Control of airborne infections with ventilation and air distribution in post COVID pandemic

POSITION PAPER BY NORDIC VENTILATION GROUP

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Nordic Ventilation Group is a group of academics sharing the same interest and concerns regarding the indoor climate and ventilation. The objective of the Nordic Ventilation Group (NVG) is to develop Nordic ventilation technologies and services for good and healthy indoor environment with an energy efficient and environmentally friendly way. The work is 100% voluntary and free from commercial interest. Possible outcomes of the work can be published through various channels with the common agreement of the group. Nordic Ventilation Group was very active in 80s and 90s when mechanical ventilation became more common in Nordic counties. The group published several guidelines for measuring air flow rates and evaluating of the performance of ventilation. The group is integrated with Scanvac activities. The history and objectives of the group are described in more details at www.scanvac.eu.

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The importance of airborne transmission of respiratory infectious pathogens has been widely recognized. The World Health Organization (WHO) acknowledged inhaling infectious aerosols as one of transmission modes for spreading COVID-19. Airborne transmission refers to inhaling virus-laden aerosols that can remain suspended in the air for extended periods and transported farther than a conversational distance away from the infected individual in a confined indoor space (WHO 2021). Transmission over distances beyond two meters has been documented and tends to be under preventable circumstances comparing short-range transmission, in which respiratory activities may play an important role (CDC, 2021, Amjadimanesh et al., 2022).

Moreover, the transmission of the infectious disease varies by pathogen infectivity, reservoirs, routes, secondary host susceptibility, environment conditions (like temperature and relative humidity in confined spaces), and ventilation performance, which includes both quantitative performance, like ventilation airflow rate, and qualitative performances, like indoor airflow pattern. Besides the social distance and personal hygiene-related guidelines recommended by WHO, increased ventilation and proper clean air distribution also contribute to reduction of airborne transmission. Furthermore, the latest studies advanced our understanding of transmission routes and the relative importance of various mitigation strategies for preventing transmission.

As engineering measures, ventilation solutions may be feasible for mitigating the spread of respiratory infection among occupants in both new buildings and existing buildings. However, different ventilation modes have different performances regarding infection control indoors. Generally speaking, mixing ventilation (MV) aims to dilute indoor contaminants by mixing supplied clean air with polluted room air. Displacement ventilation is based on moving clean air supplied near floor to the breathing zone of a person by the convective boundary layer existing around the body at comfortable room temperatures. Exposure in displacement ventilation (DV) may be rather sensitive to the location of the infected occupant in a room and to the movement of the exposed occupants as moving people will destroy their inhalation protection typical for DV (Bjørn and Nielsen, 2002; Halvonova and Melikov, 2010). The infection probability with DV seems lower than with MV, when people are in sitting still and keeping their distance (> 1.5 m in case of Covid-19) while DV will increase the infection probability when people are close to each other (< 1.5 m in case of Covid-19) (Nielsen and Xu, 2021). Recent studies show that the infection probability for several occupant- targeted ventilation methods can be lower than mixing ventilation (MV) in a classroom (Su et al., 2021). Compared to humidification at a constant ventilation rate, increasing the ventilation rate to moderate levels will have a more beneficial infection risk decrease for SARS-CoV-2, and the same trend is found for other airborne diseases like measles, human rhinovirus, and adenovirus (Aganovic et al., 2022). However, ventilation systems will not work economically under normal conditions (no pandemic) if the ventilation systems of the future are designed to supply large volumes of outdoor air during a pandemic. Rethinking airflow distribution in rooms is necessary to optimize system design and operation modes in normal and pandemic situations. With traditional methodology by dilution principle, this would be a very tough challenge, economically and technically, requiring much more power, energy, size of duct/space etc. The optimal solution should use the supplied air more rationally to create higher air quality around the people. Therefore, it must be considered timely to increase the focus on airflow distribution solutions that ensure a well-ventilated occupied zone and breathing zone, and provide occupants with an optimal climate where they live and work with a very low risk of transmission of respiratory diseases.

Nordic Ventilation Group of SCANVAC strongly supports actions to develop effective technical and non-technical solutions allowing sufficient protection against airborne transmission and the preparedness of buildings, other built environments, transportation means, and society against the future epidemic.

Conclusions

General statements regarding airborne transmission

- Respiratory pathogens are airborne and can be transmitted over long distances (more than two meters) within and between spaces in a building.
- The long-range transmission depends on indoor airflow patterns caused by ventilation, pressure (pressure difference over surrounding areas), occupants' activities and temperature differences, air distribution as well as buoyancy effects.
- The COVID-19 pandemic has made it clear that we need to pay special attention to reducing airborne transmission while ensuring effective ventilation.

Ventilation strategies

- The COVID-19 pandemic emphasized the importance of a healthy indoor environment for humans. It urged a radical change in our view of reconsidering ventilation design and implantation to promote a safe indoor environment.
- The construction sector is therefore facing a new challenge - a paradigm shift in the design of future ventilation in our buildings.
- Ventilation in more important in reducing infection risk due to exposure to respiratory pathogens than with other environmental conditions, like air temperature and relative humidity.
- Better ventilation solutions and indoor airflow distribution methods should be recognized as infection control measures in various building sectors, communities and societies.
- In healthcare facilities, patient rooms and isolation units should be negatively pressurized and avoid air recirculation. The same recommendations apply to temporary isolation rooms for infected patients.

Ventilation rate

- Increasing the ventilation rate from 0.5 ACH to 6 ACH may have a dominating effect on reducing the infection risk regardless of virus type.
- Increasing ventilation with outside air in existing buildings may not always be possible. In such cases, the effective ventilation rate per person can also be increased by limiting the number of people in the buildings.
- It is necessary to rethink ventilation solutions in order to achieve a high level of indoor air quality and to ensure the health and well-being of the occupants.

Indoor air distribution

- Air distribution is critical for lowering the infection probability in rooms with mechanical ventilation, air cleaner/purifier and natural ventilation.
- Dilution, removal, and deactivation of airborne respiratory pathogens will reduce the risks of infection indoors.
- Occupant target ventilation with an advanced airflow distribution method may significantly reduce the infection risk with relatively low energy consumption (Su et al. 2022).
- Personalized ventilation performed the best to prevent cross-infection, followed by displacement ventilation, impinging jet ventilation, stratum ventilation and wall attachment ventilation (with deflector) (Su et al. 2022).
- Personalized ventilation integrated with MV may provide clean air directly to the breathing zone of occupants while controlling the room air cleanliness with lower energy consumption.
- Protected occupied zone ventilation is able to separate a room into two zones with a different concentration level of contaminant (Aganovic et al. 2022).

Proposed actions in the post pandemic

- All regulations, building codes, standards, and guidelines should be revised to ensure the preparedness of buildings for periods with an elevated risk of airborne infection regarding the ventilation rates and air distribution.
- Action plans should be available for technical personnel and facility managers or anyone responsible for describing actions that need to be taken in case of the elevated risk of airborne transmission of respiratory pathogens in buildings both during epidemic and pandemic periods. These plans should describe activities during the non-pandemic period securing the maintenance and proper operation of the building systems, which should be able to monitor indoor air quality (IAQ) used when the risk of infection is increased.
- Special technical solutions for the pandemic period and proper operation of the existing systems should be certified by eligible personnel. ■

References

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