidence-based ventilation and air cleaning advice can be developed. The research outcomes can then be applied to a next generation of guidance in order to be better prepared for the next pandemic.

5 Conclusions

As far as minimum fresh air supply and minimum air exchange rate is concerned: the online search showed that many countries acknowledge the importance of adequate ventilation, but many do not present concrete advice on how much to ventilate to make spaces 'safe enough' (in terms of SARS-CoV-2 infection risks). The documents also showed some controversy about the added value of CO_2 monitoring. Generally speaking, it is regarded as useful to identify underventilated spaces but less reliable e.g. in spaces where people sing or talk loudly or have high activity levels.

Several documents explained that air cleaning technology can help to decrease infection risks. But not as a substitute for regular fresh air supply solutions but as an *addition* to it. Traditional HEPA filter solutions are preferred by most countries, but some also allow for more exotic technologies (assuming their virus removal effectiveness has been proved adequately). Many documents also give concrete advice on HVAC system settings that are effective to limit cross-infection risks e.g. related to operating hours and recirculation. Some documents also mentioned the effect of increased temperature and ditto humidity on virus survival rates, but most do not give specific recommendations about setpoint values as in order to have real substantial effects one would have to expose building occupants to real unpleasant indoor climate conditions.

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