INSPQ INSTITUT NATIONAL DE SANTÉ PUBLIQUE DU QUÉBEC

COVID-19: Indoor Environment

Version 1.1 – May 6, 2020

Questions & Answers

This document is intended to summarize current knowledge regarding the viability and transmission of the SARS-CoV-2 virus in indoor environments, with the exception of healthcare establishments and other care facilities. The content of the responses provided below has, in most cases, been based on the most up-to-date scientific and technical literature. Because the situation and knowledge about the SARS-CoV-2 (COVID-19) virus are rapidly evolving, the information presented in this document are subject to periodic updates. Note that this document is in no way an exhaustive review of the literature and that the technical terms used in the text herein are those employed by the cited authors. Likewise, it should be noted that several scientific publications on COVID-19 cited in this document have been published without peer review.

Questions

Québec

Summary

The topics discussed in this document include SARS-CoV-2 transmission in indoor environments, with the exception of healthcare facilities, the environmental parameters that contribute to maintaining the viability of the virus indoors (temperature and relative humidity) and survival time on various types of surfaces. Also discussed is the potential transmission of the virus through ventilation and air conditioning systems, measures for maintaining these devices and the relevance of filtering indoor air. Finally, the impact of various types of equipment and devices that may be present in living spaces or in public places on the potential dispersion of COVID-19 is also discussed (e.g. pedestal fans, hand dryers and humidifiers). From the data in the literature, several observations can be established to inform occupants, users and managers of public and private buildings on the practices to adopt in indoor spaces to minimize the risk of transmitting COVID-19.

How is SARS-CoV-2 transmitted in indoor environments?

Generally, it is assumed that a symptomatic person infected with SARS-CoV-2 (the virus that causes COVID-19) can produce significant viral loads (or infectious doses) in indoor air (Buonanno *et al.,* 2020), especially when they do not follow appropriate respiratory hygiene measures. This viral load can be dispersed in indoor air in the form of particles of varying sizes that, depending on their diameter and density, and on certain environmental conditions, can stay suspended in air for a period of time (Dietz *et al.*, 2020).

Droplets (particles ≥ 5 micrometres or μm) that are currently believed to be mostly responsible for transmitting COVID-19 would not be transported, in most cases, more than a distance of 1-2 metres before landing on surrounding surfaces (Heffernan, 2020; REHVA, 2020; WHO, 2014). The virus can also be transmitted from person to person via physical contact (e.g. exchanging saliva or a handshake followed by touching the mouth, nose, or eyes). It can also be transmitted by droplets containing the virus which are expelled by an infected person's cough, sneezing or spittle and then inhaled by another person.

According to Wilson *et al.* (2020) and Lewis (2020), there is still no consensus on the potential transmission by aerosols (particles smaller than 5 μm). In fact, until just recently, indoor air was not considered to be a vector by which the virus could propagate in the environment, as the virus can be rapidly deactivated there. However, more and more authors are of the opinion that propagation via infectious aerosols is plausible and should be taken into consideration (van Doremalen *et al.*, 2020; Fears *et al.*, 2020; ASHRAE, 2020d; Wathelet, 2020; Morawska & Cao, 2020), especially when preventative measures are established. Furthermore, it is known that some activities in healthcare facilities and medical interventions performed on patients can generate aerosols at risk of containing an infectious viral load (e.g. bronchoscopy, tracheal intubation and extubation, sputum induction, etc.) (Guo *et al.*, 2020; Wilson *et al.*, 2020; INSPQ, 2020a). Finally, transmission of the virus could occur through contact with contaminated surfaces, considering that SARS-CoV-2 has a certain level of stability on various types of surfaces subject to environmental conditions commonly encountered in indoor spaces. However, although transmission through contact with surfaces should be considered plausible, Dietz *et al.* (2020) specify that to date no case of COVID-19 infection caused by contact with contaminated inert surfaces has been documented.

What do we know about the indoor spaces in which COVID-19 has been transmitted?

In a recent study conducted in China on COVID-19 transmission in indoor environments, the most frequent outbreaks (of 3 or more cases) occurred at home (254 episodes), followed by on means of transportation (108 episodes) (Qian *et al.*, 2020). These results suggest that outside of domestic spaces, collective public transit may be a significant site of transmission (Qian et al, 2020; Shen *et al.*, 2020; Yang *et al.*, 2020). Additionally, Li *et al.* (2020) studied an episode of COVID-19 transmission that occurred in a restaurant dining room. Park *et al.* (2020) also documented an outbreak in a call centre in Seoul, South Korea. While they could not definitively state the reasons behind the observations, some authors support the hypothesis by which low ventilation rates coupled with high passenger or occupant density could explain these results. Other authors also suggest that such conditions would lead to the possible accumulation of infectious aerosols in the indoor air of certain environments (Morawska & Cao, 2020).

In summary, episodes of COVID-19 infection are likely to occur in various indoor spaces. Furthermore, the exact modes of COVID-19 transmission are not yet entirely clear, and according to the current scientific data, experts cannot rule out the possibility of airborne transmission (fine infected respiratory secretions).

Which environmental conditions contribute to maintaining the viability of SARS-CoV-2 in indoor environments?

Although viruses are obligate intracellular parasites, SARS-CoV-2 can survive for some time outside of infected cells, including in indoor spaces (REHVA, 2020). The viability of viruses in a given environment varies, depending especially on air temperature and relative humidity (RH).

Dietz *et al.* (2020) highlight that reaching higher temperatures can cause the lipid envelope of coronaviruses to deteriorate, resulting in their deactivation. In 2010, Casanova *et al.* demonstrated in the laboratory that viruses belonging to the SARS-CoV subgroup could remain viable at 4°C for up to 28 days (on stainless steel). The persistence of viability over time (or survival time) generally decreases as temperature increases. Kampf *et al.* (2020) collected the various studies on the survival times of human coronaviruses on different types of inert surfaces (steel, aluminium, wood, paper, plastic, etc.). The results show that the survival time of some viruses is lower at 30°C than at 20°C. Similar results were obtained specifically for SARS-CoV-2 in the laboratory by Chin at al. (2020), who demonstrated that the viability of the virus is optimal at 4°C and can easily persist for 7 days at 22°C. However, above 70°C, the deactivation time does not exceed 5 minutes.

With regard to RH, Casanova at al. (2010) reported that the relationship between deactivation of coronaviruses and this parameter is not linear, contrary to what is observed with temperature. They observed a higher virus survival time on surfaces at 4°C at low RH rates (20%) than at moderate rates (50%). Also, Chan *et al.* (2011) demonstrated that viruses of this same subgroup can remain viable for more than 5 days on surfaces kept at an RH of 40–50% and a temperature of 22–25°C.

As for the viability of coronaviruses at very high RH rates (e.g. 80%), it appears that survival time is much longer at a low temperature (4–6°C) than at an ambient temperature (21°C) (Ijaz *et al.*, 1985; Casanova *et al.*, 2010). This observation is also corroborated by Chan *et al.* (2011), who demonstrated that the viability of coronaviruses declines rapidly at high temperatures as well as in high humidity (e.g. 38°C and RH > 95%).

In summary, the ideal preservation conditions for coronaviruses are a temperature of 4°C and an RH of 20–40% (NASEM, 2020b). In light of the information presented above, it is possible that SARS-CoV-2 could survive for several days in an indoor environment. Despite this, it is still recommended to maintain the RH of residential buildings within the ranges deemed acceptable by Health Canada (2015): about 30% in winter and about 50% in summer. These rates also help maintain the integrity of buildings, limit fungal proliferation and ensure the comfort of the occupants.

What is the survival time of SARS-CoV-2 on various types of surfaces?

Few studies specifically interested in the survival time of the SARS-CoV-2 virus on surfaces have been collected to date. Experimental data from the study done by van Doremalen *et al.* (2020) indicate that the virus may be viable for up to 4 hours on a copper surface, 24 hours on cardboard, 48 hours on stainless steel and 72 hours on a polypropylene (a type of plastic) surface. It is important to specify here that the authors inoculated the surfaces in a laboratory, a process that does not reflect how droplets are typically deposited when ejected by coughing, sneezing or spittle. It should also be noted that the survival times documented in this study were evaluated under experimental conditions (that is, at a temperature of 21–23°C and an RH of 40%) over a period of 7 consecutive days. The results obtained therefore do not necessarily represent the variability of environmental conditions potentially present in indoor environments. Furthermore, they give little information as to the infectivity of the virus for the individuals susceptible to its exposure. It should be noted that the results of other recent studies on the survival time of SARS-CoV-2 on surfaces should be published shortly (NASEM, 2020c).

Kampf *et al.* (2020) have collected various studies on the survival time of human coronaviruses on different types of inert surfaces (steel, aluminium, wood, paper, plastic, etc.). The results highlight that the survival time of some viruses is lower at 30°C than at 20°C. The authors conclude that coronaviruses can remain infectious for several days at room temperature on various types of inert surfaces. Dietz *et al.* (2020) nonetheless specify that although it seems probable that SARS-CoV-2 persists on inert surfaces from several hours to several days, depending on the material type, at present there have been no documented cases of COVID-19 caused by contact with contaminated inert surfaces.

In any case, since SARS-CoV-2 is relatively stable on various types of surfaces subject to common environmental conditions, potential transmission by means of these surfaces must be considered plausible. This possibility serves as justification for respecting the hygiene measures recommended by government authorities.

What is the risk of contracting COVID-19 through ventilation systems?

Generally speaking, few recent studies have shown a significant association between viral propagation and the ventilation of indoor spaces other than healthcare facilities. However, there is evidence demonstrating an association between ventilation, movement of air in buildings and transmission of some infectious diseases such as measles, tuberculosis, chickenpox, flu, smallpox and SARS (Li *et al.*, 2007). However, studies have also demonstrated that increasing ventilation, particularly through mechanical ventilation systems, can reduce the incidence of respiratory illness by reducing the concentrations of pathogenic agents (including viruses) present in indoor air (CETAF, 2018).

Qian and Zheng (2018) recall the dual role of ventilation systems in the fight against transmitting respiratory infections such as SARS in 2003 and H1N1 in 2009. In addition to contributing to the extraction and dilution of infectious bioaerosols, fresh air flow can be used to prevent contamination from droplets by creating directional air currents and spaces with negative or positive pressure (e.g. isolation rooms in healthcare facilities). To this end, the Haut Conseil de la santé publique (HCSP), which is the High Counsel for Public Health in France, recently examined the risk of SARS-CoV-2 transmission via ventilation systems in buildings in both healthcare and domestic settings, concluding that no studies proving virus transmission by these systems exist (HCSP, 2020). As an example, Xu *et al.* (2020) did not observe any connection between the Diamond Princess cruise ship's ventilation and indoor air conditioning system and the significant episode of COVID-19 transmission that took place on board in February 2020.

From a theoretical point of view, the risk of SARS-CoV-2 dispersion in the form of droplets or aerosols via a ventilation system cannot be completely ruled out (NASEM, 2020a; Dietz *et al.*, 2020), although, according to Ezratty and Squinazi (2008), this risk is unlikely. The risk itself is closely related to the potential aerosolization of the viral agent and its maintained infectivity through ventilation and indoor air conditioning system ducts (Ezratty & Squinazi, 2008). Microparticles containing viruses are in fact generally heavier than air and therefore fall to the ground due to gravity. In the majority of residential and commercial buildings, return air grills are primarily located in the ceiling, rendering aspiration of the virus by ventilation systems improbable (CETAF, 2020). Recall here that Liu *et al.* (2020) nonetheless detected SARS-CoV-2 in aerosol form in various rooms in two hospitals in Wuhan (China) accommodating a number of infected patients. Airborne transmission therefore seems possible, but does not appear associated with an appreciable proportion of cases, and its significance in the current pandemic remains difficult to evaluate (CCNSE, 2020).

Should you continue to run a ventilation system in a given building when a person infected with COVID-19 has occupied or is occupying the building?

According to recognized organizations in the field, it remains important to apply adequate ventilation to occupied buildings, especially if infected individuals reside in it, no matter the type of housing or accommodation (CDC, 2020a; ASHRAE, 2020a). Recently, ASHRAE stated that airborne transmission of SARS-CoV-2 was sufficiently probable to justify deploying preventative measures in order to limit exposure to the virus through this route (ASHRAE, 2020a). To this end, changing the way mechanical systems in buildings, especially heating, air conditioning and ventilation systems, operate could reduce such exposures (ASHRAE, 2020c). ASHRAE further specifies that in indoor environments, ventilation cannot, however, counter rapid deposition of infectious droplets (≥ 5 µm) (ASHRAE, 2020d), which are predominant in the COVID-19 transmission process (WHO, 2020).

It is therefore recommended that any infected person reside in a single room of a home and that this room be ventilated by a ventilation system (or air exchanger) continuously, meaning 24 hours a day, 7 days a week (ASHRAE, 2020b; REHVA, 2020), or by frequent opening of the windows (CDC, 2020a; ACSP, 2020; REHVA, 2020). The approach in this second case consists of frequently over-ventilating the occupied room (a minimum of 3 times per day, with the windows open for at least 15 minutes each time), particularly during episodes of high discharge of droplets by the infected person. The HCSP provides an additional recommendation to ventilate the room separately from the rest of the home while keeping the door to the room closed (HCSP, 2020).

As for mechanically ventilated, multi-dwelling buildings, the risk of diffusing infectious droplets via the ventilation systems is considered negligible because of their short range of 1 to 2 metres (Heffernan, 2020; REHVA, 2020) and limited survival time in the environment, and the low potential of indoor air mixing among dwellings (Ezratty & Squinazi, 2008). However, the NCCEH (2020), REHVA, (2020) and ASHRAE (2020d) recommend applying a series of preventative measures in mechanically ventilated buildings to avoid transferring air from an apartment where an infected person is living to shared spaces, and to reduce the concentration of infectious particles in the entire building's indoor air. These measures include:

- Increasing the flow of fresh air intake and the extraction of contaminated air from the infected person's dwelling;
- Avoiding using the system's recirculation mode;
- Using energy-saving strategies prudently (e.g. demand-controlled ventilation controlled by a timer or by CO_2 concentration); and
- Ensuring that hallway pressurization (positive pressure), if applicable, is sufficient to avoid diffusing air from apartments where infected people are living into the central hallway where other residents circulate. This pressurization must be maintained 24 hours a day.

Is it necessary to apply particular measures for ventilation system maintenance during the pandemic period?

No study demonstrating human-to-human transmission of SARS-CoV-2 via infectious aerosols distributed through the ventilation system ducts of residential buildings was found in the current exercise. However, several organizations recommend verifying that systems are functioning properly and adequately ventilating all inhabited indoor spaces (HCSP, 2020; NCCEH, 2020; ASHRAE, 2020d). Furthermore, it is generally recommended to:

- Make sure that ventilation registers are not obstructed by objects or by excessive dust accumulation;
- Check that the mechanical system's motors and dampers are functioning properly; and
- Ensure that the filters in use are clean.

Do you need to disinfect the ventilation systems in a given building when a person infected with COVID-19 is present or has been present in the building?

Since the available information indicates that it seems unlikely that a viral load maintains its infectivity through indoor ventilation system and air conditioning ducts, applying disinfection measures to these ducts in the residential setting is not currently recommended (Ezratty & Squinazi, 2008). REHVA (2020) specifies that ventilation systems are not considered to be a source of contamination, especially if the instructions to avoid energy-saving strategies (e.g. demand-controlled ventilation controlled by a timer or CO_2 detectors) and recirculation of contaminated air are respected. The virus, whether or not it is adsorbed on microparticles, will be deposited on duct surfaces or expelled outside of the building. Being an obligate parasite, the virus will not multiply on contact with damp surfaces or substrates rich in organic material present in ventilation system ducts like bacteria and mould can (IRSST, 1994). Consequently, it is not necessary to make changes (e.g. SARS-CoV-2-specific disinfection) to the usual duct cleaning and maintenance procedures. It remains much more important to increase fresh air flow and to avoid recirculating contaminated air inside a building (REHVA, 2020).

Could filtration be useful in reducing the risk of infection?

Viruses generally vary in size from 0.004 to 1 µm. The SARS-CoV-2 virus varies from 0.06 to 0.140 µm (Cascella *et al.*, 2020). The filters that are typically used in ventilation and air conditioning systems (MERV 5 to 13) are not designed to retain particles smaller than 1 to 3 µm. Additionally, it is difficult to imagine using very high-efficiency HEPA-type filters, which can retain over 99.9% of particles smaller than 0.3 µm, in currently-installed ventilation units and systems considering the very high energy cost of using them (e.g. additional static load) and the technical constraints inherent to this type of filter (e.g. installation and maintenance) (Ezratty & Squinazi, 2008; INSPQ, 2019; CCNSE, 2020). Furthermore, these high-efficiency filters would only be partially effective in containing viruses, which largely limits this avenue for controlling pathogenic agents like SARS-CoV-2 (Dietz *et al.*, 2020). In a recent study conducted in Korea, Ham (2020) reports that the flow of purified air generated by portable filtration devices can also contribute to dispersing infectious droplets in indoor spaces when these appliances are not used properly.

Despite these constraints and the uncertain efficacy of this air purification technology in the current context, ASHRAE (2020d) emphasizes that filtration units, when correctly selected, deployed and maintained, can be effective in reducing concentrations of infectious aerosols, however, they add that these systems cannot entirely eliminate propagation risk, since these risks depend on numerous other factors.

In summary, because of the transmission mode of SARS-CoV-2 (mainly by droplets and from person to person), air purification appliances and devices cannot be considered as a first line of defence against this virus. An air purifier equipped with a HEPA filter can contribute to reducing the concentration of viral particles in indoor air, but it will in no way stop transmission by droplets or from person to person (Heffernan, 2020). Observing respiratory and hand hygiene measures and applying adequate ventilation are still the preferred means of reducing transmission risk (REHVA, 2020).

Can SARS-CoV-2 be dispersed in an indoor environment by active air conditioning?

There is currently little information concerning the impact of air conditioning devices on the dispersion of SARS-CoV-2 in indoor spaces. As previously mentioned, it is known that an individual infected with COVID-19 can generate significant viral loads in indoor air (Buonanno *et al.*, 2020) if this person does not apply appropriate respiratory hygiene measures. Such viral loads can be dispersed in indoor air in the form of particles, which stay suspended in air for a period of time (Dietz *et al.* 2020). In this context, competent organizations recommend using proper ventilation to extract indoor air contaminants and ensure their dilution by bringing in new, fresh air, for all residence types and service facilities (CDC, 2020a; ASHRAE, 2020a).

However, because air conditioning devices are generally used for their main role of cooling indoor air to ensure the thermal comfort of occupants, most appliances recycle indoor air without taking in large volumes of fresh air. In doing so, the cooled air propelled by the appliance contributes to creating an air corridor likely to contain and propagate droplets and aerosols generated nearby. Furthermore, since air conditioning devices generally possess a limited capacity for capturing air contaminants (the filters they contain are more effective at catching large particles), they offer negligible indoor air purification power. In summary, we cannot rule out that these devices could contribute to dispersing SARS-CoV-2 in certain under-ventilated indoor spaces (that is, spaces that do not meet the requirements of the Code de construction du Québec, the Québec construction code, to have approximately one entire air change every three hours).

Can air conditioning facilitate transmission of COVID-19 in an indoor environment?

While the potential to spread SARS-CoV-2 in indoor environments cannot be completely ruled out, few studies have been published on COVID-19 transmission in air conditioned environments. The documents identified include a recent study by Lu *et al.* (2020) describing a case of COVID-19 transmission related to the use of an air conditioner in a small, densely occupied Chinese restaurant. The authors report that the air circulation caused by the use of the wall air conditioner (a mini split unit with no fresh air intake or exhaust hose) may have facilitated transmission of the virus by dispersing the infectious particles expectorated by an infected customer near the unit's air intake. Due to the way in which they operate, air conditioners may also contribute to the stability of SARS-CoV-2 in an indoor environment by creating cooler ambient temperatures and drier air, favourable conditions to the virus's survival (Chan *et al.*, 2001; Chin *et al.*, 2020; NASEM, 2020b).

In a second study on cases of COVID-19 transmission occurring on a cruise ship off the coast of Japan, the authors report that the ship's air conditioning system (integrated into an HVAC [heating, ventilation and air conditioning] system similar to those found in large commercial and institutional buildings) does not appear to have played a role in the process of transmission among the ship's passengers (Xu *et al.*, 2020). It is important to note that unlike the majority of air conditioning units that cause indoor air to recirculate (e.g. window and mini split units), the system on the cruise ship ventilated the premises with a certain intake of fresh air from outside (e.g. 30% fresh air from outside for the cabins, 50% for public spaces and 100% for the kitchens).

While the results of these studies encourage caution, they also imply that having well-ventilated indoor environments remains the recommended best practice, regardless of whether the premises are air conditioned. Moreover, ASHRAE reports that complete interruption of air conditioning systems may cause heat stress for occupants, consequently compromising their immune defence against SARS-CoV-2 (ASHRAE, 2020e). Regardless of whether the air conditioning system is installed in a residential, institutional or commercial environment (ASHRAE, 2020e; REHVA, 2020), or on a means of transportation (Sustainable Bus, 2020; The University of Sydney, 2020), it appears appropriate to maintain the use of air conditioning while optimizing ventilation, either by opening the windows or using the mechanical ventilation system, if present. It of course remains essential to apply the usual recommended maintenance measures for all components of fresh air intake systems (including inspection and replacement of filters, if applicable).

To summarize, air conditioning could theoretically spread the dispersed plume of droplets expectorated by an infected individual farther than 2 metres and contribute to COVID-19 transmission if others are within the column of air generated.

Can using pedestal fans contribute to spreading SARS-CoV-2 in an indoor environment?

No studies establishing a link between pedestal fans and the spread of SARS-CoV-2 in indoor air were identified in this overview of the scientific literature. As previously stated, an infected person (symptomatic or not) may create a plume of infectious particles in their immediate environment when not applying appropriate respiratory hygiene measures (Dietz *et al.* 2020). While heavier droplets tend to fall quickly within approximately 1 to 2 metres of their initial source, aerosolized microdroplets appear to depend on a number of environmental factors and remain a subject of debate. The same goes for the resuspension of particles that, once deposited on a surface (fomites), could theoretically act as a secondary source of contamination (NASEM, 2020b). In this context, the use of a pedestal fan in the vicinity of an infected person could theoretically spread the dispersed plume of expectorated microdroplets beyond 2 metres and contribute to COVID-19 transmission if others are within the column of air generated. Some recent case studies demonstrate the impact of forced air circulation on COVID-19 transmission in indoor environments, whether through air purifiers (Ham, 2020) or air conditioners (Lu *et al.*, 2020). For this reason, and in light of the available information, it appears plausible that pedestal fans, as well as devices of a similar nature, could contribute to spreading microdroplets containing SARS-CoV-2 in the presence of infected individuals, regardless of whether or not they are symptomatic.

Pedestal fans should therefore be used with caution. They should not be used in the presence of an infected person unless this person is alone in an isolated room, which should have a consistent source of fresh air from the outside.

Can using a hand dryer impact the risk of spreading SARS-CoV-2 in an indoor environment?

At present, there are few articles examining the link between hand dryers and viruses, and to our knowledge, none concerning SARS-CoV-2. Some studies published in the 2000s do examine potential bacterial transmission in relation to hand drying. According to Huang *et al.* (2012), effective hand drying after washing should be an integral part of the hand hygiene process. According to the authors, bacteria is more likely to be transmitted from damp skin than from dry skin. The findings from their review of the literature indicate that paper towels can allow for effective hand drying and eliminate bacteria while reducing contamination of the indoor air in bathrooms. According to the authors, paper towels are therefore superior to hand dryers from a hygienic perspective (Huang *et al.*, 2012).

Electric hand dryers are known to spread microorganisms in indoor air (Kimmitt & Redway, 2016; Huesca-Espitia *et al.*, 2018). Hand dryers can also deposit pathogenic bacteria onto users' hands and bodies. Bacteria are distributed into the general environment whenever dryers are running and could be inhaled by users and others in the room (Alharbi *et al.*, 2016).

The WHO reports that using this type of device does not destroy the SARS-CoV-2 virus nor does it offer any protection against its propagation (WHO, 2019). The WHO has not made any specifications on the risk of this device spreading the virus. Health Canada has not adopted a position on the pertinence of using or not using hand dryers. This federal department does however state that the use of disposable paper towels is preferable for drying hands after washing, and that a reusable hand towel may also be used if it is replaced when it becomes damp (Health Canada, 2020). The CDC's position is in line with that of the WHO; they do not discourage its use but recommend thoroughly washing the hands with soap and water first (CDC, 2020b). The CDC acknowledges that the best hand drying method cannot be specified given the small number of studies conducted on this subject, their scope (some studies examine the overall concentration of microbes, not only pathogenic microorganisms), and their sometimes contradictory results (CDC, 2020c).

Can using a portable humidifier impact the viability of SARS-CoV-2 in indoor air?

At present, no studies have been carried out to examine any potential link between humidifiers and the increased presence or viability of SARS-CoV-2 in an indoor environment. However, it is known that the viability of viruses in an indoor environment mainly varies depending on air temperature, RH and the type of surface on which they are deposited (REHVA, 2020).

The studies currently available indicate that SARS-CoV-2 is highly stable at 4°C and could easily persist for seven days at 22°C, while in temperatures exceeding 70°C, the time for virus inactivation is reduced to 5 minutes (Chin *et al.*, 2020). The viability of the virus does not, however, have a similarly linear relationship with RH. According to Casanova *et al.* (2010), coronaviruses will survive for a longer period at low RH (20%) and high RH (80%) than at moderate RH (50%). The impact of RH rates usually found in indoor environments (around 30–50%) on the viability of SARS-CoV-2 are therefore likely negligible. The authors also indicate that the interaction between temperature and humidity may potentially affect survival time.

Furthermore, RH rates in indoor environments, which depend on various factors (occupancy rate, behaviour, ventilation, and airtightness of the building envelope), are particularly significant as they can create discomfort and lead to health problems if they are too low or too high.

In the cold season in countries with a cold or temperate climate, warm, damp indoor air that is exfiltrated from the building naturally (e.g. through openings, door thresholds or old windows) or by mechanical ventilation, is replaced by the cold outdoor air, which has a lower capacity to hold moisture than warm air (Natural Resources Canada, 2017). The entry of this colder air dries out the indoor air, especially when the only sources of ambient humidity are the occupants themselves. As the nasal and tracheal mucus membranes are constantly exposed to ambient air during breathing, they are affected by the ambient temperature and humidity of the inhaled air. In addition to creating discomfort, dry indoor air can contribute to drying out respiratory mucus membranes, which increases their sensitivity to irritation and in turn, the risk of contracting respiratory infections, especially for older people (Biktasheva, 2020). According to Moriyama *et al.* (2020), inhaling dry, cold air can also impair mucociliary clearance and mucin production for some people.

In cases of very dry air, using a portable humidifier can be helpful for increasing humidity, thus preventing difficulties and health problems related to air dryness to some extent. The use of portable humidifiers can, however, have certain disadvantages. First, there are several different ways in which they operate, and their capacity to humidify the air varies by model and is often limited to one room of the home. Also, they must be carefully maintained and regularly cleaned as their reservoirs can become a breeding ground for mould and bacteria, which are then likely to be diffused into the air and inhaled (University of Rochester Medical Center, 2020; Government of Canada, 2012).

Since viruses are obligate parasites, they cannot multiply inside humidifier reservoirs. Coronaviruses are also sensitive to oxidizers (e.g. chlorine) present in treated drinking water (INSPQ, 2020b). However, studies have shown that coronaviruses can maintain their viability for a number of days in (unchlorinated) drinking water from groundwater systems and in deionized water at the usual temperatures found in indoor environments (Gundy *et al.*, 2008; Casanova *et al.*, 2009). While no specific study was identified on the possible risk of infection from humidifiers dispersing the virus, it is pertinent to apply respiratory and hand hygiene measures both before and while filling a device's reservoir. It appears unlikely that the contents of the reservoir could be contaminated after it has been filled and installed in the device.

Conversely, very high RH (> 70%) can promote the growth of mould and dust mites on various indoor substrates. Excessively humid conditions and the presence of microorganisms in the indoor air (in the form of spores, fragments and fecal material) increase the risk of susceptible individuals developing allergic respiratory symptoms or experiencing aggravated asthma. People living in homes where there is excessive humidity and mould are consequently more susceptible to experiencing irritation of the eyes, nose, and throat, a runny nose, coughing, wheezing, shortness of breath, a noticeable increase in the severity of asthma symptoms, etc. (Government of Québec, 2020; Health Canada, 2015).

In summary, as coronaviruses appear relatively unaffected by the desired RH conditions generally found in indoor environments, it is still recommended to keep building RH rates within the range considered acceptable by Health Canada (2015): around 30% in winter and around 50% in summer. These rates help maintain the integrity of buildings and limit the health risks associated with overly dry or overly humid air. Lastly, it should be emphasized that using a humidifier neither increases risk of exposure to SARS-CoV-2 nor guards against possible infection by the virus.

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COVID-19: Indoor Environment

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Publication Nº: 2992 – English version

The French version is entitled *COVID-19 : Environnement intérieur* is also available on the website of the Institut national de santé publique du Québec at: https://www.inspq.qc.ca/publications/2992-environnement-interieur-qr-covid19

Institut national de santé publique Québec