FläktGroup

# PREVENTING VIRAL TRANSMISSION IN HEATING, VENTILATION AND AIR-CONDITIONING SYSTEMS

**IAQ – INDOOR AIR QUALITY v2**

# IAQ
# Indoor Air Quality v2

The current pandemic has, naturally, increased the focus on indoor air quality. The quality of the indoor environment is a combination of all elements of the ventilation system and to date, there has not been a well-documented SARS-CoV-2 (Covid-19) outbreak traced to aerosol transmission through a central supply and extract ventilation system.[4]

The spread of infections due to central mechanical supply and extract ventilation devices is, therefore, very unlikely. There are many academic studies underway to understand the transmission of the virus through particles suspended in the air and it makes sense that precautionary measures to reduce the possible spread of such particles in ventilation systems should be taken.

These precautions affect all elements of the ventilation system and our paper attempts to share best practice for practical measures that can be taken to minimise the risk of transmission.

**Ventilation is also a very important way of diluting any airborne pathogens and there is good evidence that demonstrates room occupants are more at risk of catching an illness in a poorly ventilated room than in a well-ventilated room. This is because in a poorly ventilated room occupants are exposed to a higher concentration of airborne pathogens, and the risk will increase with a greater amount of time spent in such an environment.** [19]

**RISK = EXPOSURE X TIME**

**THE RISK OF AIRBORNE INFECTION TO THE INDIVIDUAL CAN THEREFORE BE REDUCED BY:**

- Reducing time spent in the location
- Reducing airborne exposure concentration of infectious material
- Reducing risk of contact spread through regular handwashing, surface cleaning and reducing deposition of infectious particles.

Ventilation rate and effectiveness play a role in both airborne exposure and deposition rates.

The risk for SARS-CoV2 transmission will be from asymptomatic or pre-symptomatic individuals who occupy a building without knowledge that they are shedding viral particles. [19]

‘In the face of such uncertainty, we argue that the benefits of an effective ventilation system, possibly enhanced by particle filtration and air disinfection, for contributing to an overall reduction in the airborne infection risk are obvious’. [16]

## Content

# Disclaimer

This document is based on; Historical and current worldwide academic research, the current recommendations of ventilation professional organisations and our own knowledge as one of the world's leading HVAC manufacturers.

In many aspects' corona virus (Covid-19) information is limited or not existing.
In the last two decades there have been three coronavirus disease outbreaks:

• SARS in 2002-2003 (SARS-CoV-1),

• MERS in 2012 (MERS-CoV)

• Covid-19 in 2019-2020 (SARS-CoV-2).

In this document our focus is on the last aspect of SARS-CoV-2 transmission. When a reference is to the SARS outbreak in 2002/2003, we will use the name of SARS-CoV-1. Previous Influenza A evidence has also been utilized for best practice recommendations. As more academic research is published and recommendations from professional organisations are revised, this document will be updated. This is version 1 14th July 2020

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# Steps to prevent airborne viral transmission

**The best available summary is from the European Centre For Disease Prevention And Control in their paper 'Heating, ventilation and air-conditioning systems in the context of COVID-19' 28, published on 22 June 2020. They conclude;**

- Transmission of COVID-19 commonly occurs in closed indoor spaces.
- There is currently no evidence of human infection with SARS-CoV-2 caused by infectious aerosols distributed through the ventilation system ducts of HVACs. The risk is rated as very low.
- Well-maintained HVAC systems, including air-conditioning units, securely filter large droplets containing SARS-CoV-2. It is possible for COVID-19 aerosols (small droplets and droplet nuclei) to spread through HVAC systems within a building or vehicle and stand-alone air-conditioning units if air is recirculated.
- Air flow 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 recirculation of air and increasing the use of outdoor air.

Given the concern about airborne transmission, building managers, safety experts, and others might take steps to optimize ventilation and airflow indoors and limit viral spread. In the first instance there are some Low-tech strategies to prevent airborne viral transmission that should be implemented.[5]

**BEST PRACTICE IS TO FOLLOW THE HIERARCHY DESCRIBED BY THE 'US CENTERS FOR DISEASE CONTROL'**

Low-tech strategies for preventing airborne viral transmission in localities that have reopened, business leaders, school officials, and others have already taken many steps to make their facilities safer. Some have installed physical barriers, made corridors one-way, increased the frequency of cleaning, and widened the space between desks.

Staggered shifts are now common at many companies to decrease physical distancing, and masks are often mandatory.

**OTHER SIMPLE STEPS THAT MAY PREVENT AIRBORNE TRANSMISSION INCLUDE THE FOLLOWING:**

- Rearranging furniture to avoid having several people on the same airflow "corridor"
- Opening windows in buildings with basic HVAC systems, which cannot filter or deliver outside air, to increase the exchange of fresh air
- Locking windows in buildings with central HVAC systems, when permissible, to reduce indoor temperature changes; if a fan does not have to increase its speed because of an inflow of warm or cold air, turbulence will remain low
- Designing novel seating arrangements, such as having employees on a shop floor work back-to-back rather than face-to-face
- Limiting the number of people allowed in a room
- Replacing hand dryers with paper towels to reduce air turbulence

MOST EFFECTIVE

**ELIMINATION** To physically remove the pathogen

**ENGINEERING CONTROLS** To separate the people and the pathogen

**ADMINISTRATIVE CONTROLS** To instruct people what to do

**PPE** To use masks, gloves etc.

LEAST EFFECTIVE

# Specific advice for the operation of Heating, Ventilation and Air Conditioning

European Centre For Disease Prevention And Control give specific advice for the operation of Heating, Ventilation and Air Conditioning.

Building administrators should maintain heating, ventilation, and air-conditioning systems according to the manufacturer's current instructions, particularly in relation to 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 CO2 detectors, should be avoided. Consideration should be given to extending the operating times of HVACs 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, in accordance with 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.

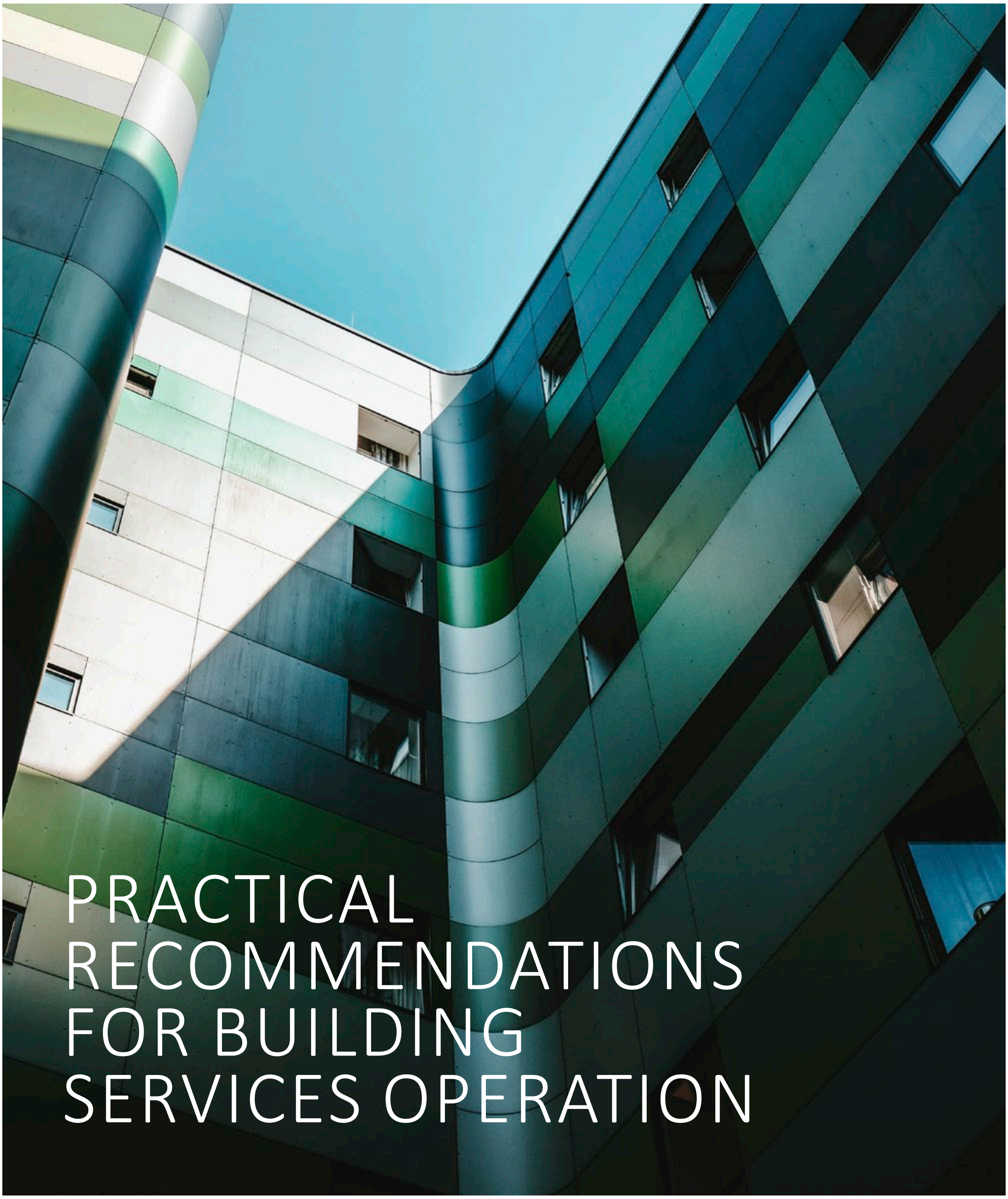
The application of the above guidance should be in accordance with national and local regulations (e.g. building regulations, health and safety regulations) and appropriate to local conditions.

**FOR THE OPERATION OF BUILDING SERVICES, REHVA HAVE ALSO SUMMARISED PRACTICAL MEASURES THAT CAN BE TAKEN.**[1]

1. Secure ventilation of spaces with outdoor air
2. Switch ventilation to nominal speed at least 2 hours before the building usage time and switch 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 lower speed
4. Ensure regular airing with windows (even in mechanically ventilated buildings)
5. Keep toilet ventilation 24/7 in operation
6. Avoid open windows in toilets to assure 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. Switch fan coils either off or operate so that fans are continuously on
11. Do not change heating, cooling and possible humidification setpoints
12. Do not plan duct cleaning for this period
13. Replace central outdoor air and extract air filters as usually, according to maintenance schedule
14. Regular filter replacement and maintenance works shall be performed with common protective measures including respiratory protection

**FläktGroup have a range of solutions for toilet ventilation (point 5) and can offer a service visit in several countries to address the requirements of points- 8, 9, 13 and 14.**

**Specific details for these points are shown below.**



# PRACTICAL RECOMMENDATIONS FOR BUILDING SERVICES OPERATION

**REHVA have given more detailed advice on practical recommendations for building service operation.[1]**

**We have added additional recommendations to the REHVA content were applicable.**

**Not all individual country's professional bodies agree with all aspects of REHVA's advice. We have identified these variances below. Where country professional bodies align we have indicated this alignment by the use of the appropriate flag.**

# Increase air supply and exhaust ventilation

In buildings with mechanical ventilation systems extended operation times are recommended. Change the clock times of system timers to start ventilation at nominal speed at least 2 hours before the building usage time and switch to lower speed 2 hours after the building usage time.

In demand-controlled ventilation systems change CO2 setpoint to 400 ppm value. This figure is the fresh air concentration of CO2 and will ensure in the operation of AHUs at an optimal speed.

Keep the ventilation on 24/7, with lowered (but not switched off) ventilation rates when people are absent. In buildings that have been vacated due to the pandemic (some offices or educational buildings) it is not recommended to switch ventilation off, but to operate continuously at reduced speed. Considering a springtime with small heating and cooling needs, the recommendations above have limited energy penalties, while they help to remove virus particles out of the building and to remove released virus particles from surfaces.

The general advice is to supply as much outside air as reasonably possible. The key aspect is the amount of fresh air supplied per person. If, due to smart working utilization, the number of employees is reduced, do not concentrate the remaining employees in smaller areas but maintain or enlarge the social distancing (min physical distance 2-3 m between persons) among them in order to foster the ventilation cleaning effect.

Care should be taken in areas which are under positive pressure as virus particles may be forced out of rooms into other areas such as corridors.

Currently, there is no yet information what outdoor air ventilation rate will safely reduce the infection risk. At least existing standards should be followed. Existing standards in non-residential buildings advise 10 L/s per person which is equivalent to at least 2 ach (air changes per hour). REHVA state 'In hospitals with an excellent 12 ACH ventilation rate, aerosol transmission is mostly eliminated, but in poorly ventilated spaces, it may be dominant.' [1]

Buildings where the ventilation rate was established by ACH should be checked to ensure that the ventilation rate is at least 10 L/s based on occupancy.

It is known what ventilation rates are too small. Research papers about so called superspreading events show that infections have been associated with very low ventilation rates of about 1 L/s per person.

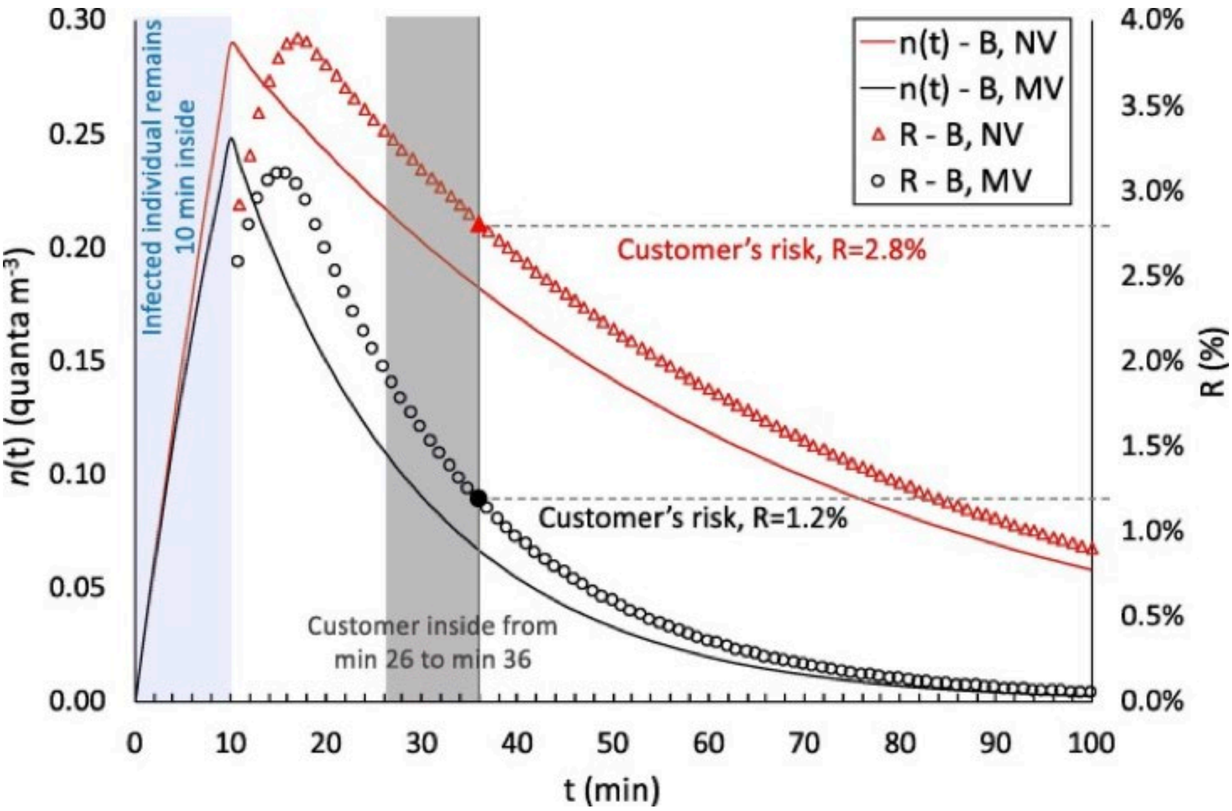
Research needs to be done to see if ventilation rates of 10 L/s per person are enough or whether this value should be increased to, for instance, 20-25 L/s per person – this information is currently not available Covid-19.

## COMPARING MECHANICAL VENTILATION WITH NATURAL VENTILATION

A paper published in August 2020 'Quantitative assessment of the risk of airborne transmission of SARS-CoV-2 infection: Prospective and retrospective applications' [36] seeks to presents a method for assessing the risk of an individual infection risk of a person exposed to in indoor environments in the presence of an asymptomatic infected SARS-CoV-2 subject. The same authors also published 'Estimation of airborne viral emission Quanta emission rate of Covid for infection risk assessment.' [37]

The papers are highly technical but can be used to show the comparative risks between mechanically and naturally ventilated buildings.

The figure below (reference 37) shows the comparative risk associated with an individual person entering a pharmacy following the entry of an infected individual (first 10 min) and the risk for a customer entering the building (at minute 26) and remaining inside for 10 minutes.

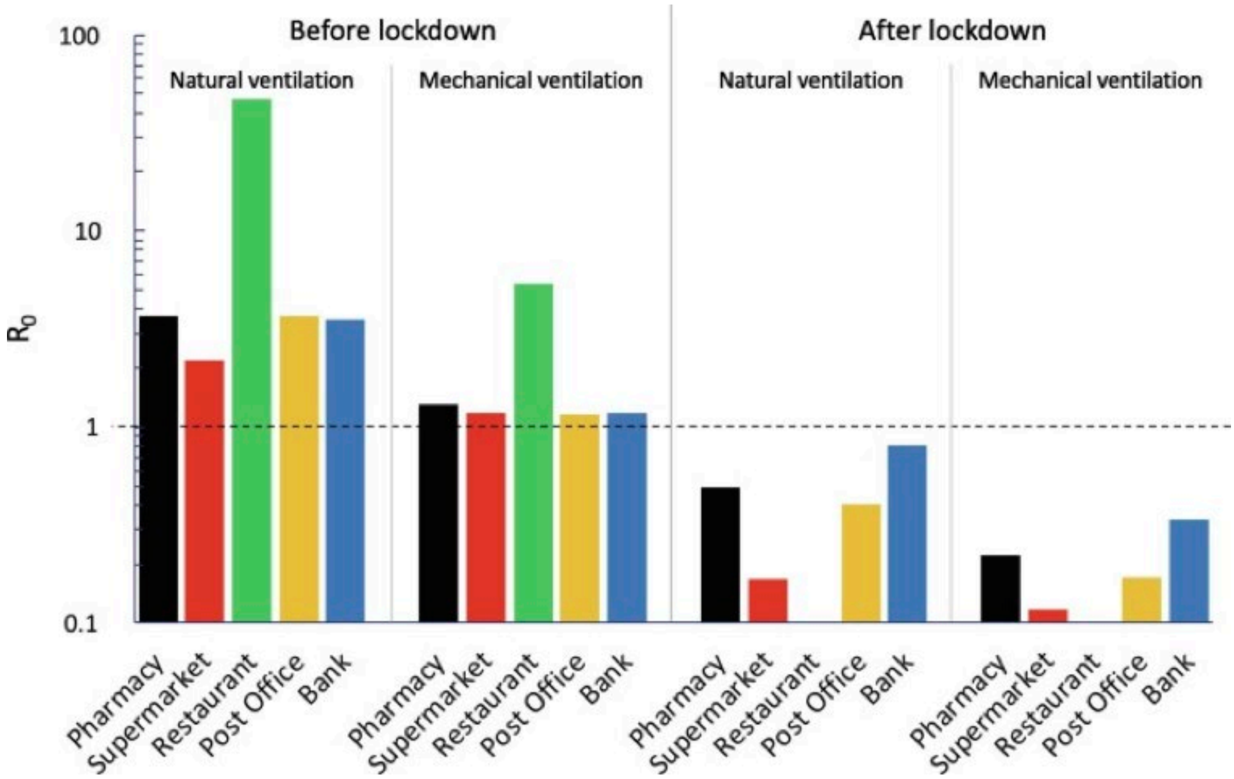



— n(t) -B, NV represents the risk of infection if the building was naturally ventilated

— n(t) -B, MV represents the risk of infection if the building was mechanically ventilated

**It is clear, in this scenario, that the risk in the naturally ventilated building (2.8%) is more than twice that of the mechanically ventilated building (1.2%).**

**The same analysis for other buildings shows that in every case there is less risk in a mechanically ventilated building. See figure below (reference 37)**




# Use more window airing

General recommendation is to stay away from crowded and poorly ventilated spaces. In buildings without mechanical ventilation systems or areas air conditioned by split units without a fresh air connection it is recommended to open windows-even if this reduces thermal comfort.

In these circumstances window airing is the only way to boost air exchange rates. Open windows for at least 15 minutes before entering the room (especially when the room was occupied by others beforehand). In buildings with mechanical ventilation, window airing can be used to further boost ventilation.

If areas are conditioned by split units and have no fresh air connection or openable window then the recommendation is to turn the unit off.

# Humidification

**It has long been understood that there is a link between the rate of Influenza A infection and the relative indoor humidity.**

The European Centre For Disease Prevention And Control have said 'Studies indicate that SARS-CoV-2 particles can remain infectious on various materials, as well as in aerosols in indoor environments, with the duration of infectivity depending on temperature and humidity' [27]

In 2007 a published study; 'Influenza Virus Transmission Is Dependent on Relative Humidity and Temperature',[7] concluded that "The most recent of these reports shows viral stability to be maximal at low Relative Humidity (RH) (20%–40%), minimal at intermediate RH (50%), and high at elevated RH (60%–80%)." In this context stability is the ability of the virus particle to infect a human.
This result is shown here in graph form.

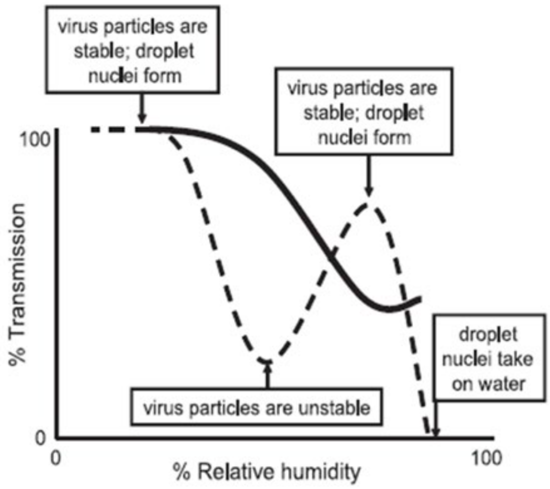



**Figure 6.** Variation of Transmission Efficiency with Relative Humidity: A Model

*The solid line is for an internal temperature of 20°C.*

*The dashed line is for an internal temperature of 5°C*

'High Humidity Leads to Loss of Infectious Influenza Virus from Simulated Coughs' [8]
Published in 2013.

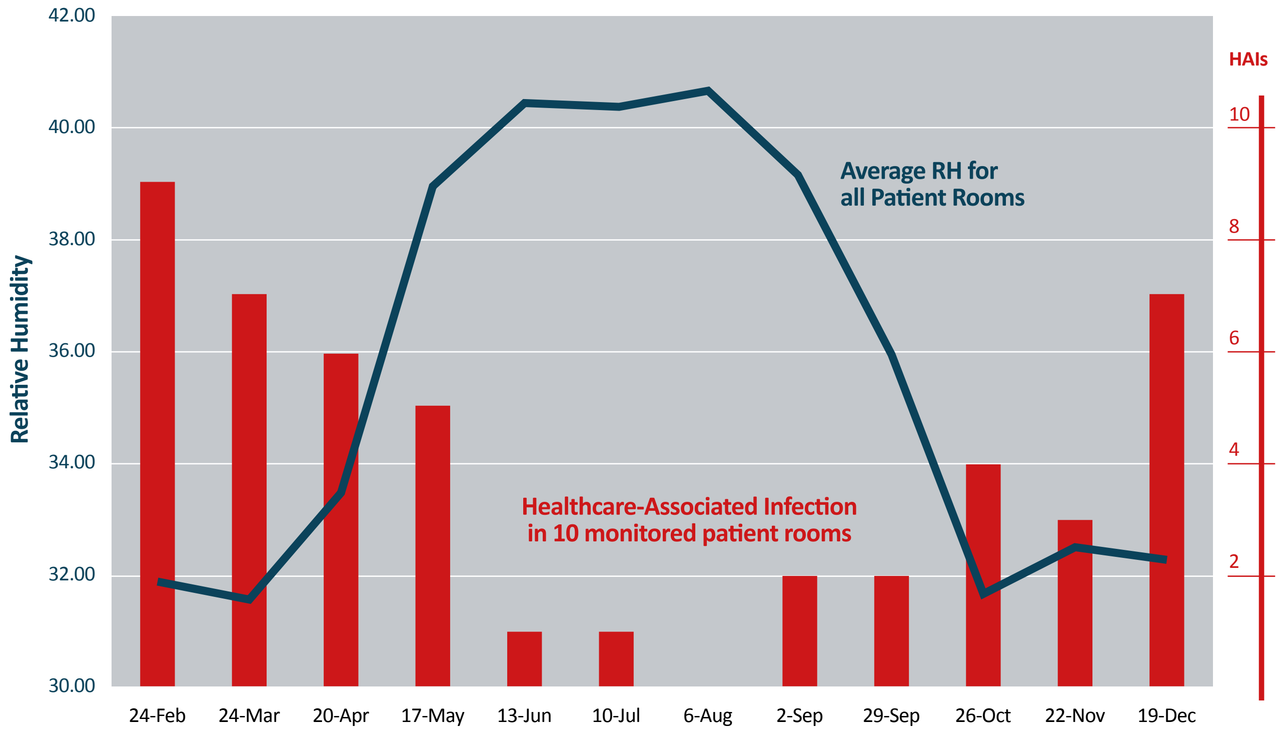
***"At a relative humidity between 20 and 35 %, the risk of becoming infected with an influenza A virus as about three times as high as at 50 %." This is partly due to the timespan for which virus particles retain their infectivity. "The study showed that one hour after coughing, ~5 times more virus remains infectious at 7–23% RH than at >43% RH."***

'Relationship between Humidity and Influenza A Viability in Droplets and Implications for Influenza's Seasonality' [9]
Published in 2012.

***"The minimum viabilities occurred between 40–70% RH, we found minimum viabilities at 50%."***

'Decline in temperature and humidity increases the occurrence of influenza in cold climate' [10]
Published in 2014.

***"According to these results, a 1°C decrease in temperature and 0.5 g decrease per m³ in Absolute Humidity increased the estimated risk by 11%"***




*This graph is taken from 'Bacterial colonization and succession in a newly opened hospital'* [11]
*Where HAIs are Hospital Acquired Infections.*

'Effects of temperature, humidity, and diurnal temperature range on influenza incidence in a temperate region' [12] Published in 2019.

***"The risk of influenza incidence was significantly increased with low daily temperatures of 0-5°C and low (30%–40%) or high (70%) relative humidity"***

ASHRAE's technical handbook, in the chapter on humidifiers, aligns with the research.13

## PREVENTION AND TREATMENT OF DISEASE

Relative humidity has a significant effect on the control of airborne infection. At 50% rh, the mortality rate of certain organisms is highest, and the influenza virus loses much of its virulence. The mortality rate of these organisms decreases both above and below this value. The graph below is taken from the ASHRAE handbook.

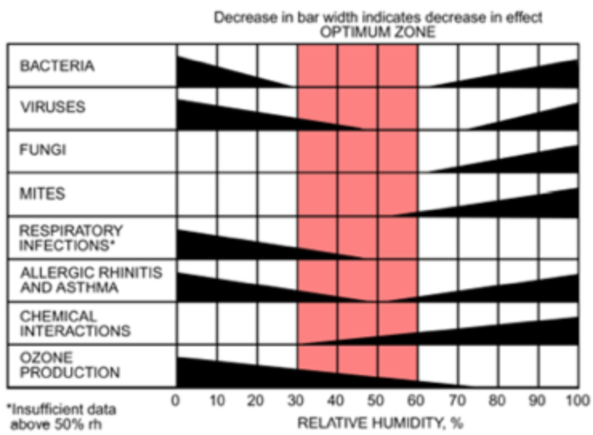
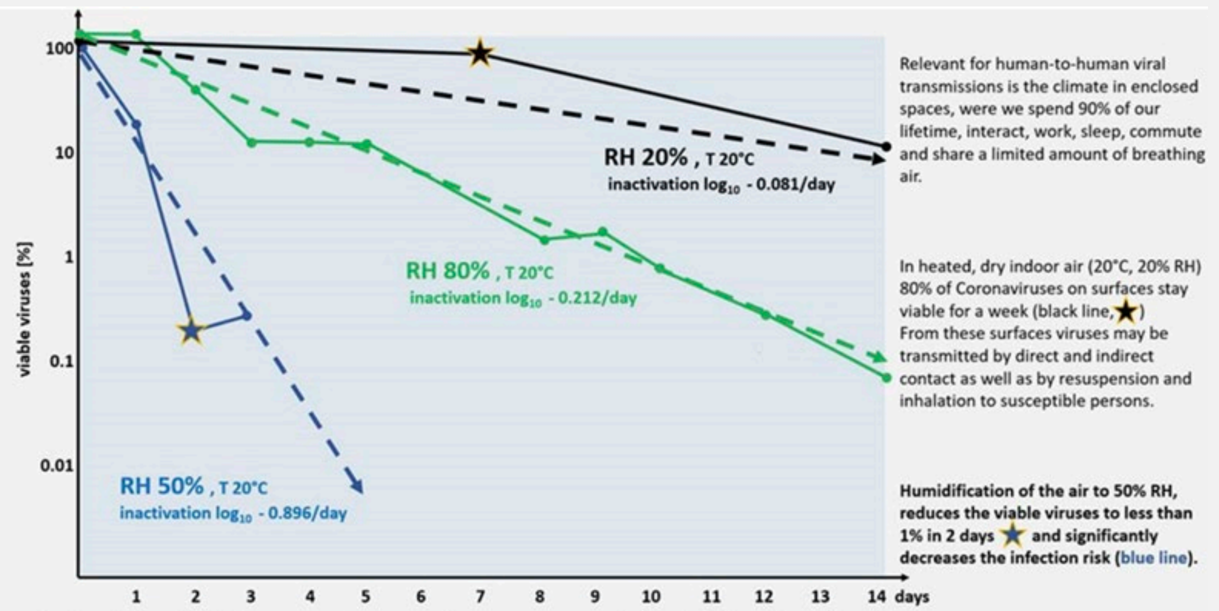



**Fig. 1 Optimum Humidity Range for Human Comfort and Health**
(Adapted from Sterling et al. 1985)

A study after the SARS-CoV-1 outbreak 'Effects of Air Temperature and Relative Humidity on Coronavirus Survival on Surfaces' [14]
Published in 2010.

***"The relationship between inactivation and Relative Humidity was not monotonic, and there was greater survival or a greater protective effect at low RH (20%) and high RH (80%) than at moderate RH (50%)."***

This result is shown in graph form below.




**Graph 1** Inactivation of SARS Coronavirus–Surrogate TGEV at room temperature 20°C and at different humidities of 20% (black), 80% (green) und 50% (blue). Fastest inactivation at 50% RF (- 2.5 $\log_{10}$ in 2 days)

**Casanova LM et al**, Effects of Air Temperature and Relative Humidity on Coronavirus Survival on Surfaces, APPLIED AND ENVIRONMENTAL

The first study on the effect of humidity on Covid-19 'High Temperature and High Humidity Reduce the Transmission of COVID 19'15 Published on 9th March 2020 concludes that Covid-19 virus reacts in a similar manner. "We find, under a linear regression framework for 100 Chinese cities, high temperature and high relative humidity significantly reduce the transmission of COVID-19."

New studies are being published monthly. In April 2020 a publication '2019 Novel Coronavirus (COVID 19) Pandemic Built Environment Considerations To Reduce Transmission'28, states that "Based on data related to SARS and MERS, we predict that the viability of SARS-CoV-2 in aerosol is likely longer at lower relative humidity levels." And goes on to say, "Previous research has found that, at typical indoor temperatures, relative humidity (RH) above 40% is detrimental to the survival of many viruses, including CoVs in general."

A recent study 'A psychrometric model to predict the biological decay of the SARS-CoV-2 virus in aerosols' [30] proposes "a psychrometric model to predict the biological decay rate of the virus in aerosols. This revealed that it is possible to predict with a high degree of accuracy the biological decay constant for SARS-CoV-2 using a regression model with enthalpy, vapour pressure and specific volume as predictors."

The conclusion is that "[the] survival of the SARS-CoV-2 virus in aerosols is inversely related to both air temperature and vapour pressure, with survival greatly increasing during the winter months when the air is cooler and drier". The model developed shows that the "the average half-life of the virus in aerosols was in the region 13–21 times longer (in London) in March, when the outbreak was accelerating, than it was in August when it was at its nadir." This result is mirrored by the model for all climates, for example "in Milan during March 2020 (when the Italian COVID-19 epidemic started to accelerate) the predicted mean half-life of the virus was 517 minutes, whereas in July and August (when the Italian epidemic reached its low point) the mean half-life was just 26 minutes".

**In Conclusion Indoor relative humidity is a key factor in reducing the viability of virus particles in the built environment and in increasing the resistance of humans to contracting viral diseases.**

**The optimal Indoor relative humidity is 50% but maintaining the indoor humidity, at normal internal temperatures, between 40% and 60% has a positive effect in reducing the viability of virus particles and in improving resistance to infection.**

It should be noted that REHVA's advice is contrary to the above. However, REHVA's advice seems to refer, principally – when their publication was written, to spring conditions. Low relative humidity in winter will be more critical.
In addition, REHVA refer only to relative humidity. There is some research which indicates that enthalpy (or absolute humidity) rather than relative humidity is the important factor. 18 In that context reducing internal temperatures to increase relative humidity should not be advised.

## FLÄKTGROUP OFFER

FläktGroup can offer a variety of solutions that contribute to keeping the indoor relative humidity within the target zone.

Of the three types of heat recovery devices (i.e. cross plates, run around coils and thermal wheel) only thermal wheels allow moisture recovery.

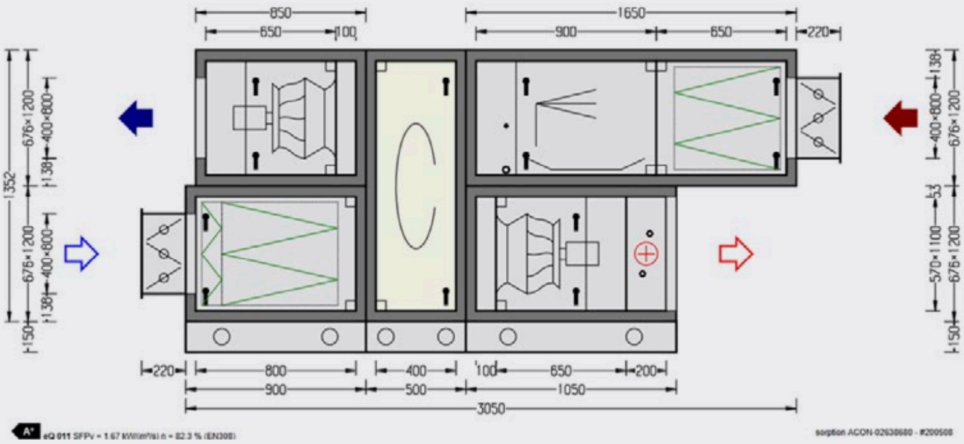
There are three forms of thermal wheel;

- Sensible heat recovery only where there is no moisture transfer and therefore no benefit in maintain indoor humidity.
- Hygroscopic wheels which can recover approximately 50% of moisture
- Sorption wheels which recover up to 75% of the moisture.

FläktGroup offer is for Sorption rotors and are therefore the best at maintaining indoor humidity.

If there is insufficient moisture being generated within a building, then active humidification is required. Traditional humidifiers are expensive to run and have in recent years become less common. FläktGroup can supply traditional humidifiers.

An alternative, low running cost solution is adiabatic humidifiers mounted in the extract leg of an Air Handling Unit and coupled with a Sorption rotor. This is a standard solution from FläktGroup. In the example shown below it is possible to maintain indoor humidity at 50% with an external temperature of -10°c




| Product | | Winter calculation | | |
|---|---|---|---|---|
| Product code | Function | Flow [m³/sec] | Temp [°C] | Humidity [% relative] |
| Supply inlet | | | -10 | 90 |
| | Connection section | 1.01 | -10 | 90 |
| | Filter | 1.01 | -10 | 90 |
| | Heat exchanger | 1.01 | -10 | 90 |
| | Plenum fan | 0.97 | 11.6 | 87.4 |
| | Air heater | 0.97 | 12.2 | 83.8 |
| Supply outlet | | 1 | 21 | 47.8 |

# Safe use of heat recovery sections

Under certain conditions virus particles in extract air can re-circulate into the building.

Heat recovery devices may (but there is no evidence that virus-bearing particles starting from 0.1 micron would) carry over virus attached to particles from the exhaust air side to the supply air side via leaks. Because the leakage rate does not depend on the rotation speed of rotor, rotors should not be switched off. 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, thus higher ventilation rates are recommended.

Regenerative air to air heat exchangers (i.e. rotors, called also enthalpy wheels) may be sensitive for considerable leaks in the case of poor design and maintenance. Leakage rates for plate heat exchangers are in the range of 1-2%. For properly operating rotary heat exchangers, fitted with purging sectors and correctly set up, the leakage of potentially contaminated by pathogens from extract air to supply air stream is typically very low and in practice negligible leakage rates and can be as low as 0%.

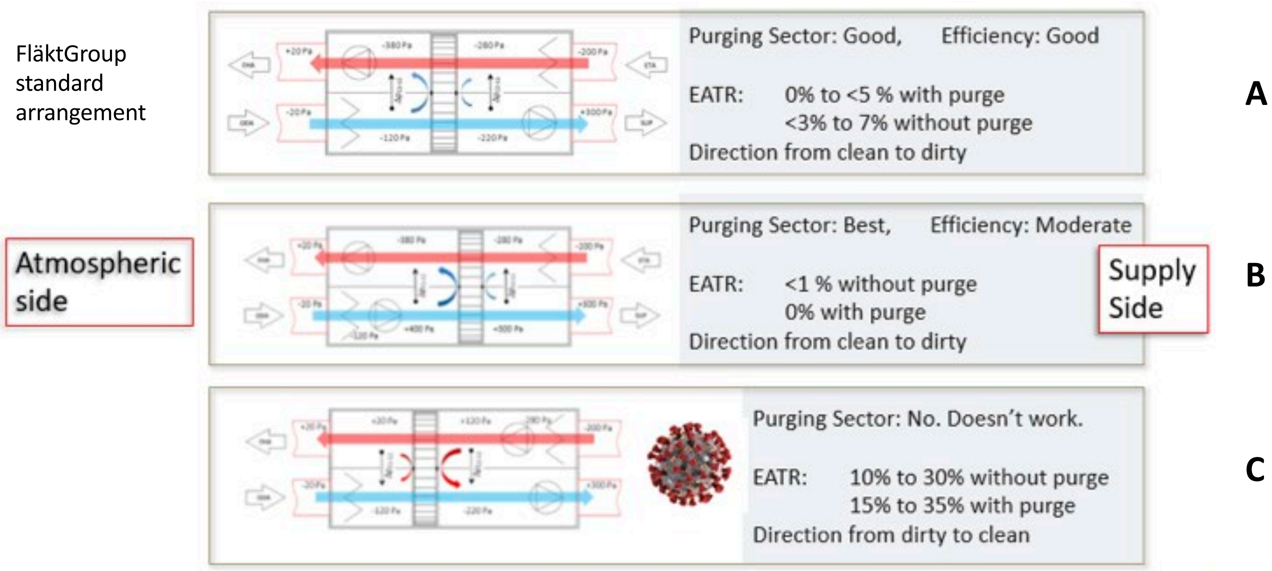
**All FläktGroup AHUs manufactured in Sweden with rotors are always supplied with a purge sector. FläktGroup AHUs manufactured in Germany can be fitted with purge sectors. We advise that in the future all units are supplied with purge sectors. Some units previously supplied may not have purge sectors fitted. An additional safety measure should be to check, and change if necessary, the brush seals for the rotor.**

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 that higher pressure on the exhaust air side is created. This will cause leakage from extract air into the supply air. The degree of uncontrolled transfer of polluted extract air can, in these cases, be up to 35%, that is not acceptable.

The leakage from exhaust to supply airstreams is known as ‘Exhaust Air Transfer Ratio’ (EATR). EN 16798-3:2018 contains the definition for the calculation of EATR. If the rotor has a purge sector and the correct internal pressure balance, then the EATR is 0%. That is, there is no transfer of exhaust air to supply air.

REHVA have published a specific guide “REHVA COVID-19 specific guidance document- Limiting air leakages across the rotary heat exchanger” [2]

REHVA reference the recently published Eurovent guidelines “Eurovent REC 6-15 - Air leakages in Air Handling Units - First Edition – 2020” [17]. This document details all the leakage rates associated with the 4 different possible fan configurations and a summary of this data is shown below.




**A** is the standard configuration supplied by FläktGroup and very low risk

**B** is an available configuration from FläktGroup and very low risk

**C** can result in very high recirculation and should be switched off or run as an extract only system

To eliminate a leakage, it is critical to set the correct relation between system side supply and exhaust pressures. Exhaust pressure should be less than supply pressure, ideally at least 20 Pa.

Depending on the configuration of fans, this can be done by throttling as follows:

**Both fans after the rotor (A):**
add pressure to the extract air such that Δ between the extract and supply is -20 Pa. If the throttling device (e.g. damper) is not available in an AHU, it should be installed in the ductwork.

**Both fans on the outdoor side (B):**
There is no need to use throttling in this case.

**Both fans on the building side (C):**
There is no possibility to use throttling in this case.

If leaks are suspected in the heat recovery sections, pressure adjustment or bypassing (some systems may be equipped with bypass) can be an option in order to avoid a situation where higher pressure on extract side will cause air leakages to supply side. Pressure differences can be corrected by dampers or by other reasonable arrangements.

**In conclusion, we recommend an inspection of the heat recovery equipment including the pressure difference measurement. Maintenance personnel should follow standard safety procedures, including wearing gloves and respiratory protection.**

**Virus particle transmission is not an issue when a HVAC system is equipped with a run around coil system that guarantees 100% air separation between exhaust and supply side.**

## FLÄKTGROUP OFFER

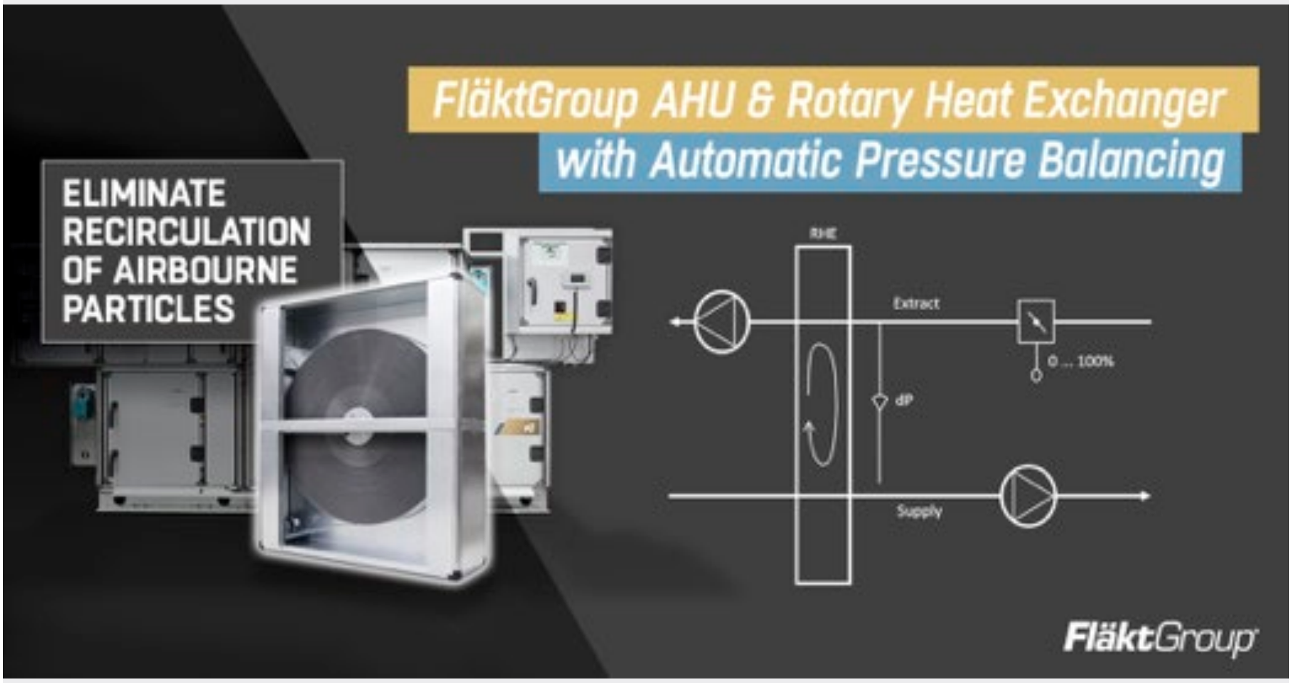
FläktGroup's eQ Master range has offered pressure control over the rotor as a selectable option for several years. This is only available when the unit is supplied with integrated controls. For eQ Prime pressure control is available via adjustable diffusion plates. For CAIRplus pressure control is now available by contacting the controls group CSS department.

The leakage at the rotor from extract to supply air is minimized, by measuring and controlling the differential pressure from the extract to the supply air to a low but negative set point.

As default the set point is -10 Pa.

To achieve this, the extract air damper is equipped with a modulating actuator (0–10VDC), which is controlled to close to reduce the pressure and controlled to open to increase the pressure.

***Note:*** the software function in the Climatix controller can also control a modulating damper in the outdoor air. This part of the function is used for Active mixing to create the mixing flow.



# Recirculation- AHUs

Virus particles in return ducts can also re-enter a building when centralized air handling units are equipped with recirculation sectors. It is recommended to avoid central recirculation during SARS-CoV-2 episodes: close the recirculation dampers (via the Building Management System or manually). In case this leads to problems with cooling or heating capacity, this has to be accepted because it is more important to prevent contamination and protect public health than to guarantee thermal comfort.

Exhaust air filters in AHUs with recirculation sections are unlikely to be of a grade to capture virus particles. The presence of exhaust filters should not be a reason to keep recirculation dampers open unless they are HEPA class H13 or better.

Recirculation sections may assist outside of operating hours in maintaining optimal temperature and humidity but should be disabled as soon as a building is occupied.

This should only be considered in situations where the re-circulation is disabled by the BMS system.

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. REHVA are currently preparing advice on the sizing and installation of UV-C systems.

UV-C 'in-duct' application within air-conditioning systems and ventilation ducts may also be a practical approach for disinfecting contaminated extracts or in cases where it is not possible to stop recirculation of ventilation flows. [16]

These systems are of little benefit against person-to-person transmission within the occupied zone but do have a benefit where central supply and extract air handling units are recirculating air from within the space or building.

The US Centers for Disease Control has approved both upper-room and in-duct systems for use in controlling tuberculosis transmission as an adjunct to HEPA filtration. [16]

Provision of such a system should enable re-circulation systems to be put back into service provided that the re-circulation section is closed in the event of UV-C failure.

**FläktGroup can supply correctly dimensioned UV-C solutions to disinfect either components or the supply and/or extract airstream. UV-C can be either unit or duct mounted and comes complete with; light traps to prevent UV-C light leakage, safety cut outs and casings constructed of materials not subject to deterioration from UV-C.**

# No use of recirculation – Fan Coils

There is very little correlation between countries on the use of fan coils.

REHVA have produced a specific document for the operation of fan coils; "REHVA COVID-19 specific guidance document -Use of fan coils and avoiding recirculation" [3]

## FLÄKTGROUP OFFER

In applications where fan coil units are used, we recommend avoiding recirculation mode and ensure sufficient outdoor air ventilation.

There are two options how to ensure ventilation;

Active operation of window airing together with the installation of CO2 sensors.

Or the installation of a standalone mechanical ventilation systems. This is the only way to ensure sufficient outdoor air supply to the rooms at all times.

Primary air ventilation rate should be increased as much as possible in fan coils equipped with primary ventilation supply air. Single rooms or homes with fan coil units need only regular airing the space. In the case of large rooms occupied by many people, fan coil units are recommended to be continuously operated at low speed. If such control adjustment is not possible, the units must be forced to operate. During the occupancy hours, leave the windows partially open to ensure a certain degree of ventilation.

Strong air flows from one person to another might cause infection. Therefore, good air distribution, i.e. providing even ventilation rate at low air velocity within all points in the room is important.

# Duct cleaning has no practical effect

Duct cleaning is not necessary, because viruses stay viable no longer than 2-3 days on plastic and stainless-steel surfaces. In the ductwork, this time is probably even shorter, as in the airflow they stay viable only for 3 hours.

If duct cleaning is undertaken dust emission rates can be very high. Commonly vacuum collector units are used to create necessary pressure and air speed in the ductwork part under cleaning, and the dust is collected to the filter unit of the vacuum collector. These units are typically equipped with HEPA filters which are also needed to capture possible virus particles. Therefore, the equipment and standards for ductwork cleaning are sufficient. Detailed information on the ductwork cleaning work planning and equipment is available in REHVA Guidebook 8.

Personnel undertaking duct cleaning or any other operations which involve accessing, in particular, exhaust air ducts will require suitable PPE (see filter section).

# Altering the grade of outdoor air filters is not necessary

In COVID-19 context, it has been asked should the filters to be replaced and what is the protection effect in very rare occasions 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 or ISO ePM2.5 or ePM1) which filtrate well particulate matter from outdoor air. The size of a naked coronavirus particle of 80-160 nm (PM0.1) is smaller than the capture area of F8 filters (capture efficiency 65-90% for PM1), but many of such small particles will settle on fibres of the filter by diffusion mechanism. SARS-CoV-2 particles also aggregate with larger particles which are already within the capture area of filters. This implies that in rare cases of virus contaminated outdoor air, standard fine outdoor air filters provide a reasonable protection for a low concentration and occasionally spread viruses in outdoor air.

Heat recovery and recirculation sections are equipped with less effective extract air filters (G4/M5 or ISO coarse/ ePM10) which aim is to protect equipment from dust. These filters do not have to filter out small particles as virus particles will be ventilated out by exhaust air (see also the recommendation not to use recirculation under 'no use of recirculation').

From the filter replacement perspective, normal maintenance procedures can be used. Clogged filters are not a contamination source in this context, but they reduce supply airflow which has a negative effect on indoor contaminations itself. Thus, filters must be replaced according to normal procedure when pressure or time limits are exceeded, or according to scheduled maintenance. In conclusion, we do not recommend changing existing outdoor air filters and replace them with other type of filters nor do we recommend changing them sooner than normal.

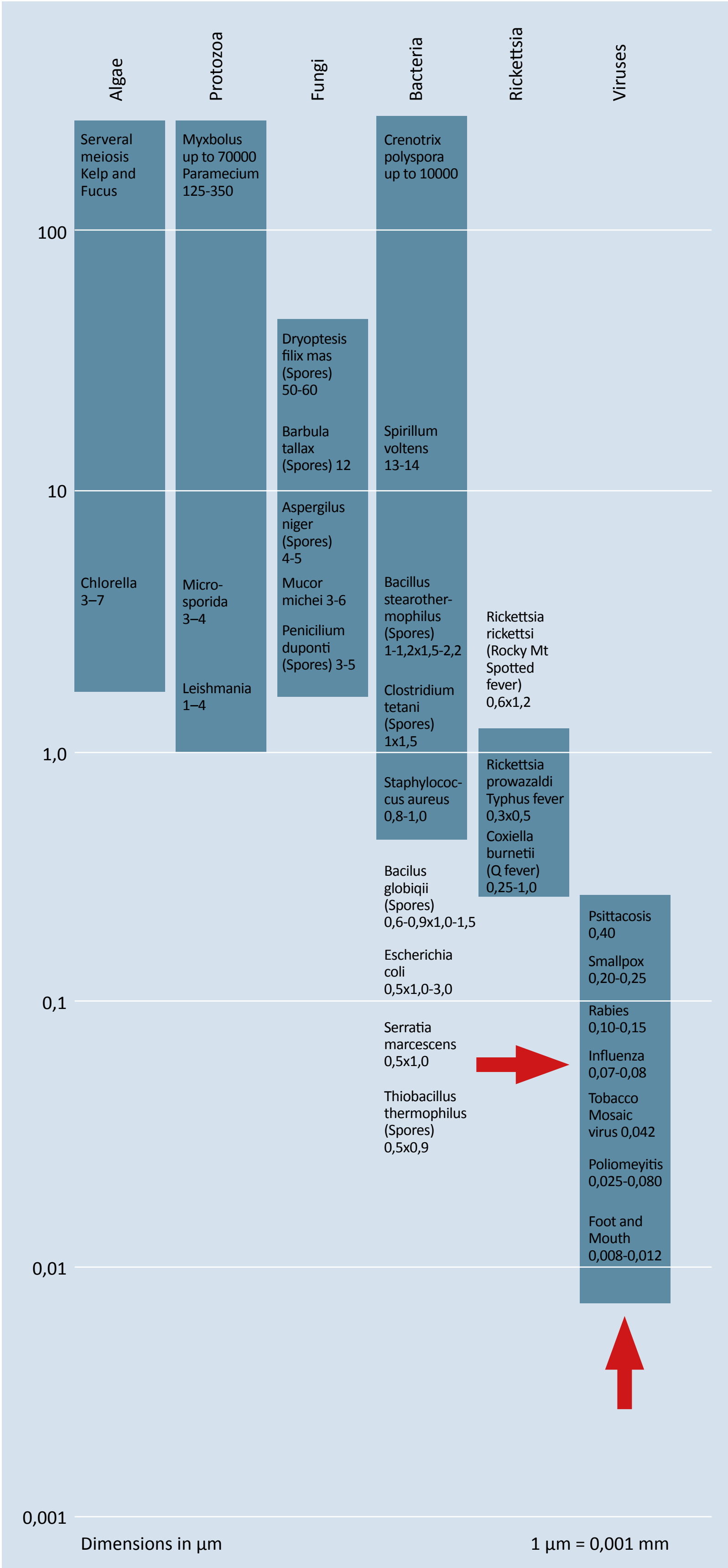
HVAC maintenance personnel could be at risk when filters (especially extract air filters) are not changed in line with standard safety procedures. To be on the safe side, always assume that filters have active microbiological material on them, including viable viruses. This is particularly important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

RLT's Covid-19 advice v4 states that "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." This advice is also applicable for return air filters either extracting to atmosphere or for recirculation sections.

## SPECIFIC FILTRATION IN HOSPITALS

For isolation rooms with patients with airborne infections there will be high levels of virus particles. Exhaust air to atmosphere should be filtered using HEPA filters whenever there is a risk of cross contamination from the exhaust air outlet to nearby windows or outdoor air intakes. For wards for patients with infectious diseases any ventilation system should be updated to meet the requirement for isolation rooms.

## VIRUSES VARY BETWEEN 0,01 TO 01 µM AND ARE CONSIDERED THE SMALLEST MICRO-ORGANISMS

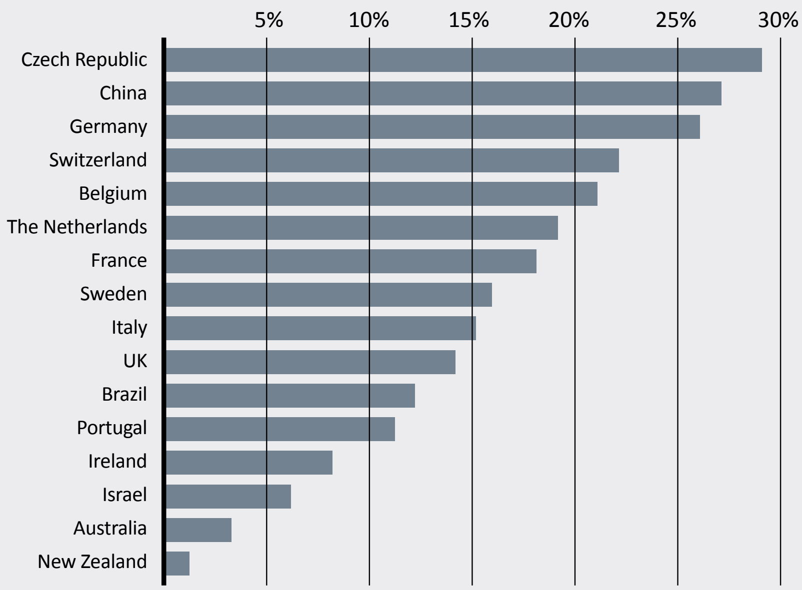



Source: Philips

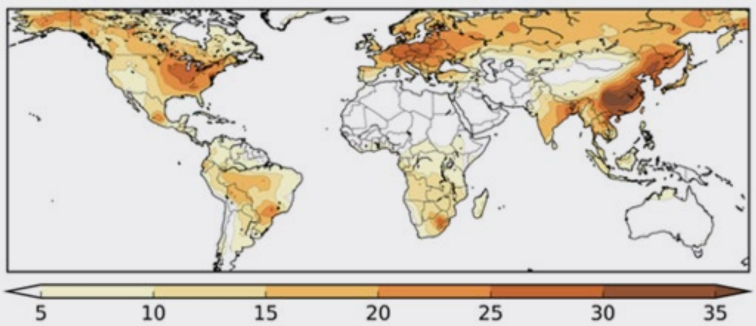
## LINKING POLLUTION TO COVID-19

There is an increasing amount of evidence that links pollution with susceptibility to increased impact due to Covid-19. 'Regional and global contributions of air pollution to risk of death from Covid-19' [31] The conclusion was that "the percentage increase of Covid-19 mortality risk per mg/m$^3$ increase of exposure to PM2.5, was found to be 8%" This equates to ~19% of the mortality due to Covid-19 in Europe.

### PERCENTAGE OF COVID-19 DEATHS THAT COULD BE LINKED TO LONG-TERM POLLUTION EXPOSURE

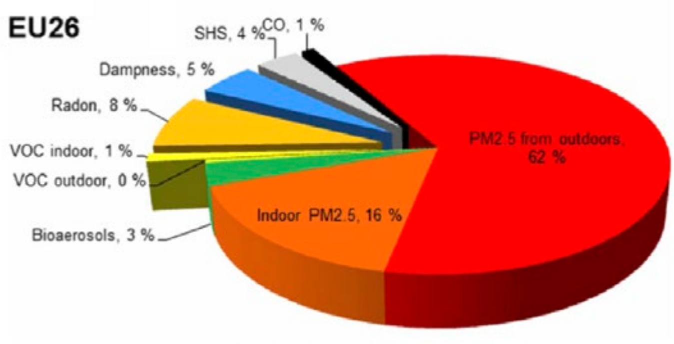



Using that formula, it is then possible to predict the estimated percentages of Covid-19 mortality attributed to air pollution. The figure below displays the results. The darker the colour the higher the risk.




The study above is referenced in a study requested by the ENVI ( Environment, Public Health and Food Safety) committee of the European Parliament on Air pollution and Covid-19. Within that study is a figure which shows the Burden of disease based on the indoor pollution. As can be seen the large majority of indoor pollution is as a result of PM2.5 particles from outdoors. It is clear that there will be increasing focus in the future on filtering outdoor air pollution to minimise the burden of disease.

### BURDEN OF DISEASE DUE TO INDOOR POLLUTION




Note: Based on 26 EU countries (no data were obtained for Croatia and Malta) (2.1 M Disability Adjusted Life Years (DALY)/year).

Source: Asikainen et al., 2016.

# Strong, high velocity airflows

The latest guidance from REHVA (version 4 published in November 2020) gives detailed advice on minimising high airflow velocities in the occupied zone and thus reducing the potential for onward transmission. The information is too extensive to summarise in this publication, so it is advised to download from the REHVA website. In addition, there is a ventilation risk calculator [38] designed to assist experts who have read and understood the related COVID-19 guidance document in making an objective assessment of benefits of mechanical ventilation in minimising transmission.

While studies are still ongoing about how the coronavirus spreads via air, evidence suggests that measures to change indoor airflow patterns could play a role in reducing transmission.

Some studies have found that the coronavirus was likely transmitted when strong airflows from split air conditioning units or fan coils resulted in high velocity air streams which spread large droplets from an infected person. These droplets can travel more than one metre – further than usual, but less than the distance aerosols can typically travel. Care should also be taken if increasing the general ventilation rate to ensure that are not put under positive pressure so virus particles are pushed out of rooms into other areas such as corridors.

Changing airflow patterns to create laminar vertical airflow—air moving in the same speed and in a straight path – may effectively prevent the airborne transmission of coronavirus particles. This principle is already used to prevent the spread of particles in several settings.
For example, clean rooms and hospital operating rooms minimize contamination via sophisticated systems to direct air from the ceiling to the floor with laminar flow.

In some cases, consideration could be given to add physical barriers, such as partitions that separate open space, to manage airflows within rooms. Some building managers and others may want to take steps to prevent contamination between rooms—something that could occur if the coronavirus is found to spread via airborne transmission. These solutions might include installing doors or air curtains.

# Room air cleaners can be useful in specific situations

Room air cleaners remove effectively particles from air which provides a similar effect compared to ventilation. To be effective, air cleaners need to have at least HEPA filter efficiency.

Devices that use electrostatic filtration principles (not the same as room ionizers!) often work quite well too. Portable consumer air cleaning devices may be beneficial in smaller rooms, although it should be recognised that such devices must be appropriately sized for the space. [16]

There is a new range of AP BIO purifiers – available from FläktGroup – where the filtration media deactivates virus material. The airflow through air cleaners has typically been limited, the floor area they can effectively serve is normally quite small, typically less than 10 $m^2$. The range of FläktGroup AP BIO Purifiers can safely purify rooms up to 50 $m^2$. This aligns with published papers which state that "Air cleaners were similarly effective against removing both airborne bacterial and fungal spores from the air at clean air delivery rates of between 26 and 980 $m^3$/h corresponding to effective cleaning of between 5 and 189 $m^3$ room volumes respectively." [16] If one decides to use an air cleaner (again: increasing regular ventilation often is much more efficient) it is recommended to locate the device close to the breathing zone.

Special UV cleaning equipment to be installed for the supply air or room air treatment is also effective at killing bacteria and viruses but this is normally only a suitable solution for the equipment for health care facilities. REHVA guidance targets common non-residential buildings and in this case, outdoor air is NOT a contamination source. Therefore, UV-treatment of outdoor air in air handling units is not necessary. This is the reason they do not recommend UV-applications.

UV-C treatment of exhaust air, in particular where the central AHU has a re-circulation section, to ensure economical running of the ventilation system. Extreme care would need to be taken to ensure that the UV-C solution has been correctly dimensioned.

## FLÄKTGROUP OFFER

FläktGroup can supply correctly dimensioned UV-C solutions to disinfect either components or the supply and/or extract airstream. UV-C can be either unit or duct mounted and comes complete with; light traps to prevent UV-C light leakage, safety cut outs and casings constructed of materials not subject to deterioration from UV-C.

# Specifics of service visits

- **Keep toilet ventilation 24/7 in operation.**

  Toilet extract systems, if they exist, should be checked by a service engineer to ensure that they are working correctly. Non-functioning fans should be replaced. Exhaust ventilation systems of toilets should result in an under-pressure such that they create air movement that is unlikely to spread any airborne viral particles, especially to avoid the faecal-oral transmission. Toilets are high traffic areas where human contact with surfaces is inevitable. The risk of virus transmission in toilets is high. In addition, Covid-19 can be spread into the atmosphere when a toilet is flushed.

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

  **FläktGroup have a range of extract fans that can be supplied for toilet systems. If the position of toilet exhaust grille is such that exhaust air may be inhaled by people consideration should be made to fit a HEPA filter to the system of at least H13 grade. FläktGroup can supply these if required.**

- **Switch air handling units with recirculation to 100% outdoor air**

  Re-circulation of potentially contaminated air is not recommended. The damper in any re-circulation section of an AHU should be closed. This may be possible via the BMS system but can also be done manually by a service visit.

  **FläktGroup service engineers, where available can undertake this work if required.**

- **Inspect AHUs with rotors to establish the following**

  – Check the location of the fans. If both fans are on the system side of the rotor FläktGroup can advise on replacement units or the addition of UV-c

  – Check to see if the rotor has a purge section. If the rotor does not have a purge sector then FläktGroup may be able to supply a replacement rotor.

  – Check the pressure balance to ensure internal airflow is in the direction of clean fresh air to dirty extract air.

  **FläktGroup service engineers, where available can undertake this work if required.**

- **Inspect heat recovery equipment to be sure that leakages are under control.**

  Plate heat exchangers may leak. A controlled smoke test could be undertaken to check the direction of any leakage. Eurovent certified plate heat exchanger manufacturers declare the leakage of their equipment. Typically, this figure is between 1% and 2%

REHVA have established a methodology for measuring leakage in units with rotary heat exchangers. Details below.

**FläktGroup service engineers, where available can undertake this work if required.**

- Method to estimate leakage (EATR) for on-site tests
- The precise test of internal air leakage must be carried out at the laboratory. However, a draft of a new upcoming standard (prEN 308) provides a simple method for the estimation of EATR by temperature measurement that can be performed on-site. The test procedure includes measurements of temperatures t11, t21 and t22 in steady-state conditions with the rotor stopped.
- Next, EATR is calculated as:

$$EATR = \frac{t_{22} - t_{21}}{t_{11} - t_{21}}$$

Where,

- t11 is temperature exhaust air inlet;
- t21 is temperature supply air inlet;
- t22 is temperature supply air outlet.
- The part of leakage related to the rotation of wheel (carry-over) cannot be determined by this method.

- **Replace central outdoor air and extract air filters as usually, according to maintenance schedule.**

  In general, it is wise to assume that filters have active microbiological material on them. Whether this represents an important infectious disease risk from viruses is not known, but the precautionary principle would suggest that care should be taken. This becomes particularly important in any building (including residential) where there are known or similar cases of any infectious disease including COVID-19. The system should be turned off when changing filters and taking all necessary protective measures such as wearing gloves, including an FFP3 respirator if available, outdoors if possible and disposed of in a sealed bag.

  General ventilation filters are not designed to capture virus particles. The addition of HEPA filters can be beneficial for critical areas but are unlikely to be a practical solution for general ventilation systems.

**FläktGroup service engineers, where available can undertake this work if required.**

- **Regular filter replacement and maintenance works shall be performed with common protective measures including respiratory protection.**

  All FläktGroup service teams are equipped with the necessary PPE to ensure safe removal of filters and have clear instructions for the safe disposal of the dirty filters.

**FläktGroup service engineers, where available can undertake this work if required.**

# Clarifications of research papers linking ventilation or air conditioning to virus transmission

**To date we have become aware of at least three research papers or articles which link ventilation or air-conditioning to virus transmission. The intention of this section is to analyze these papers and identify if they are applicable to FläktGroup products. This will enable sales engineers to have discussions with customers based on the actual contents of the papers rather than hearsay or inaccurate newspaper headlines.**

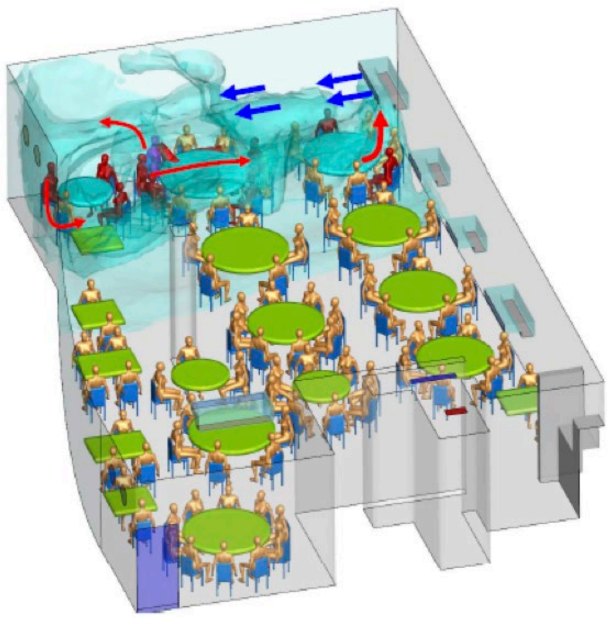
Many people have referenced a research paper titled "COVID-19 Outbreak Associated with Air Conditioning in Restaurant, Guangzhou, China" This paper is actually titled "Evidence for probable aerosol transmission of SARS-CoV-2 in a poorly ventilated restaurant" [20]

This was NOT a central supply and extract system and the conclusions in the report are shown below.

"Virus-laden small (<5 µm) aerosolized droplets can remain in the air and travel long distances, >1 m. However, none of the staff or other diners in restaurant X were infected. ***Moreover, the smear samples from the air conditioner were all nucleotide negative.*** This finding is less consistent with aerosol transmission. However, aerosols would tend to follow the airflow, and the lower concentrations of aerosols at greater distances might have been insufficient to cause infection in other parts of the restaurant." [20]

"We conclude that in this outbreak, droplet transmission was prompted by air-conditioned ventilation. ***The key factor for infection was the direction of the airflow***. Of note, patient B3 was afebrile and 1% of the patients in this outbreak were asymptomatic, providing a potential source of outbreaks among the public. To prevent spread of COVID-19 in restaurants, we recommend strengthening temperature-monitoring surveillance, increasing the distance between tables, ***and improving ventilation.***" [20]

Only people within the throw pattern of the specific air conditioning unit were infected.



**On the 11th July the Telegraph newspaper, published in the UK had article titled "Open windows while using air conditioning, experts say as WHO shifts stance on airborne coronavirus. Units that only used recirculated air could exacerbate the spread of virus particles"** [21]

Another UK paper, The Daily Mail, copied the contents and, on 12th July, published an article titled "British experts say turn OFF air conditioning to reduce risk of spreading coronavirus as WHO admits pathogen can spread through tiny floating droplets" [22]

It should be noted that this refers to split air conditioning units only. The article quotes Dr Shaun Fitzgerald, one of the authors of the CIBSE advice (specific clause shown below), as saying "The recommended strategy now, if you have one of these split units, is to throw the window open and sacrifice your desire for a cold or cooler environment. If there is a modicum of wind it will move the air around. If you can't open a window turn the unit off.'

**CIBSE COVID-19 VENTILATION GUIDANCE 4.2.7**
**Split air systems**

Within a room/zone these systems are good at providing thermal comfort by warming or cooling the indoor air and the air movement they provide can help prevent stagnant areas of air within a room. However, it is important to understand that they do not provide any outside air into the room/zone and without a dedicated source of outside air supply into a room they could be responsible for recirculating and spreading airborne viral particles into the path of socially distanced building users. Ensure that there is a source of outside air provision (either natural or mechanical ventilation) when these units are in operation.

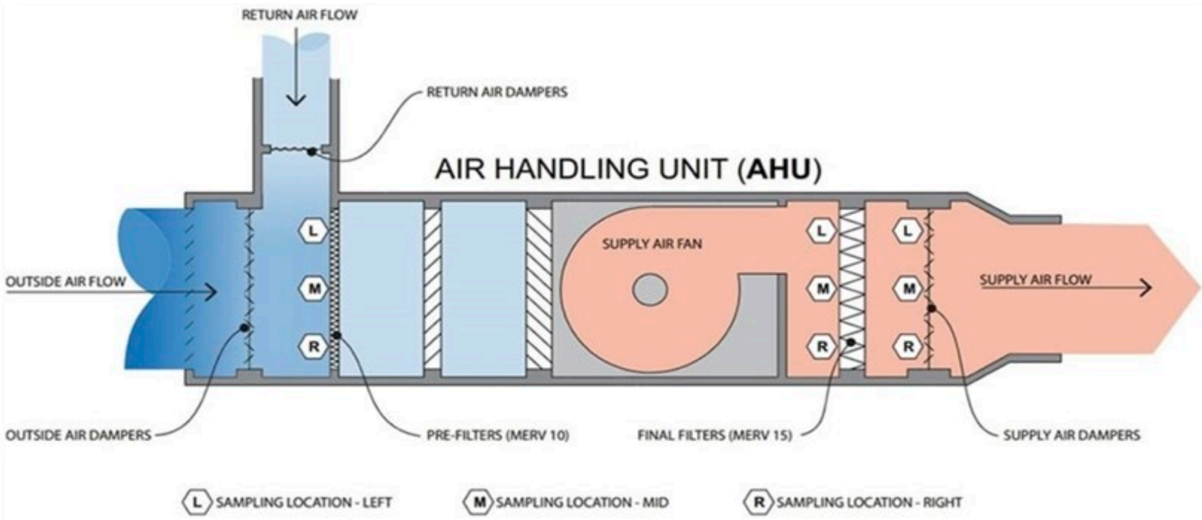
**A new study has been published after an investigation at Oregon Health and Science University (OHSU) Hospital, titled "Identification of SARS-CoV-2 RNA in Healthcare 1Heating, Ventilation, and Air Conditioning Units"** [23]

The conclusion was that "This investigation demonstrates the presence of SARS-CoV-2 RNA at multiple locations within mechanical AHUs, and more specifically, AHUs serving multiple floors of a hospital tower in which COVID-19 patients were housed."

"The infectious potential of this viral genetic material is currently unknown."

The pre-filters are rated at MERV10 (European equivalent is M5, ePM10<60%) and final filters are rated at MERV15 (European equivalent is F9, ePM1>80%)

However, as can be seen from the diagram of the unit below the AHU is a re-circulation unit. This should be stressed in any conversations with customers on this topic.



**A research paper titled "Detection of air and surface contamination by SARS-CoV-2 in hospital rooms of infected patients"** [24]

The study was undertaken in airborne infection isolation rooms (AIIRs) at the National Centre for Infectious Diseases, Singapore. These rooms had 12 air changes per hour, an average temperature of 23 °C, relative humidity of 53–59%, and exhaust flow of 579.6 $m^3$/h.

"The extent of environmental contamination we found in our study could be attributable to direct touch contamination by either the patient or healthcare workers after contact with infected respiratory fluids. However, contamination through respiratory droplets emitted through coughing and sneezing, as well as through respiratory aerosols, is also plausible. Contamination of surface sites not frequently touched (***air exhaust vents and floor***) support this latter hypothesis." [24]

While the exhaust air vents were found to be contaminated no study was made to see if any particles returned to the ventilation system. The ventilation system itself is not described in the paper. The size of the rooms and the proximity of the infected patient to the exhaust grille are also not stated.

**A research paper titled "Airborne transmission of COVID-19: epidemiologic evidence from two outbreak Investigations" by Ye Shen, et al. was published in April 2020** [26]

It links the transmission of Covid-19 to "air conditioning". The outbreak was associated with a training workshop from 12–14 January in Hangzhou city, Zhejiang province. It had 30 attendees from different cities, who booked hotels individually and did not eat together at the workshop facility. The workshop had four 4-hour group sessions, which were in two closed rooms of 49 square metres and 75 square metres. An automatic timer on the central air conditioners ***circulated the air in each room for 10 minutes every four hours, using 'an indoor re-circulating mode'***. No trainees were known to be symptomatic during the workshop. During the period 16–22 January 2020, 15 of them were diagnosed with COVID-19.

This suggests airflow within the conference room was largely contained, continually exposing workshop participants. The particularly high attack rate, approaching 50%, is alarming and suggests large community gatherings, especially those in enclosed settings with minimal air ventilation, should be limited.

### "REPORTS OF A COVID-19 SUPERSPREADER AT STARBUCKS IN KOREA LINKED TO AIR CONDITIONING" [34]

This was another example of the transmission being linked to the high velocities of airflow associated with ceiling mounted air conditioning cassettes.


### "CORONAVIRUS FOUND IN HOSPITAL VENTILATION SYSTEM" [35]

Traces of Covid-19 were found in the exhaust air system filters up to 50m away from the wards where patients with Covid were being treated. The units are run around coil type. There is zero risk of any Covid material being recirculated. The virus that the researchers found was not active, so it was not contagious. The likelihood is that Covid material entered the duct and dried out and was then carried by the airstream to the filters. The ductwork itself was also tested and came back negative for Covid.

### REVIEW OF VENTILATION STRATEGIES TO REDUCE THE RISK OF DISEASE TRANSMISSION IN HIGH OCCUPANCY BUILDINGS [39]

This paper received some publicity in the UK trade press. In promotes natural ventilation as a better alternative to Air Handling Unit powered systems. However, it erroneously refers to current standards of ventilation rates from ASHRAE of 5 L/s/person and for office buildings 2.5 L/s/person. Building Regulations Part F (NBS, 2013b) require a minimum ventilation rate of 10 L/s/person for office applications and EN 13779 suggests for medium indoor air quality a figure of between 10-15 L/s/person (>15 L/s/person for high IAQ) These ventilations are exceptionally difficult to achieve with natural ventilation.

In addition, this paper suggests that AHU are associated "predominantly" with ventilation methods that produce "turbulent, mixing airflows within rooms". It is not the AHU which produces high air flow velocities within the occupied zone, so much as the distribution network. The paper goes on to suggest that displacement ventilation systems are only available utilizing natural ventilation systems. This is not the case. AHUs can be used to provide the supply and extract air for displacement systems.

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This page also includes a FAQ section and is updated periodically. They have published the following specific advice documents;


1. REHVA COVID-19 **guidance document ver3**
2. REHVA COVID-19 specific guidance document **Limiting air leakages across the rotary heat exchanger**
3. REHVA COVID-19 specific guidance document **Use of fan coils and avoiding recirculation**

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