State of knowledge in Sweden during the Corona pandemic

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During the ongoing Corona pandemic, a survey of Swedish authorities, industry associations, and consultancy and real estate companies summarize the need to increase competence on HVAC and indoor environment. The knowledge improvement span the entire area: from the choice of technical components to the design, operation and maintenance. A topic emphasized is the requirement of an interdisciplinary perspective related to establishing knowledge.

Keywords: Ventilation; Indoor environment; HVAC; Interview survey; Corona pandemic, COVID-19; Interdisciplinary; Guidelines; Design; Maintenance

Background

At the beginning of the year 2020, the Corona Pandemic swept over the world like a Tsunami. Among other things, the use of the built environment and the operation have changed in many ways. There is a common understanding of the linkage between workplace use, in terms of, e.g. occupancy density, and spread of the virus. As an example, for buildings with constant airflow (CAV), reduced occupancy (because of the pandemic), could imply that the supplied airflow per person can be higher than the designed rate, or vice versa. When the supplied ventilation change, energy use in the built environment are affected.

The success to reduce the infection rate in the built environment can depend on the knowledge of the maintenance staff. Since the pandemic situation is new, the staff has to act outside customary conditions. The knowledge (or lack of knowledge) may affect the operational decisions made and not made during the now ongoing corona-pandemic. In order to prepare for future similar pandemics, it is useful to understand how these organizations have responded or not to Corona pandemic. Have they acted on knowledge, to which extent, and using what knowledge?

About the survey

The study included two parallel activates: a literature study to collect information about the Corona pandemic and its consequences regarding buildings' operation, especially for hospitals and care facilities, and interviews with experts and practicing professionals in the indoor environment and HVAC, in Sweden. Additionally, a reference group supported the processes of identification of interviews.

The study included twenty-one interviews, carried out during May-June 2020. The interviewees were personnel from public authorities, associations, consultants, suppliers, and real estate companies, see **Table 1**. The opinions expressed by the interviewees, should not be construed as the formal opinions of their organizations, but rather as individual opinion based on their experience.

Table 1. *List of organizations and number of interviewees.*

Swedish Authorities	*6*	
Industry Associations	*3*	
Consultancy Companies	*Design and Construction: 2*	*Distributors: 2*
Real Estate Companies	*Private Enterprises: 5*	*Public Enterprises: 3*

The precautionary principle

When it comes to reducing the spread of COVID-19 in indoor air, it is necessary to consider the evidence of airborne transmitted SARS-CoV-2 infection of humans. Currently, there is no conclusive evidence of human infection of SARS-CoV-2 by infectious aerosols through the ventilation systems in the built environment. Nevertheless, there is also a lack of evidence of that humans cannot be infected that way. As per the precautionary principle, due to the lack of such evidence the worst-case scenario, wherein humans could be affected with SARS-CoV-2 via indoor ventilation, cannot be rejected either.

The hierarchy for controlling the spread of infection

There are various measures to reduce the risk of airborne transmission of COVID-19 in buildings. The European organization REHVA has introduced an infection control pyramid [REHVA, 2020] that hierarchically places measures to reduce airborne risk in four levels, developed from a theory proposed by the US Centers for Disease Control, see **Figure 1**.

The most effective approach to reduce the risk of airborne infections is to remove the pathogen physically. The second most effective approach is to apply technical control, which in this context may involve technical ventilation measures. Then follows administrative measures, such as instructions and guidance. The relatively least effective measure, in REHVA's hierarchical infection control pyramid, is to provide personal protective equipment, such as facemasks and gloves.

Guidelines and Regulations

Several international organizations have revised their guidelines to deal with risks for airborne infection. In Sweden, there has been no revision of the building regulation. The interviewees of the authorities and one company expressed the opinion that it is too early to assess whether there is a need to revise the regulations. However, some interviewees argue for revisions. As per the interviewees, some specific future revisions of Swedish regulations could include increase possibilities for system flexibility, improved ventilation operation and control in hospital buildings, and increased possibilities for zoning of buildings.

According to the study, interviewees from the industry organizations expressed trust in the revision of REHVA's guidelines to reduce the risks for airborne

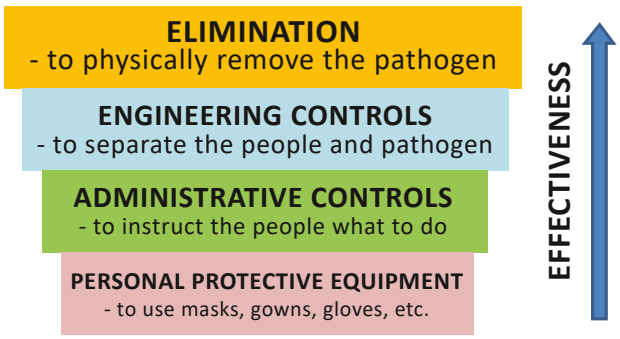

Figure 1. Hierarchical infection control pyramid, adopted from REHVA (2020), with four levels, for reducing the relative risk of airborne infection, where the top level is most effective and the bottom least effective.

infection. However, in this study, we have not valued the impact of revised guidelines. It can be a subject for future studies.

Real Estate Management

According to the interviews, the tenants express relatively little concern about virus infection from ventilation in their apartments. However, they expressed concern about the visits in the apartment from maintenance staff for HVAC-inspection and service, such as filter changes. During the pandemic conditions, the tenants have the option to deny entry for mandatory inspection and service. It may be worth investigating whether and how the lack of inspection and/replacement of filters harms the indoor environment.

As per the interviews, there are no cases when maintenance staff have adjusted airflows due to COVID-19. However, some systems automatically adjust the airflow (VAV-systems) based on demand, e.g. occupants in the room. The use of VAV-control and human infection during such pandemic may be worth to investigate further.

In hospitals and care facilities, there are cases wherein implemented measures where airflows and pressure were adjusted to reduce the possible spread of COVID-19. These measures were in accordance to already established guidelines from the period before COVID-19. Future studies could include the applicability of these guidelines.

Technical systems in the buildings

There are examples from the literature review of UV-radiation used in healthcare, with evidence of inactivating certain viruses and bacteria. However,

there is currently no evidence of how effectively UV-radiation can eliminate SARS-CoV-19.

As per the interviewed experts working on filters, effective filtering of viruses requires HEPA filters. When used in air cleaners, it enables efficient purification. However, for good efficiency, high airflows are required, and conversion of the entire air volume in the room.

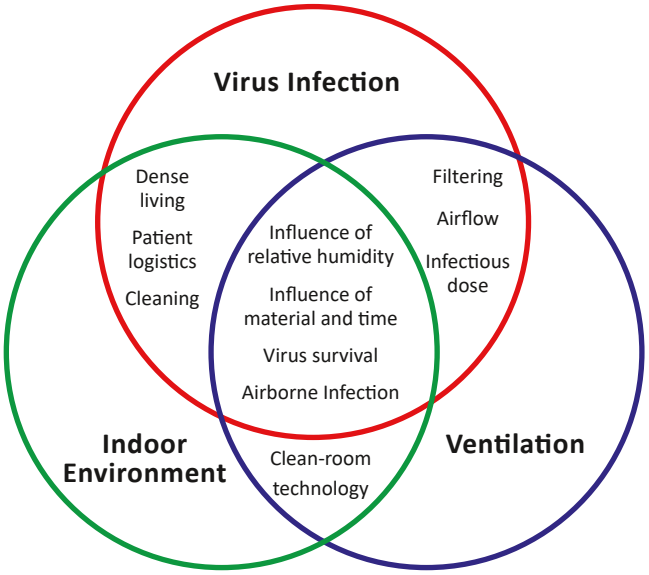

Figure 2. Illustration of interdisciplinary approach on addressing the spread of infection in the indoor environment as emerged from the interviews.

Knowledge gap

The survey results suggest needs to increase knowledge in the field of ventilation and indoor environment, including improving the general competence and expert competence on the topic. The knowledge improvement span the entire area of ventilation technology, such as design, operation, and maintenance.

Many interviewees emphasized the interdisciplinary of the issue. This perspective is essential to take into account when formulating strategies for strengthening knowledge. For the future, the study suggests the industry and the authorities to consider joint efforts to coordinate interdisciplinary expertise and finding budget. Several areas of knowledge gap emerged from the interviews. The study calls for continued interdisciplinary research and development work within the ventilation, indoor environment and virus infection. **Figure 2** provides an illustration of the identified knowledge gaps and disciplinary intersections.

Suggestions for future efforts

During the interviews, a few proposals on measures to reduce the risk of indoor airborne infection in the future emerged, for example:

- Establish a national expert service to support building maintenance professional to help their decisions to reduce risks for airborne virus infections in the indoor environment
- Develop appropriate information materials for the public to act in a manner to reduce risks for virus infections
- Facilitate broader interdisciplinary expert competence for developing future HVAC guidelines and regulations
- Initiate interdisciplinary educational efforts on basic and expert competence levels
- Coordinate expert competence for future training initiatives on ventilation, indoor environment and risks of indoor airborne infection for professionals
- Funding programs for interdisciplinary research and development on ventilation, indoor environment and airborne virus infection ■

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