REHVA

Federation of European Heating, Ventilation and Air Conditioning Associations

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(this document updates previous April 3 and March 17 versions. Further updates will follow as necessary)

How to operate HVAC and other building service systems to prevent the spread of the coronavirus (SARS-CoV-2) disease (COVID-19) in workplaces

1 Introduction

In this document, REHVA summarizes advice on the operation and use of building service systems during an epidemic of a coronavirus disease (COVID-19), to prevent the spread of COVID-19 depending on HVAC (Heating, Ventilation, and Air Conditioning) or plumbing systems related factors. The advice below should be treated as *interim* guidance; the document will be complemented with new evidence and information when it becomes available.

The suggestions below are meant as an addition to the general guidance for employers and building owners that are presented in the WHO document ‘Getting workplaces ready for COVID-19’. The text below is intended primarily for HVAC professionals and facility managers. It may be useful for occupational and public health specialists and others involved in decisions on how to use buildings.

In this document, building services related precautions are covered. The scope is limited to commercial and public buildings (e.g., offices, schools, shopping areas, sports premises, etc.) where only occasional occupancy of infected persons is expected. Residential buildings are out of the scope of this document.

The guidance is focused on temporary, easy-to-organise measures that can be implemented in existing buildings that are in use during or after epidemic with normal or reduced occupancy rates.

Disclaimer:
This document expresses REHVA expert advice and views based on the available scientific knowledge of COVID-19 available at the time of publication. In many aspects, SARS-CoV-2 information is not complete, so evidence[1] from previous SARS-CoV-1 experience has been used for best practice recommendations. REHVA, the contributors and all those involved in the publication exclude all and any liability for any direct, indirect, incidental damages or any other damages that could result from, or be connected with, the use of the information presented in this document.

[1] In the last two decades we have been confronted with three coronavirus disease outbreaks: (i) SARS in 2002-2003 (SARS-CoV-1), (ii) MERS in 2012 (MERS-CoV) and COVID-19 in 2019-2020 (SARS-CoV-2). In the present document our focus is on the current instance of SARS-CoV-2 transmission. When referring to the SARS outbreak in 2002-2003 we use the name SARS-CoV-1.

Summary

New evidence on SARS-CoV-2 airborne transmission and general recognition of long-range aerosol-based transmission have developed recently. This has made ventilation measures the most important engineering controls in the infection control. While physical distancing is important to avoid a close contact, the risk of an aerosol concentration and cross-infection from 1.5 m onward from an infected person can be reduced with adequate ventilation and effective air distribution solutions. In such a situation at least three levels of guidance are required: (1) how to operate HVAC and other building services in existing buildings right now during an epidemic; (2) how to conduct a risk assessment and assess the safety of different buildings and rooms; and (3) what would be more far-reaching actions to further reduce the spread of viral diseases in future in buildings with improved ventilation systems[2]. Every space and operation of building is unique and requires specific assessment. We make 15 recommendations that can be applied in existing buildings at a relatively low cost to reduce the number of cross-infections indoors. Regarding airflow rates, more ventilation is always better, but is not the only consideration. Large spaces such as classrooms which are ventilated according to current standards tend to be reasonably safe, but small rooms occupied by a couple of persons show the highest probability of infection even if well ventilated. While there are many possibilities to improve ventilation solutions in future, it is important to recognise that current technology and knowledge already allows the use of many rooms in buildings during a COVID-19 type of outbreak if ventilation meets existing standards and a risk assessment is conducted[3].

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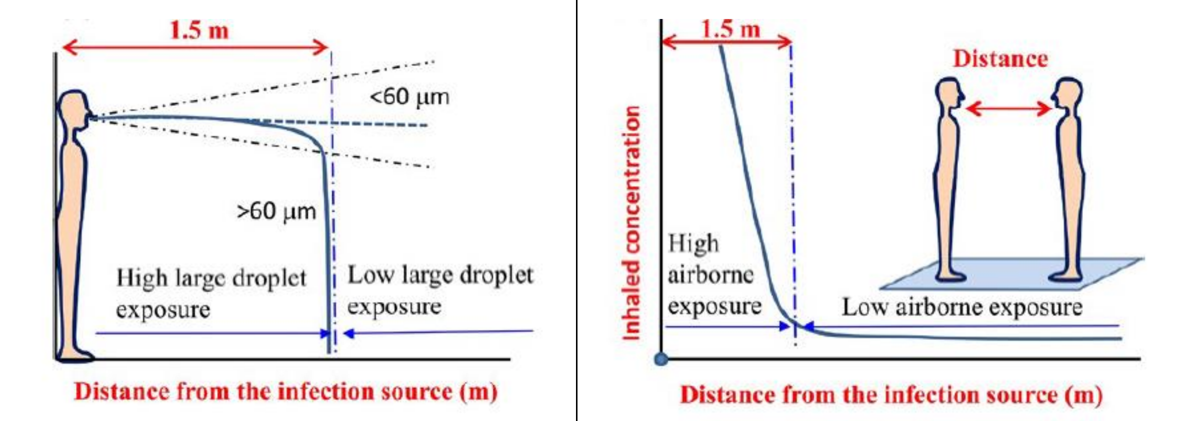
[2] More information regarding points 2 and 3 are currently under development by REHVA's COVID-19 Task Force.
[3] Currently under development by REHVA's COVID-19 Task Force.

2 Transmission routes

It is important for every epidemic to understand the transmission routes of the infectious agent. For COVID-19 and for many other respiratory viruses three transmission routes are dominant: (1) combined droplet and airborne transmission in 1-2 m close contact region arising from droplets and aerosols emitted when sneezing, coughing, singing, shouting, talking and breathing; (2) long-range airborne (aerosol-based) transmission; and (3) surface (fomite) contact through hand-hand, hand-surface, etc. contacts. The means to deal with these routes are physical distance to avoid the close contact, ventilation to avoid airborne transmission and hand hygiene to avoid surface contact. This document mainly focuses on reduction measures of airborne transmission while personal protective equipment such as wearing masks is out of the scope of the document. Additional transmission routes that have gained some attention are the faecal-oral route and resuspension of SARS-CoV-2.

The size of a coronavirus particle is 80-160 nanometre[4,i] and it remains active on surfaces for many hours or a couple of days unless there is specific cleaning[ii,iii,iv]. In indoor air SARS-CoV-2 can remain active up to 3 hours and up to 2-3 days on room surfaces at common indoor conditions[v]. An airborne virus is not naked but is contained inside expelled respiratory fluid droplets. Large droplets fall down, but small droplets stay airborne and can travel long distances carried by airflows in the rooms and in extract air ducts of ventilation systems, as well as in the supply ducts when air is recirculated. Evidence suggests that airborne transmission has caused, among others, well known infections of SARS-CoV-1 in the past[vi,vii].

Expelled respiratory droplets that are suspended in air (which means airborne) range from less than 1 μm (micrometre = micron) to more than 100 μm in diameter, which is the largest particle size that can be inhaled. They are also referred to as aerosols, i.e. particles suspended in air, since droplets are liquid particles. The main airborne transmission mechanisms are illustrated in Figure 1.



Close contact: combined exposure from droplets and droplet nuclei (aerosols)

Long range: exposure from droplet nuclei (aerosols) can be controlled with sufficient ventilation

Figure 1. The distinction between close contact combined droplet and aerosol transmission (left) and long-range aerosol transmission (right) which can be controlled with ventilation diluting the virus concentration to a low level. (Figure: courtesy L. Liu, Y. Li, P. V. Nielsen et al.[xii])

Airborne transmission depends on the droplet size[viii,ix,x] and is usually divided into close contact and long-range regions as follows:

1. Short-range droplet transmission region for close contact events can be defined through the distance travelled before the drops and large droplets (up to 2000 μm = 2 mm) fall down to surfaces. At an initial droplet velocity of 10 m/s larger droplets fall down within 1.5 m.

[4] 1 nanometer = 0.001 micron

Respiratory activities correspond to a droplet velocity of 1 m/s for normal breathing, 5 m/s for talking, 10 m/s for coughing and 20-50 m/s for sneezing. Expelled droplets evaporate and desiccate in the air so that the final droplet nuclei shrink to roughly a half or one-third of the initial diameter[xi]. Droplets with initial diameter smaller than 60 μm do not reach the ground before they desiccate entirely and may be carried further than 1.5 m by airflows.

2. Long-range airborne transmission applies beyond 1.5 m distance for droplets <50 μm. Droplet desiccation is a fast process; for instance, 50 μm droplets desiccate in about two seconds and 10 μm droplets in 0.1 s to droplet nuclei with roughly a half of the initial diameter[5]. Droplet nuclei <10 μm may be carried by airflows for long distances since the settling speeds for 10 μm, and 5 μm particles (equilibrium diameter of droplet nuclei) are only 0.3 cm/s and 0.08 cm/s, so it takes about 8.3 and 33 minutes respectively to fall 1.5 m. Because of instant desiccation, the term "droplet" is often used for desiccated droplet nuclei which still include some fluid explaining why viruses can survive. Droplet nuclei form a suspension of particles in the air, i.e. an aerosol. With effective mixing ventilation, the aerosol concentration is almost constant from 1-1.5 m distance onward. This concentration is most dominantly affected by air change rates in adequately ventilated rooms but is also reduced by deposition and decay of virus-laden particles.

More important than how far different size droplets travel, is the distance from the source or infected person at which an almost constant aerosol concentration will be reached. As shown in Figure 1, right, the concentration of droplet nuclei will decrease rapidly within the first 1-1.5 meter from a person's exhalation[xii]. This effect is due to the aerodynamics of the exhalation flow and the flow in the microenvironment around people (plume). The droplet nuclei distribution depends on the position of people, air change rate, the type of air distribution system as, e.g., mixing, displacement, or personal ventilation, and other air currents in the space[xiii]. Therefore, close contact within the first 1.5-meter creates high exposure to both large droplets and droplet nuclei that is supported by experimental and numerical studies[xii]. Aerosol concentrations and cross-infection from 1.5 m or more from an infected person can be controlled with adequate ventilation and air distribution solutions. The effect of ventilation is illustrated in Figure 2.

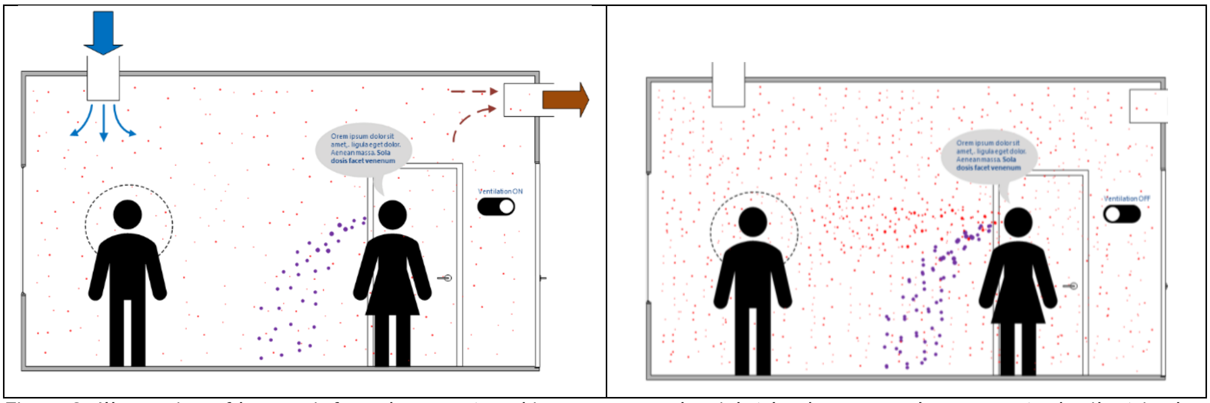


Figure 2. Illustration of how an infected person (speaking woman on the right) leads to aerosol exposure (red spikes) in the breathing zone of another person (man on the left in this case). Large droplet exhalation is marked with purple spikes. When the room is ventilated with mixing ventilation system, the amount of virus-laden particles in the breathing zone is much lower than when the ventilation system is off. Left figure: ventilation system on, right figure: ventilation system off.

For SARS-CoV-2, the long-range aerosol-based route with infection through exposure to droplet nuclei particles was first acknowledged by the WHO for hospital aerosol-generating procedures and was addressed in the guidance to increase ventilation[xiv]. Japanese authorities were one of the first to address the possibility of aerosol transmission under certain circumstances, such as when talking to

[5] Physics of suspended respiratory droplets in air shows that a droplet with initial diameter of 20 μm will evaporate within 0.24 seconds in room air with 50% RH shrinking at the same time to a droplet nuclei with equilibrium diameter of about 10 μm. For this droplet nuclei of 10 μm, including still some fluid, it takes 8.3 minutes to fall down 1.5 m in still air.

many people at a short distance in an enclosed space, and associated risk of spreading the infection even without coughing or sneezing[xv]. After that, many other authorities have followed including the US CDC, UK Government, Italian Government and the China National Health Commission. Important evidence came from a study[v] concluding that aerosol transmission is plausible, as the virus can remain viable in aerosols for multiple hours. Analyses of superspreading events have shown that closed environments with minimal ventilation strongly contributed to a characteristically high number of secondary infections[xvi]. Well known superspreading events reporting aerosol transmission are from a Guangzhou restaurant[xvii] and Skagit Valley Chorale event[xviii] where outdoor air ventilation rate was as low as 1–2 L/s per person. The fact that substantial evidence has quickly emerged indicating that SARS-CoV-2 is transmitted via aerosols has been required to be generally recognised by many scientists[xix,xx]. To date, the European Centre for Disease Prevention and Control review on HVAC-systems in the context of COVID-19 as well as the German Robert-Koch-Institut have recognised aerosol transport[xxi,xxii]. Finally, after an open letter by 239 scientists[xxiii],the WHO added aerosol transmission to their transmission mode scientific brief[xxiv]. Generally, a long-range aerosol-based transmission mechanism implies that keeping 1-2 m distance from an infected person is not enough, and concentration control with ventilation is needed for effective removal of particles in indoor spaces.

Surface (fomite) contact transmission may occur when expelled large droplets fall on nearby surfaces and objects such as desks and tables. A person may be infected with COVID-19 by touching a surface or object that has the virus on it and then touching their mouth, nose, or possibly their eyes, but US CDC concludes that this route is not thought to be the main way this virus spreads[xxv].

The WHO recognises the faecal-oral, i.e. aerosol/sewage transmission route for SARS-CoV-2 infections[xxvi]. The WHO proposes as a precautionary measure to flush toilets with a closed lid. Additionally, it is essential to avoid dried-out drains and U-traps in floors and other sanitary devices by regularly adding water (every three weeks depending on the climate) so that the water seal works appropriately. This prevents aerosol transmission through the sewage system and is in line with observations during the SARS 2002-2003 outbreak: open connections with sewage systems appeared to be a transmission route in an apartment building in Hong Kong (Amoy Garden)[xxvii]. It is known that flushing toilets are creating rising air flows containing droplets and droplet residue when toilets are flushed with open lids. SARS-CoV-2 viruses have been detected in stool samples (reported in recent scientific papers and by the Chinese authorities)[xxviii,xxix,xxx].

Conclusion about the aerosol (airborne) transmission route:

New evidence and general recognition of the aerosol-based transmission route have developed recently. When the first version of this document was published on March 17, 2020, REHVA proposed following the ALARP principle (As Low As Reasonably Practicable) to apply a set of HVAC measures that help to control the aerosol route in buildings. To date, there is evidence on SARS-CoV-2 aerosol-based transmission, and this route is now recognised worldwide. The relative contribution of different transmission routes in the spread of COVID-19 is not yet known. Therefore, it is impossible to say whether aerosol-based transmission has a major or just a significant role. Transmission routes also depend on the location. In hospitals with an excellent 12 ACH ventilation rate, aerosol transmission is mostly eliminated, but in poorly ventilated spaces, it may be dominant. Transmission routes remain an important research subject, and it has already been reported that the short-range aerosol-based route dominates exposure to respiratory infection during close contact[xxxi]. Medical literature has started to talk about a new paradigm of infectious aerosols. It is concluded that there is no evidence to support the concept that most respiratory infections are primarily associated with large droplet transmission and that small particle aerosols are the rule, rather than the exception, contrary to current guidelines[xxxii]. In the context of buildings and indoor spaces there is no doubt that cross-infection risk may be controlled up to 1.5 m from a person with physical distancing and beyond that distance with ventilation solutions.

3 Heating, ventilation & air-conditioning systems in the context of COVID-19

There are many possible measures that may be taken to mitigate COVID-19 transmission risks in buildings. This document covers recommendations for ventilation solutions as the main 'engineering controls', as described in the traditional infection control hierarchy (Figure 3) to reduce the environmental risks of airborne transmission. According to the hierarchy, ventilation and other HVAC & plumbing related measures are at a higher level than application of administrative controls and personal protective equipment including masks. It is therefore very important to consider ventilation and other building services system measures to protect against airborne transmission. These may be applied in existing buildings at a relatively low cost to reduce indoor infection risk.

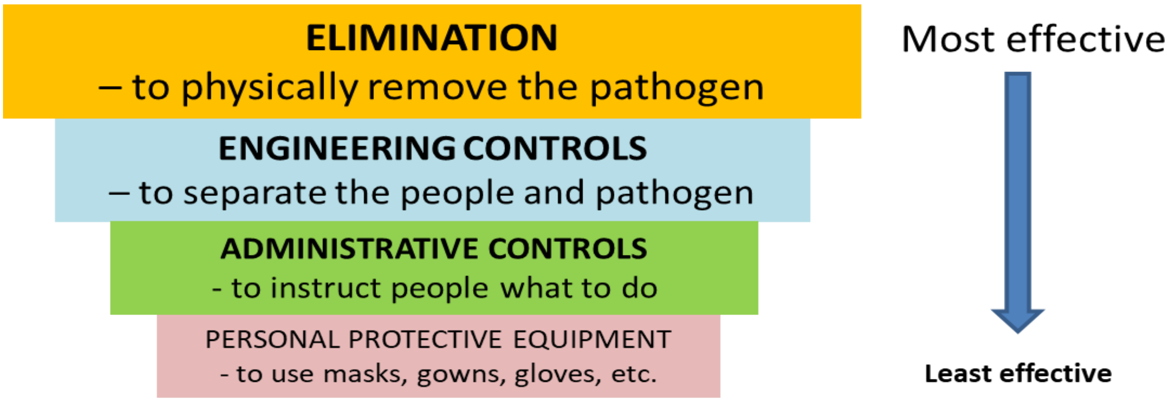


Figure 3. Traditional infection control pyramid adapted from the US Centers for Disease Control[xxiii].

The European Centre for Disease Prevention and Control (ECDC) has prepared guidance for public health authorities in EU/EEA countries and the UK on the ventilation of indoor spaces in the context of COVID-19[xxi]. This guidance is targeted at public health professionals and serves as a basis for REHVA to provide technical and system-specific guidance for HVAC professionals. The main evidence and conclusions by ECDC can be summarised as follows:

- *The transmission of COVID-19 commonly occurs in enclosed indoor spaces.*
- *There is currently no evidence of human infection with SARS-CoV-2 caused by infectious aerosols distributed through the ventilation system air ducts. The risk is rated as very low.*
- *Well-maintained HVAC systems, including air-conditioning units, securely filter large droplets containing SARS-CoV-2. COVID-19 aerosols (small droplets and droplet nuclei) can spread through HVAC systems within a building or vehicle and stand-alone air-conditioning units if the air is recirculated.*
- *The airflow generated by air-conditioning units may facilitate the spread of droplets excreted by infected people longer distances within indoor spaces.*
- *HVAC systems may have a complementary role in decreasing transmission in indoor spaces by increasing the rate of air change, decreasing the recirculation of air, and increasing the use of outdoor air.*
- *Building administrators should maintain heating, ventilation, and air-conditioning systems according to the manufacturer's current instructions, particularly concerning the cleaning and changing of filters. There is no benefit or need for additional maintenance cycles in connection with COVID-19.*
- *Energy-saving settings, such as demand-controlled ventilation controlled by a timer or CO_2 detectors, should be avoided.*
- *Consideration should be given to extending the operating times of HVAC systems before and*

after the regular period.

- *Direct air flow should be diverted away from groups of individuals to avoid pathogen dispersion from infected subjects and transmission.*
- *Organisers and administrators responsible for gatherings and critical infrastructure settings should explore options with the assistance of their technical/maintenance teams to avoid the use of air recirculation as much as possible. They should consider reviewing their procedures for the use of recirculation in HVAC systems based on information provided by the manufacturer or, if unavailable, seeking advice from the manufacturer.*
- *The minimum number of air exchanges per hour, following the applicable building regulations, should be ensured at all times. Increasing the number of air exchanges per hour will reduce the risk of transmission in closed spaces. This may be achieved by natural or mechanical ventilation, depending on the setting.*

4 Practical recommendations for building services operation during an epidemic for infection risk reduction

This REHVA guidance on building services operation covers 15 main items, as illustrated in Figure 4:

1. Ventilation rates
2. Ventilation operation times
3. Continuous operation of ventilation
4. Window opening
5. Toilet ventilation
6. Windows in toilets
7. Flushing toilets
8. Recirculation
9. Heat recovery equipment
10. Fan coils and induction units
11. Heating, cooling and possible humidification setpoints
12. Duct cleaning
13. Outdoor air and extract air filters
14. Maintenance works
15. IAQ monitoring

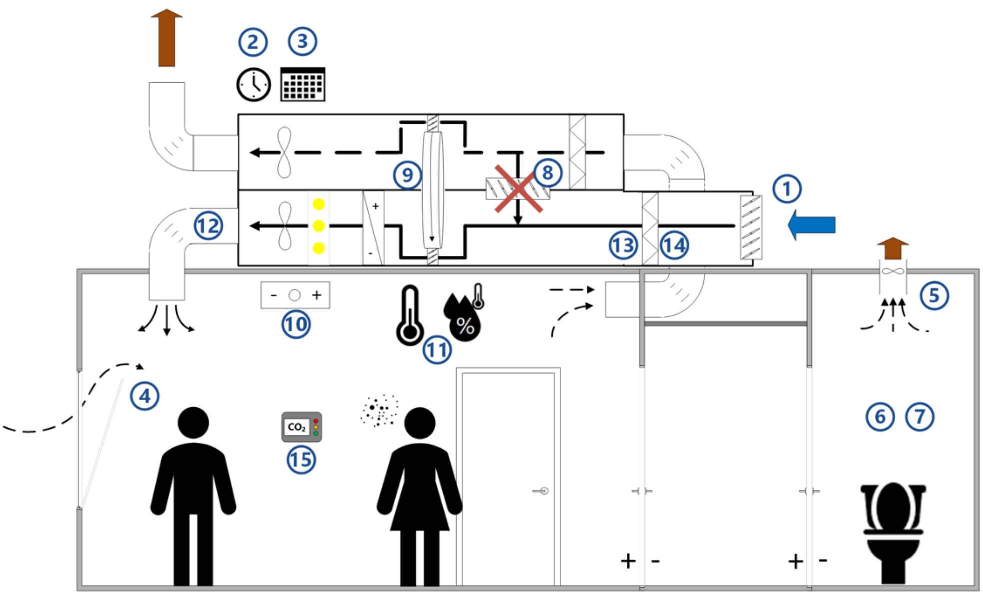


Figure 4. Main items of REHVA guidance for building services operation.

4.1 Increase air supply and exhaust ventilation

In buildings with mechanical ventilation systems, extended operation times are recommended for these systems. Adjust the clock times of system timers to start ventilation at the nominal speed at least 2 hours before the building opening time and switch to a lower speed 2 hours after the building usage time. In demand-controlled ventilation systems, change the CO_2 setpoint to 400 ppm in order to maintain the operation at nominal speed. Keep the ventilation on 24/7, with lower (but not switched off) ventilation rates when people are absent[6]. In buildings that have been vacated due to the pandemic (some offices or educational buildings), it is not recommended to switch ventilation

[6] During un-occupied periods, the ventilation may be operated periodically so that the minimum outdoor airflow rate recommended in EN 16798-1:2019 of 0.15 L/s per floor m² would be maintained.

off, but to operate continuously at reduced speed during normal operation hours. In mid-seasons with small heating and cooling needs, the recommendations above have limited energy penalties. At the same time, they help to remove virus particles from the building and to remove released virus particles from surfaces. In winter and summer, increased energy use has to be accepted, because ventilation systems have enough heating and cooling capacity to fulfill these recommendations without compromising thermal comfort.

The general advice is to supply as much outside air as reasonably possible. The key aspect is the amount of fresh air supplied per square meter of floor area. If the number of occupants is reduced, do not concentrate the remaining occupants in smaller areas but maintain or enlarge the physical distance (min 2-3 m between persons) between them to improve the dilution effect of ventilation. More information about ventilation rates and risks in different rooms will be provided in the updated version of the document in the following months.

Exhaust ventilation systems for toilets should be operated 24/7 in similar fashion to the main ventilation system. It should be switched to the nominal speed at least 2 hours before the building opening time and may be switched to a lower speed 2 hours after the building usage time. If it is not possible to control the fan speed, then the toilet ventilation should operate 24/7 at full speed.

4.2 Use openable windows more

The general recommendation is to stay away from crowded and poorly ventilated spaces. In buildings without mechanical ventilation systems, it is recommended to actively use openable windows (much more than normal, even when this causes some thermal discomfort). Window opening is then the only way to boost air exchange rates. Windows should be opened for 15 min or so when entering the room (especially when the room was occupied by others beforehand). Also, in buildings with mechanical ventilation, window opening can be used to boost ventilation further.

Open windows in toilets with a passive stack or mechanical exhaust systems may cause a contaminated airflow from the toilet to other rooms, implying that ventilation begins to work in the reverse direction. Open toilet windows should then be avoided. If there is no adequate exhaust ventilation from toilets and window opening in toilets cannot be avoided, it is important to keep windows open also in other spaces to achieve cross flows throughout the building.

4.3 Humidification and air-conditioning have no practical effect

Relative humidity (RH) and temperature contribute to virus viability, droplet nuclei forming, and susceptibility of occupants' mucous membranes. The transmission of some viruses in buildings can be altered by changing air temperatures and humidity levels to reduce the viability of the virus. In the case of SARS-CoV-2, this is unfortunately not an option as coronaviruses are quite resistant to environmental changes and are susceptible only to a very high relative humidity above 80% and a temperature above 30 ˚C[ii,iii,iv], which are not attainable and acceptable in buildings for reasons of thermal comfort and avoiding microbial growth. SARS-CoV-2 has been found viable for 14 days at 4℃; for a day at 37℃ and for 30 minutes at 56℃[xxxiv].

SARS-CoV-2 stability (viability) has been tested at a typical indoor temperature of 21-23 ℃ and RH of 65% with very high virus stability at this temperature and RH[xxxv]. Together with previous evidence on MERS-CoV, it is well documented that humidification up to 65% may have very limited or no effect on the stability of the SARS-CoV-2 virus. The current evidence does not support the view that moderate humidity (RH 40-60%) will be beneficial in reducing the viability of SARS-CoV-2 and so humidification is NOT a method to reduce the viability of SARS-CoV-2.

Small droplets (0.5 – 50 μm) will evaporate faster at any relative humidity (RH) level[xxxvi]. Nasal systems and mucous membranes are more sensitive to infections at very low RH of 10-20 %[xxxvii,xxxviii], and for this reason some humidification in winter is sometimes suggested (to levels of 20-30%), although the use of humidifiers has been associated with higher amounts of total and short term sick leave[xxxix].

In buildings equipped with centralised humidification, there is no need to change humidification systems' setpoints (usually 25 or 30%[xl]). Usually, any adjustment of setpoints for heating or cooling systems is not needed, and systems can be operated normally, as there are no direct implications for the risk of transmission of SARS-CoV-2.

4.4 Safe use of heat recovery sections

Virus particle transmission via heat recovery devices is not an issue when an HVAC system is equipped with a twin coil unit or another heat recovery device that guarantees 100% air separation between the return and supply side[xli].

Some heat recovery devices may carry over particle and gas phase pollutants from the exhaust air side to the supply air side via leaks. Rotary air to air heat exchangers (i.e., rotors, called also enthalpy wheels) may be liable to significant leakage in the case of poor design and maintenance. For properly operating rotary heat exchangers, fitted with purging sectors and correctly set up, leakage rates are very low, being in the range of 1-2% that is in practice insignificant. For existing systems, the leakage should be below 5% and should be compensated with increased outdoor air ventilation, according to EN 16798-3:2017. However, many rotary heat exchangers may not be properly installed. The most common fault is that the fans have been mounted in such a way as to create a higher pressure on the exhaust air side. This will cause leakage from the extract air into the supply air. The degree of uncontrolled transfer of polluted extract air can in these cases be of the order of 20%[xlii], which is not acceptable.

It has been shown that rotary heat exchangers which are properly constructed, installed, and maintained have almost zero transfer of particle-bound pollutants (including air-borne bacteria, viruses, and fungi), and the transfer is limited to gaseous pollutants such as tobacco smoke and other smells[xliii]. There is no evidence that virus-laden particles larger than about 0.2 μm would be transferred across the wheel. Because the leakage rate does not depend on the rotation speed of the rotor, it is not necessary to switch rotors off. The normal operation of rotors makes it easier to keep ventilation rates higher. It is known that the carry-over leakage is highest at low airflow, so higher ventilation rates should be used as recommended in Section 4.1.

If critical leaks are detected in the heat recovery sections, pressure adjustment or bypassing (some systems may be equipped with bypass) can be an option to avoid a situation where higher pressure on the extract side will cause air leakage to the supply side. Pressure differences can be corrected by dampers or by other reasonable arrangements. In conclusion, we recommend inspecting the heat recovery equipment, including measuring the pressure difference and estimating leakage based on temperature measurement (see Specific Guidance: Limiting internal air leakages across the rotary heat exchanger).

4.5 No use of central recirculation

Viral material in extract (return) air ducts may re-enter a building when centralised air handling units are equipped with recirculation sectors. The general recommendation is to avoid central recirculation during SARS-CoV-2 episodes: close the recirculation dampers either using the Building Management System or manually.

Sometimes air handling units and recirculation sections are equipped with return air filters. This should not be a reason to keep recirculation dampers open as these filters normally do not filter out viral material effectively since they have coarse or medium filter efficiencies (G4/M5 or ISO coarse/ePM10 filter class).

In air systems and air-and-water systems where central recirculation cannot be avoided because of limited cooling or heating capacity, the outdoor air fraction has to be increased as much as possible and additional measures are recommended for return air filtering. To completely remove particles and viruses from the return air, HEPA filters would be needed. However, due to a higher pressure drop and special required filter frames, HEPA filters are usually not easy to install in existing systems. Alternatively, duct installation of disinfection devices, such as ultraviolet germicidal irradiation (UVGI) also called germicidal ultraviolet (GUV), may be used. It is essential that this equipment is correctly sized and installed[7]. If technically possible, it is preferred to mount a higher class filter in existing frames and to increase exhaust fan pressure without reducing the airflow rate. A minimum improvement is the replacement of existing low-efficiency return air filters with ePM1 80% (former F8) filters. The filters of the former F8 class have a reasonable capture efficiency for virus-laden particles (capture efficiency 65-90% for PM1).

4.6 Room level circulation: fan coil, split and induction units

In rooms with fan coils only or split units (all-water or direct expansion systems), the first priority is to achieve adequate outdoor air ventilation. In such systems, mechanical ventilation is usually independent of the fan coils or split units and two options are possible to achieve ventilation:

1. Active operation of window opening together with the installation of CO_2 monitors as indicators of outdoor air ventilation;
2. Installation of a standalone mechanical ventilation system (either local or centralised, according to its technical feasibility). This is the only way to ensure a sufficient outdoor air supply in the rooms at all times.

If option 1 is used, CO_2 monitors are important, because fan coils and split units with both cooling or heating functions improve thermal comfort, and it may take too long before occupants perceive poor air quality and lack of ventilation[xliv]. See an example of a CO_2 monitor in the Specific Guidance document for School Buildings.

Fan coil units have coarse filters that practically do not filter smaller particles but may still collect potentially contaminated particles which may then be released when fans start to operate. Fan coils and induction units may need additional measures as follows:

1. Fan coils, chilled beams, and other induction units equipped with primary outdoor supply air (air-and-water systems), delivering outside air do not need any specific measures other than to increase as much as possible the outdoor air ventilation rate;
2. Fan coils only and split units in single office rooms and homes do not need any measures other than a regular supply of outside air to the space;
3. Fan coils only and split units in common spaces (larger rooms with fan coil or split units occupied by many persons) can be either operated at low speed during no-occupancy hours or switched-off one hour after and then turned on one hour before occupancy with open windows, according to which of these procedures is well suited for the specific case and less energy consuming. During the occupancy hours, leave the windows partially open (if operable) to ensure a certain degree of ventilation.

4.7 Duct cleaning has no practical effect

There have been some overreactive statements recommending cleaning ventilation ducts to avoid SARS-CoV-2 transmission via ventilation systems. Duct cleaning is not effective against room-to-room infection because the ventilation system is not a contamination source if the above guidance about heat recovery and recirculation is followed. Viruses attached to small particles will not deposit easily

[7] Currently under development by REHVA's COVID-19 Task Force.

in ventilation ducts and will normally be carried out by the airflow.[xlv]. Therefore, no changes are needed to normal duct cleaning and maintenance procedures. Much more important is to increase the outside air supply and to avoid recirculation of air according to the recommendations above.

4.8 Change of outdoor air filters is not necessary

In the COVID-19 context, questions have been asked about filter replacement and the protective effect in very rare cases of outdoor virus contamination, for instance, if air exhausts are close to air intakes. Modern ventilation systems (air handling units) are equipped with fine outdoor air filters right after the outdoor air intake (filter class F7 or F8[8] or ISO ePM2.5 or ePM1), which filter particulate matter from the outdoor air well. The size of the smallest viral particles in respiratory aerosols is about 0.2 μm (PM0.2), smaller than the capture area of F8 filters (capture efficiency 65-90% for PM1). Still, the majority of viral material is already within the capture area of filters. This implies that in rare cases of virus-contaminated outdoor air, standard fine outdoor air filters provide reasonable protection for a low concentration and occasional occurrence of viral material in outdoor air.

Heat recovery and recirculation sections are equipped with less effective medium or coarse extract air filters (G4/M5 or ISO coarse/ePM10) whose aim is to protect equipment against dust. These filters have a very low capture efficiency for viral material (see Section 4.4 for heat recovery and 4.5 for recirculation).

From the filter replacement perspective, normal maintenance procedures can be used. Clogged filters are not a source of contamination in this context, but they reduce supply airflow, which has a negative effect on reducing indoor contamination levels. Thus, filters must be replaced according to the normal procedures when pressure or time limits are exceeded, or according to scheduled maintenance. In conclusion, it is not recommended to change existing outdoor air filters and replace them with other types of filters, nor is it recommended to change them sooner than usual.

4.9 Safety procedures for maintenance personnel

HVAC maintenance personnel may be at risk when conducting scheduled maintenance, inspection or replacement of filters (especially extract air filters) if standard safety procedures are not followed. To be safe always assume that filters, extract air ducts, and heat recovery equipment may have active microbiological material on them, including viable viruses. This is particularly important in any building where there has recently been an infection. Filters should be changed with the system turned off, while wearing gloves and respiratory protection and disposed of in a sealed bag.

4.10 Room air cleaners and UVGI can be useful in specific situations

Room air cleaners remove particles from the air, which provides a similar effect compared to the outdoor air ventilation. To be effective, air cleaners need to have HEPA filter efficiency, i.e., to have a HEPA filter as the last step. Unfortunately, most attractively priced room air cleaners are not effective enough. Devices that use electrostatic filtration principles instead of HEPA filters (not the same as room ionizers!) often work with similar efficiency. Because the airflow through air cleaners is limited, the floor area they can serve is usually quite small. To select the right size air cleaner, the airflow capacity of the unit (at an acceptable noise level) has to be at least 2 ACH and will have positive effect until 5 ACH[xlvi] (calculate the airflow rate through the air cleaner in m^3/h by multiplying the room volume by 2 or 5). If air cleaners are used in large spaces, they need to be placed close to people in a space and should not be placed in the corner and out of sight. Special UVGI disinfection

[8] An outdated filter classification of EN779:2012 which is replaced by EN ISO 16890-1:2016, Air filters for general ventilation - Part 1: Technical specifications, requirements and classification system based upon particulate matter efficiency (ePM).

equipment may be installed in return air ducts in systems with recirculation, or installed in room, to inactivate viruses and bacteria[9]. Such equipment, mostly used in health care facilities needs to be correctly sized, installed and maintained. Therefore, air cleaners are an easy to apply short term mitigation measure, but in the longer run, ventilation system improvements to achieve adequate outdoor air ventilation rates are needed.

4.11 Toilet lid use instructions

If toilet seats are equipped with lids, it is recommended to flush the toilets with lids closed to minimize the release of droplets and droplet residues from air flows[xlvii,xxvi]. Building occupants should be clearly instructed to use the lids. Water seals must work at all times[xxvii]. Regularly check the water seals (drains and U-traps) and add water if required, at least every three weeks.

4.12 Risk of Legionellosis after shut-down

Throughout the duration of the SARS-CoV-2 (COVID-19) epidemic, many buildings have been experiencing reduced use or complete shut-down over extended periods of time. This includes, for example, hotels/resorts, schools, sports facilities, gyms, swimming pools, bath houses and many other types of buildings and facilities equipped with HVAC and water systems.

Depending on a variety of factors, including system layout and design, prolonged reduced (or no) use can lead to water stagnation in parts of the HVAC and water systems, enhancing the risks of an outbreak of Legionnaires' disease (Legionellosis) upon reassuming full operation.

Before restarting the system, a thorough risk analysis should be carried out to assess any Legionellosis risks involved. Several relevant authorities provide information on related risk assessment and restart procedures, including[xlviii,xlix,lli,lii].

4.13 IAQ monitoring

The risk of indoor cross-contamination via aerosols is very high when rooms are not ventilated well. If ventilation control needs actions by occupants (hybrid or natural ventilation systems) or there is no dedicated ventilation system in the building, it is recommended to install CO_2 sensors at the occupied zone that warn against underventilation especially in spaces that are often used for one hour or more by groups of people, such as classrooms, meeting rooms, restaurants, During an epidemic it is recommended to temporarily change the default settings of the traffic light indicator so that the yellow/orange light (or warning) is set to 800 ppm and the red light (or alarm) up to 1000 ppm in order trigger prompt action to achieve sufficient ventilation even in situations with reduced occupancy. In some cases, standalone CO_2 sensors or 'CO_2 traffic lights' can be used, see an example in the Specific Guidance document for School Buildings. Sometimes it may work better to use CO_2 sensors that are part of a web-based sensor network. The signals from these sensors can be used to warn building occupants to use operable windows and mechanical ventilation systems with multiple settings in the right way. One can also store the data and, provide facility managers with weekly or monthly data so that they know what is going on in their building and rooms with high concentration and subsequently identify the infection risk.

[9] More information about UVGI equipment is currently under development by REHVA's COVID-19 Task Force.

5 Summary of practical measures for building services operation during an epidemic

1. Provide adequate ventilation of spaces with outdoor air
2. Switch ventilation on at nominal speed at least 2 hours before the building opening time and set it to lower speed 2 hours after the building usage time
3. At nights and weekends, do not switch ventilation off, but keep systems running at a lower speed
4. Open windows regularly (even in mechanically ventilated buildings)
5. Keep toilet ventilation in operation 24/7
6. Avoid open windows in toilets to maintain the right direction of ventilation
7. Instruct building occupants to flush toilets with closed lid
8. Switch air handling units with recirculation to 100% outdoor air
9. Inspect heat recovery equipment to be sure that leakages are under control
10. Adjust fan coil settings to operate so that fans are continuously on
11. Do not change heating, cooling and possible humidification setpoints
12. Carry out scheduled duct cleaning as normal (additional cleaning is not required)
13. Replace central outdoor air and extract air filters as normal, according to the maintenance schedule
14. Regular filter replacement and maintenance works shall be performed with common protective measures including respiratory protection
15. Introduce an IAQ sensor network that allows occupants and facility managers to monitor that ventilation is operating adequately.

Feedback

If you are specialist in the issues addressed in this document and you have remarks or suggestions for improvements, feel free to contact us via info@rehva.eu. Please mention 'COVID-19 interim document' as subject when you email us.

Colophon

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