Position Paper – Air Conditioning units in non-healthcare settings

Managing the COVID-19 risks

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Executive Summary

Indoor ventilation is an important consideration regarding viral transmission; correctly applied it can reduce spread. Conversely, poor ventilation promotes viral transmission. The odds of transmission in a Japanese study show that COVID-19 spread was *18 fold higher* in an enclosed environment than in an outdoor environment [36].

The 2 most commonly used types of air conditioners used are: split unit and central ducted with fresh outside air capability. Each type has advantages & disadvantages and the risks of each can be mitigated with relatively simple & inexpensive measures, outlined in this document.

Buildings without any air conditioning:

If buildings don't have any air conditioners, with the ability to introduce fresh air, determine whether the building meets the requirements for natural ventilation, where the room or space must be ventilated to an external window, door or flue and the opening must meet minimum surface area requirements (as provided in SANS 10400 part O). Importantly, the opening must remain open to be compliant with the requirements.

Building with air conditioners:

Air conditioning systems with fresh makeup air capability

If buildings have air conditioning systems with fresh air capability – then operation of the system should aim for 6 air changes per hour or better. This equates to 15L/s/person. CO_2 can be measured as an indicator gas to help ensure ventilation systems are delivering the recommended minimum quantities of outside air to the building's occupants. Importantly, the CO_2 gas readings must be obtained while the workspace is deemed to be *fully occupied* (i.e. the maximum number of people that would routinely occupy the space).

This guideline for office ventilation during COVID-19 further asserts that indoor CO2 concentrations in a *fully occupied* workspace should not exceed 400 ppm above outdoor CO_2 concentrations. When this level is exceeded, it is a measure of poor ventilation, indicating that corrective action is necessary.

In explanation, if a building has low occupancy and CO_2 concentrations do not exceed 400ppm above outside air, this does not indicate that 6 air changes per hour or better is being achieved, since a higher occupancy may result in CO_2 concentrations exceeding 400ppm.

Split unit air-conditioners

If buildings have split unit air conditioners, (without fresh makeup air capability) then there are two scenarios:

- If there is a supplementary mechanical ventilation system, it must be determined whether the system is designed to achieve 6 air changes per hour and whether it capable of achieving this (the system may not perform as designed for a number of reasons);
- If there is no supplementary mechanical ventilation system, then, in the short term, determine whether the building is able to meet the SANS 10400 part O requirements for natural ventilation, where:
    - If yes, then ventilate the room using natural ventilation; and

- o If no, then the building is unsuitable for use until it is compliant with either natural or mechanical ventilation requirements of SANS 10400 part O;

There is no need for COVID-specific changes in humidity & temperature settings, or even changes in duct & filter maintenance.

HEPA filters are not recommended as mandatory outside health care settings.

Maintenance of air conditioner equipment should be carried out in line with routine manufacture specification. Maintenance should be performed using suitable PPE & training.

Introduction

The outbreak of COVID-19, the illness caused by the coronavirus SARS-CoV-2 began in late 2019, leading to a global pandemic. At the time of writing this document there have been over 9.5 million cases worldwide, and over 537’000 deaths (as on 06/07/2020)[1]. The speed of the spread of the SARS-CoV-2 virus is attributable to several features, including a high attack rate (“basic reproductive number” (R_0) is about 2x that of seasonal flu) and a long asymptomatic infectious period (on average 5.5 days). In fact, many people develop COVID-19 without any symptoms at all – all of whom are unknowingly spreading virus.

The two main routes of transmission of the SARS-CoV-2 virus are via droplets (produced by breathing, speaking, coughing and sneezing) and fomites (contaminated surfaces). An additional route of droplet transmission is generated via flushing toilets.

A fraction of droplets survive from 30 seconds up to one or two minutes. In a confined space, especially with circulating air driven by a fan or split unit air conditioner, these characteristics can lead to transmission much further than 2m from the source.

Likelihood of infection increases with the viral dose to which a person is exposed. Dose is proportional to concentration over time. The viral dose produced by an infected person therefore increases over time in a confined space (e.g. an office with closed windows). When the room air is actively recirculated (split unit air conditioners) the risk of viral spread of COVID-19 is increased.

This global emergency demands efforts to slow viral spread. The main “universal” barriers to transmission are surface disinfection, hand sanitation, personal hygiene, behavioural (cough / sneeze etiquette, social distancing), source isolation (masks), engineering controls (barriers, ventilation) and workplace human proximity controls (seating spacing, shift management, etc.).

This document examines the potential role of air conditioners and workplace ventilation in viral spread and considers steps to be taken to mitigate this.

Legal Requirements

According to COVID-9 Occupational Health & Safety Measures in Workplaces (C19 OHS), 2020, version (04 June 2020), under clause 44 (*Ventilation*):

> *Every employer must –*
>
> *44.1 keep the workplace well ventilated by natural or mechanical means to reduce the SARS-CoV-2 viral load;*
>
> *44.2 where reasonably practicable, have an effective local extraction ventilation system with high-efficiency particulate air HEPA filters, which is regularly cleaned and maintained, and its vents do not feed back in through open windows;*
>
> *44.3 ensure that filters are cleaned and replaced in accordance with the manufacturer’s instructions by a competent person.*

In addition, employers must be mindful of the standard requirements prescribed by the Environmental Regulations for workplaces.[27]

Modes of Transmission

Central to the issue addressed by this paper is an understanding of the mode of transmission of the SARS-CoV-2 virus.

The standard assumption is that the dominant transmission routes are via droplets and via surface (fomite) contact (hand-hand, hand-surface etc.). A transmission route gaining attention is via droplet transmission generated from flushing toilets. Another potential route of transmission is via aerosols. This is discussed below.

Droplet Spread

Droplets emitted when breathing, speaking, coughing or sneezing vary greatly in size (10-1000µm, averaging around 150 µm) and their size affects their behaviour. The droplets begin to evaporate rapidly the moment they leave the body, becoming smaller as they lose water. The largest droplets fall rapidly and settle faster than they evaporate, contaminating the immediate vicinity of the infected individual. With decreasing size, the droplets fall more slowly and have the potential to travel further in the air.

The highest likelihood of transmission is via droplets reaching people directly if they stand within 1-2m of an infected person. They catch the virus directly by breathing in droplets produced by breathing, speaking or coughing. Sneezing can project the virus-bearing droplets up to 6m.

A fraction of these survive from 30 seconds up to one or two minutes. In a confined space, especially with circulating air driven by a fan or split unit air conditioner, these characteristics can lead to transmission much further than 2m.

This route of transmission is known as "*droplet spread*".

Flushing toilets have been shown to produce droplets and aerosols[19-22], warranting further controls to reduce the likelihood that these may be carried by ventilation systems into adjacent areas.

Aerosol Spread

A small fraction of smaller droplets evaporate faster than they settle to form very small residual infectious particles ("droplet nuclei" or "aerosols"). Whilst there is no universally agreed definition for the size of aerosols, a widely used number is <5µm. These remain airborne for hours and have the potential to travel much further than droplets. This route of transmission is known as "*aerosol" or "airborne" spread*.

Mixed Droplet and Aerosol Spread

One should note that "aerosol" is essentially a relative and not an absolute term. A larger droplet can remain airborne for longer if ambient airflows can sustain this suspension for longer. It is likely that in some strong cross-flow or natural ventilation environments, where ventilation-induced airflows can propagate suspended pathogens effectively enough to cause infection at a considerable distance away from the source.

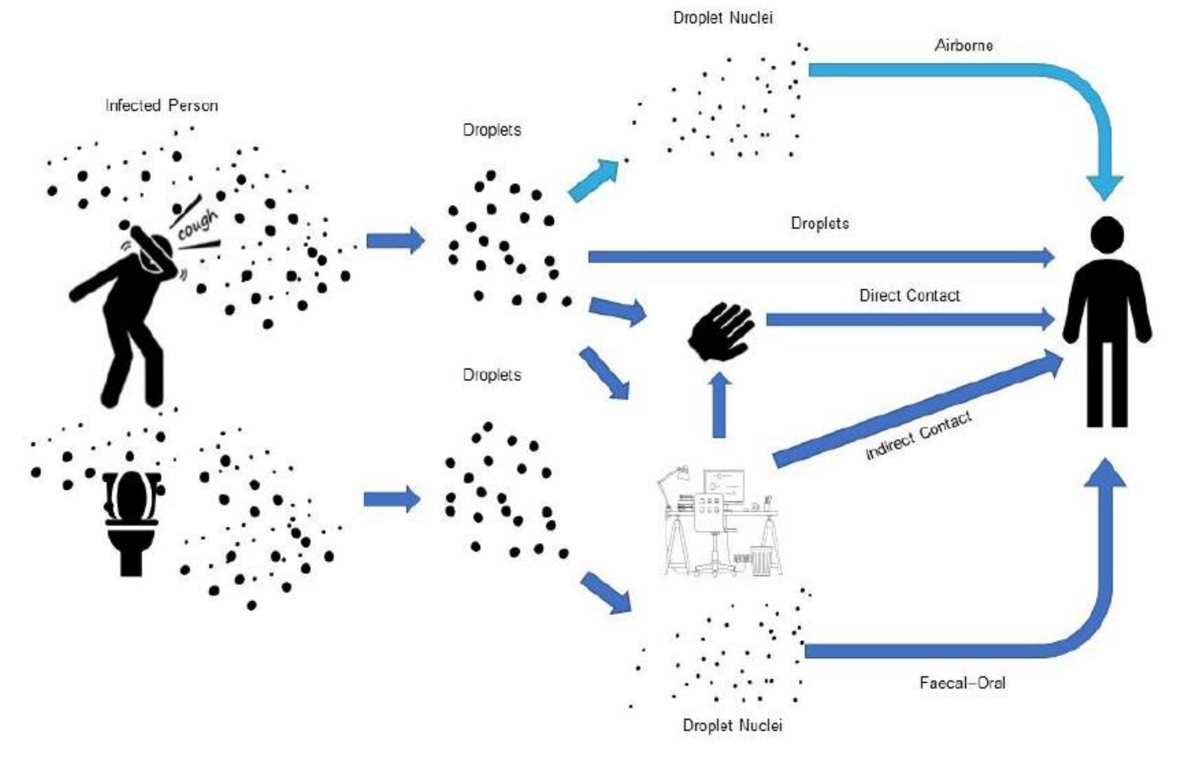
This leads to the likely conclusion that the SARS-CoV-2 virus has mixed transmission routes between droplet and aerosol, with different routes predominating depending on the specific situations. Airborne transmission[35]. This mixed transmission route is applicable for influenza viruses as well as SARS-CoV-1, where it has caused infections in the past [6,7]. It follows that the mixed transmission route is the most realistic route for SARS-CoV-2.

Fomite Spread

Droplets that land on nearby surfaces and objects ("fomites") are spread via contact. People could catch the infection by touching those contaminated surfaces or objects; and then touching their eyes, nose or mouth. The droplets on surfaces evaporate, leaving a residue in which viruses remain viable for periods of hours[16] to days (surgical gloves 8 hrs, aluminium 8 hrs, steel 48hrs, wood, paper & glass 4 days, plastic 5 days)[9, 23].

Should these viable viruses become airborne again, they introduce a potential for further airborne transmission [10-15].

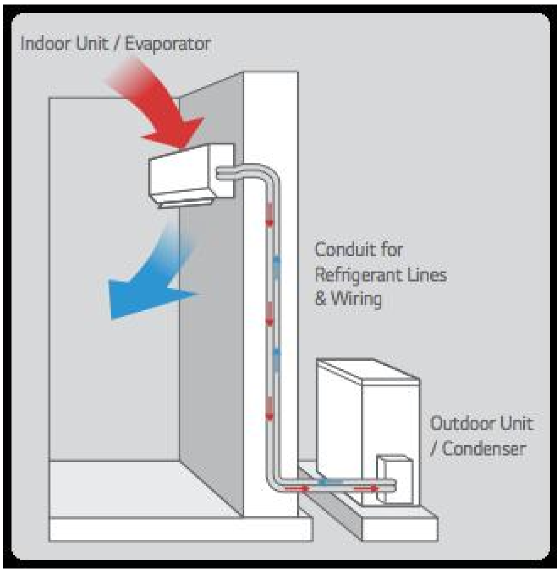
Figure 1: routes of transmission of the SARS-CoV-2 virus*



** Dark blue flows: WHO reported exposure mechanisms of COVID-19 SARS-CoV-2 droplets. Light blue flow: airborne mechanism understood for tuberculosis, measles, SARS-CoV-1 and flu. (figure: courtesy Francesco Franchimon).*

Types of Air Conditioner

Figure 2: Mid wall split unit air conditioner



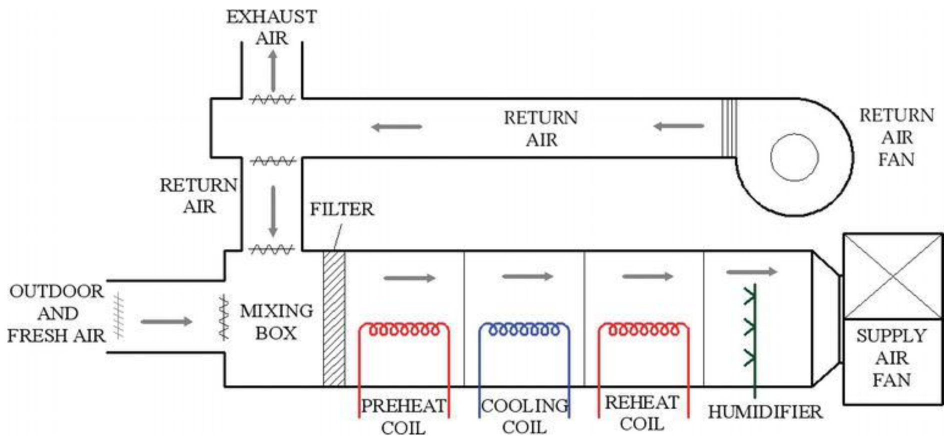
These units essentially recirculate room air, heating or cooling it down.

Unless fresh "make-up" air is added, viral concentration will build up in a room serviced by such a unit.

Make up air MUST be added. The only consistent method of introducing make up air is through the addition of a mechanical ventilation system, which introduces fresh air into the building. Typically, this is a ducted air system using diffusers in the ceiling. If this type of system is not in place a short-term solution is to open windows or doors within the building.

The introduction of fresh air significantly reduces the risk of viral transmission.

Figure 3: Central ducted air con with outside / fresh air capability



These units have many forms.

They all bring in fresh outdoor air via filtered air handling units, then adjust its temperature and humidity before propelling it through the building via ducting.

The key to minimising viral transmission is to maximise the quantities of fresh ("make up") air, and minimising leakage across the heat exchange units.

Practical recommendations for building services operation[8]

This section is a summary of a more detailed document – see "*REHVA COVID-19 guidance document*", April 3, 2020. https://www.rehva.eu/activities/covid-19-guidance

Efforts are primarily directed at removing (flushing out) circulating viruses and bringing in as much fresh (outdoor) air as possible.

In a study by Nishiura et al, that analysed superspreading events, the researchers showed that closed environments with minimal ventilation strongly contributed to a high number of secondary infections[17].

Summary of practical measures for building services operation

1. Ventilation of indoor spaces should include as much outdoor air as reasonably possible.
2. Ensure regular airing with windows (even in mechanically ventilated buildings)
3. Switch air handling units with recirculation to maximum possible percent outdoor air
4. 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
5. At nights and weekends, do not switch ventilation off, but keep systems running at lower speed
6. Keep toilet ventilation 24/7 in operation
7. Avoid open windows in toilets to assure the right direction of ventilation
8. Instruct building occupants to flush toilets with closed lid
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 according to usual maintenance schedule
14. Regular filter replacement and maintenance works must be performed with protective measures including respiratory protection

Increase air supply & exhaust ventilation

- Supply as much fresh outside air as possible, in line with the following:

- SANS 10400-O (2011): The application of the National Building Regulations Part O: Lighting and ventilation, guides that buildings to be either naturally ventilated (4.3.1) or artificially ventilated (4.3.2).
- ***Natural ventilation*** requirements include:
  - The room or space must be ventilated to an external window, door or flue and the opening must meet minimum surface area requirements. Importantly, the opening must remain open to be compliant with the requirements.
  - A building or room with a split unit air conditioner, and that has closed windows and without artificial ventilation, is non-compliant.

  A split unit air-conditioner is not considered as artificial ventilation as it introduces no fresh air. See section on split-unit air conditioners below.
- ***Artificial (mechanical) ventilation*** requirements include:
  - The room or space needs to be supplied with outside air at a rate not less than the greater rate of column 2 or 3 of Table 2 of SANS 10400-O:2011. See Table 1 below.
  - It follows that the lowest possible number of air changes in general offices is 2 air changes per hour, which includes meeting and waiting spaces.

Table 1: Extract from Table 2 of SANS 10400-O:2011

1	2	3	4
Type of occupancy	**Minimum outdoor air requirements**		**Requirement**
	Air changes per hour	**L/s per person**	
Offices			
General	2	7,5	Air supply required per person with required minimum air changes per hour
Meeting and waiting spaces	2	7,5	
Conference and board rooms	10	10,0	
Cleaner's rooms	10	1,0	Air supply required per square metre of floor area

- Keep indoor CO2 levels as low as reasonably possible
  - CO_2 concentration in indoor air provides a good indication of the effectiveness of the ventilation of occupied spaces[32,33] and is useful as an indicator of non-compliance.
  - Ambient (outside) CO_2 concentrations vary according to the environment. Approximate reference values are: Rural areas = 350ppm, small towns = 400ppm, city centres = 450ppm)[32].
  - The European Indoor Air Quality Standard (EN 16798)[32] classifies indoor air in 4 classes. See Table below.

Table 2: Indoor Air Quality and CO_2 levels and Fresh Air Face delivery (EN 16798)

Cat	Indoor Air Quality	CO_2 above outdoor air (ppm)	Fresh Air Face (L/s/person)
IDA1	High	<400	>15
IDA2	Medium	400-600	10-15
IDA3	Moderate	600-1000	6-10

Cat	Indoor Air Quality	CO_2 above outdoor air (ppm)	Fresh Air Face (L/s/person)
IDA4	Low	>1000	<6

Comparison of Table 1 (SANS 10400) & Table 2 (EN16798) indicates:

- The SANS Fresh Air Face value of 7.5L/s/person for offices, meeting rooms and waiting spaces equates to the EN13779's IDA3. This equates to CO_2 levels in the range of 600-1000 above outside air. (Table 2 yellow row).
- SANS 10400 and IDA3 aligns with the ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) recommendation that office indoor air CO_2 levels should not exceed 700ppm above outside air.[33] This standard is based on occupants' comfort and reduction of body odours.
- The highest indoor air quality category (IDA1) requires the CO_2 levels to be < 400ppm above outside air. (Table 2 green row)
- Rudnick et al[34] investigated indoor CO_2 concentrations as a measure of ventilation adequacy and viral transmission risk. This study suggests that an indoor CO_2 value maintained as <400ppm above ambient (outside) air limits viral transmission.

Summary guideline on ventilation targets:

Guideline target for indoor CO2

Taking into account the above, a guideline for a minimum target for the adequacy of indoor air ventilation during COIVD-19 is an ***indoor CO_2 maintained as <400ppm above outside air***. This equates to a minimum of >15L/s/person fresh air.

Guideline target for air changes per hour (acph)

The SANS minimum for *offices*, under normal circumstances, is 2 acph. This equates to 7L/s/person (Table 1). As the guideline target during COVID-19 is 15L/s/person (previous paragraph), it follows that a guideline target for acph should be a minimum of 4acph. However, as the SANS standard for conferences and board rooms is 10acph, it may be better to aim for a more conservative value of ***6acph***.

- Further recommendations regarding air supply & exhaust ventilation
  - Extend operation times in buildings with mechanical ventilation systems.
    - 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 a lower, 400 ppm value, in order to assure the operation at nominal speed.
  - Keep the ventilation on 24/7, with lowered (but not switched off) ventilation rates when people are absent.
  - Reduce the number of employees per meter of workspace to facilitate the ventilation cleaning effect.
  - Exhaust ventilation systems of toilets should always be kept on 24/7, and make sure that under-pressure is created, especially to avoid the faecal-oral transmission.

Use more window airing

- In buildings without mechanical fresh air ventilation systems use operable windows (much more than normally, even when this causes some thermal discomfort). Window airing then is the only way to boost air exchange rates.
- In buildings with fresh air mechanical ventilation, window airing can be used to further boost ventilation.
- In buildings where toilets have mechanical ventilation exhaust systems open toilet windows should be avoided as this may cause reverse air flow of contaminated airflow from the toilet to other rooms.
- If there is no 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 flow ventilation throughout the building.

Minimise recirculation of air

To improve energy efficiency, central ducted air conditioning systems with fresh air capability recirculate a percentage of the extracted air back into the building. This provides a potential route by which virus may re-enter the building, so the percentage should be kept to a minimum.

In the event of a SARS-CoV-2 incident, the recirculation dampers should be closed for a minimum of 3 days (via the Building Management System or manually). This may lead to difficulty with cooling or heating capacity, but this has to be accepted because it is more important to prevent contamination and protect public health than to guarantee thermal comfort.

Apart from healthcare and laboratory settings, air handling units and recirculation sections equipped with return air filters do not filter out particles with viruses effectively since they have standard efficiencies (G4/M5 or ISO coarse/ePM10 filter class) and not HEPA efficiencies. (HEPA = "high efficiency particulate air) and is an efficiency standard of air filter. A HEPA air filter must remove from the air that passes through at least 99.95% (European Standard[24]) or 99.97% (US standard[25]) of particles whose diameter is equal to 0.3 μm; with the filtration efficiency increasing for particle diameters both less than and greater than 0.3 μm.[26]

Split unit air conditioners

These units are typically installed with <u>no additional make up air</u> and serve only as cooling/heating units. ***A ventilation system comprising this type of split unit air conditioner is of particular concern***, as it allows the re-circulation of air in the building with no fresh air introduced. Re-circulation causes potentially increased concentration of contaminants in the room, including the SARS-CoV-2 virus.

Spilt unit air conditioners should therefore **not be used** in rooms with that do not have a mechanism for the introduction of fresh make-up air.

Ways to improve the safety of split air conditioners include:

- Open at least one window, preferably one window or door on opposite sides of the building. This will aid in achieving adequate air changeovers per hour in the room. This limits potential for recirculating air. More open windows = more fresh air allowed in = more virus blown out;
- Install an extractor fan in the frame of an outside window or place a fan at the window facing outwards. This will create a push / pull system.
- If windows of occupied rooms are unavoidably closed, the walls must have air vents
- Install a roof mounted wind turbine ventilator ("Roof Whirly") with a diffuser in the ceiling, to help extract used air.
- On the fan coil heat exchanger surface, it is possible to inactivate the virus by heating up fan coils to 60 ℃ for one hour or 40 ℃ for one day.

Humidification and air-conditioning adjustments have no practical effect

Transmission of some viruses in buildings can be limited by changing air temperatures and humidity levels. In the case of COVID-19 this is unfortunately not an option as coronaviruses are quite resistant to environmental changes and are susceptible only for a very high relative humidity above 80% and a temperature above 30 ˚C [28,29,30], which are not attainable and acceptable in buildings for reasons of thermal comfort and microbial growth. SARS-CoV-2 has been found highly stable for 14 days at 4 ℃; 37 ℃ for one day, whilst 56 ℃ for 30 minutes were needed to inactivate the virus [29].

SARS-CoV-2 stability (viability) has been tested at typical indoor temperature of 21-23 ℃ and RH of 65% with very high virus stability at this RH[16]. Together with previous evidence on MERS-CoV it is well documented that humidification up to 65% may have very limited or no effect on stability of SARS-CoV-2 virus. Therefore, the evidence does not support that moderate humidity (RH 40-60%) will be beneficial in reducing viability of SARS-CoV-2, thus the humidification is not a method to reduce the viability of SARS-CoV-2.

Safe use of heat recovery sections

To maintain correct temperatures, central ducted air conditioning systems must cool down warm circulating air and heat up cold circulating air. Heating requires heat exchange units, of which there are various types, including rotary heat exchangers and plate heat exchangers.

These heat exchange units are a point of potential "leak" of extracted air back into the supply air going into the building. When properly installed, leaks can be expected up to a maximum of 5% which must be compensated for with an increase in the outdoor air (EN 16798- 3:2017). See REHVA document for details. 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. The carry-over leakage is highest at low airflow, thus higher ventilation rates are recommended.[8]

Duct Cleaning

If above guidance about heat recovery and recirculation is followed the ventilation system is not a contamination source, eliminating the need for special additional duct cleaning measures. Viruses attached to small particles will not deposit easily in ventilation ducts and normally will be carried out by the air flow.

Therefore, no changes are needed to normal duct cleaning and maintenance procedures.

Outdoor air filter maintenance

A concern has been expressed regarding unusual circumstances of virus contamination of the outdoor air, such as 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 F84 or ISO ePM2.5 or ePM1) which are effective at filtering 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 means 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.

Normal maintenance procedures can be used for filter replacement. Clogged filters are not a contamination source, but they reduce fresh air supply which can lead to a build-up of indoor air contaminations.

In conclusion, REHVA does not recommend changing existing outdoor air filters and replace them with other type of filters nor changing them sooner than normal. This recommendation does not apply to ventilation systems in health care settings, where HEPA filters are entirely appropriate.

Safety during maintenance

Air con maintenance personnel could be at risk when filters (especially extract air filters in HVAC systems) 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.

Document History

No	Description	Date
0	New – based on outline from ASHRAE (USA)	05 May 2020
1	Re-draft – based on REHVA Guideline (Europe)	20 May 2020
2	Redraft with revisions to modes of transmission	24 May 2020
3	Redraft with additions to split air conditioners section	25 May 2020
4	Inputs from Public Health experts	01 Jun 2020
5	Further improvements to the split air conditioners section. A proposed target CO^2 concentration for indoor air during COVID-19.	23 Jun 2020
6	Addition of research paper providing a CO_2 concentration limit of <400ppm above ambient to limit risk of viral transmission	25 Jun 2020
7 & 8	Addition of more content from SANS 10400 Part O, on building regulations	25 Jun 2020
9	Amendments to section on air conditioners	30 Jun 2020
10	Minor amendments to routes of transmission	07 Jul 2020
11	Further amendments to routes of transmission and new references to indoor air risk.	14 Jul 2020

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