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COVID-19: Outdoor environment

Question and answer document based on recent literature

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Please pay close attention to the entire document,
as the changes made were too numerous to be indicated in yellow.

This document, written in the context of the COVID-19 pandemic, is primarily intended for partners in the health and social services network, public decision makers and all those wishing to learn more about the topics covered in this literature review. This rapid synthesis, presented in the form of a question and answer document, reviews the current state of knowledge on the transmission of the SARS-CoV-2 virus in outdoor environments. More specifically, the document discusses modes of transmission of the virus in the outdoor environment and factors that may influence its persistence or its culturability and its transmission. The factors examined include environmental conditions (e.g.: outdoor air quality) and meteorological conditions (e.g.: temperature, relative humidity, and sunlight) as well as individuals' behaviour (e.g.: compliance with hygiene measures). The information presented is principally based on the work carried out by the members of the Comité en santé environnementale COVID-19 of the Institut national de santé publique du Québec (INSPQ), who carried out a non-exhaustive review of the scientific literature published before November 23, 2020. Complete information on the methodology used to prepare this document is presented in Appendix 1. The recurrence and convergence of findings reported in the literature as well as the quality of the studies' designs were considered. The findings reported in this document may be reviewed and updated as new studies become available.

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Québec

Glossary

Note: The following definitions, adapted from the document *Transmission du SRAS-CoV-2 : constats et proposition de terminologie* (Anctil et al., 2021) [in French only], are intended to promote uniform terminology across all disciplines at the INSPQ.

Aerosols	Particles suspended in the air whose movement is primarily governed by the particle size, typically smaller than 100 µm (usually called droplets when > 5 µm), and which are inhalable and can be classified according to the anatomical location where they are deposited in the respiratory tract: ▶ Nasopharyngeal particles, which are deposited in the nose or throat (≤ 100 µm). ▶ Tracheobronchial particles, which are deposited in the bronchi (≤ 15 µm). ▶ Alveolar particles, which reach the pulmonary alveoli (≤ 5 µm), typically called droplet nuclei or microdroplets.
Asymptomatic	The state of an infected person who secretes virus and who will not develop symptoms.
Culturable	The quality of a virus being able to reproduce itself on appropriate cell cultures under the right conditions. A virus being culturable does not necessarily mean that it is infectious.
Droplets	Formerly defined as particles typically measuring more than 5 µm, now included in the definition of aerosols.
Drops	Particles larger than 100 µm which may be deposited directly on the mucosa (mucus membranes) of the nose, mouth, or eyes, and on surfaces or objects, following a ballistic trajectory (therefore not inhalable).
Infectivity	The ability of a pathogenic agent (such as a virus) to enter, survive in and multiply in a host.
Particles	Small pieces of solid or liquid matter.
Presymptomatic	The state of an infected person who secretes virus but has not yet developed symptoms.
Persistence	Presence of viral RNA. The persistence of the virus does not necessarily imply that it is culturable or infectious.
Transmission	The process by which a pathogenic agent is issued from a source in such a way as to cause an infection in a host.

Summary

Few studies have documented transmission of the SARS-CoV-2 virus in the outdoor environment, especially during the cold season. Transmission of SARS-CoV-2 in the outdoor environment would occur primarily through close (less than 2 metres) and prolonged (over 15 minutes) contact with an infected person. Long-range aerosol transmission (i.e., beyond two metres) or transmission via contaminated inanimate objects or surfaces (fomites) could also be possible, although epidemiological evidence remains limited to date. Various parameters associated with the outdoor environment could alter the persistence of SARS-CoV-2 according to experimental data. In particular, low temperatures may increase the persistence of the virus in the environment. However, it cannot yet be determined based on epidemiological studies whether meteorological parameters, including temperature and seasons, have a significant influence on the incidence of COVID-19 in the population. The direct effect of these parameters on the incidence of COVID-19 is likely negligible compared to individual behaviours associated with respect for protective measures recommended by public health authorities. Practicing physical activities outdoors, rather than indoors, should help to reduce the risk of transmission, particularly because of the diluting power of the atmosphere. Nevertheless, the application of public health recommendations, especially the maintenance of physical distancing, is crucial to preventing the transmission of COVID-19 when physical activities are being practiced, both outdoors and indoors. The use of a medical mask or a face covering is recommended as an added measure of respiratory etiquette when it is difficult to maintain physical distancing, regardless of the outdoor temperature or season. Finally, it has been hypothesized that past and present exposure to outdoor air pollution may play a role in the incidence and severity of COVID-19; however, the epidemiological evidence remains very limited. Confinement measures, notably the closure of schools and non-essential businesses during the first wave, helped reduce road traffic and air pollution in various urban areas of Québec, although a resurgence has since been observed.

How is SARS-CoV-2 transmitted in the outdoor environment?

KEY TAKEAWAYS

- Few studies have documented the modes of transmission of the SARS-CoV-2 virus in the outdoor environment, especially during the cold season.
- The modes of transmission of SARS-CoV-2 in the outdoor environment are presumed to be the same as those documented for the indoor environment.
- Transmission would occur primarily through drops or aerosols during close (less than 2 metres) and prolonged (over 15 minutes) contact with an infected person.
- Long-range aerosol transmission of SARS-CoV-2 (over distances greater than 2 metres) and transmission through contact with contaminated inanimate objects and surfaces (fomites) are possible; however, epidemiological evidence regarding these modes of transmission remains limited.

To date, few studies have documented transmission of the SARS-CoV-2 virus in the outdoor environment, especially during the cold season. The study designs required to identify potential transmission routes are complex, particularly as more than one route may be involved simultaneously in a transmission episode. Therefore, case analyses rely more on a process of exclusion than on a clear demonstration of transmission via a specific route. Current knowledge about the transmission routes of the virus has been acquired through studies conducted in the laboratory and in certain indoor environments (e.g.: entertainment venues, workplaces, schools, healthcare settings (National Collaborating Centre for Environmental Health [NCCEH], 2020)), and on public transport (Qian et al., 2020). In fact, the vast majority of identified transmission episodes have occurred in closed indoor environments (Bulfone et al., 2020; NCCEH, 2020; Qian et al., 2020; Weed &

Foad, 2020). This may suggest that the overall risk of transmission is generally lower outdoors than indoors, but several other factors could also be involved, such as increased respect for distancing guidelines and decreased frequency and duration of outdoor contacts. For example, the risk of outdoor transmission increases during gatherings when physical distancing is not respected, when gatherings are large and high density, and when they are prolonged (Centers for Disease Control and Prevention [CDC], 2020b; Weed & Foad, 2020).

The modes of transmission of SARS-CoV-2 in the outdoor environment are presumed to be the same as those documented for the indoor environment. Nevertheless, certain parameters of the outdoor environment (e.g.: temperature, wind, ultraviolet radiation) could modulate the risk of transmission by influencing the viral load of aerosols and the distance they travel in the ambient air, as well as the concentration of potentially infectious virus suspended in aerosols (NCCEH, 2020). The following paragraphs summarize the potential transmission routes of SARS-CoV-2 in the outdoor environment. For further details on the transmission modes of this virus, interested readers may refer to the document *Transmission du SRAS-CoV-2 : constats et proposition de terminologie* (Anctil et al., 2021) [in French only].

Principal modes of transmission: close and prolonged contact

It is considered that a person infected with SARS-CoV-2 (presymptomatic, symptomatic or asymptomatic) can generate and transmit significant viral loads to an uninfected person or to her immediate environment (Buonanno, Stabile & Morawska, 2020), especially if she do not follow the appropriate respiratory hygiene measures. The principal mode of transmission of SARS-CoV-2 is close (less than 2 metres) and prolonged (over 15 minutes) contact with an infected person (Anctil et al., 2021). This transmission route is associated with particles of all sizes; namely, drops (particles > 100 µm, which settle quickly) and aerosols (particles ≤ 100 µm, which can remain suspended in the ambient air for a while). These viral particles are, in most cases, expelled to a distance of less than 2 meters by exhalation, coughing, sneezing or during any other activity involving vocal projection (speaking, singing, shouting) or increased respiratory flow (aerobic or sports activities).

Other modes of transmission

Long-range aerosol transmission

Results from laboratory studies have shown that aerosols can be dispersed over a distance greater than 2 metres if they are expelled or expectorated forcefully or if they are carried by air currents (Blocken et al., 2020a; Bourouiba, 2020; Guerrero, Brito and Cornejo, 2020; CDC, 2019). Various environmental factors will influence the propensity of aerosols to remain suspended in the ambient air as well as whether the virus potentially present in the aerosols remains culturable.[1] As with transmission through close and prolonged contact, potential transmission via long-range aerosols would also be influenced by the state of the exposed person's immune system (host receptivity), the infected person’s proximity, the duration of exposure, and the infectious dose received by the host (Groupe de travail sur la ventilation, 2021). It should be noted that the dose of SARS-CoV-2 required to infect a human is not yet known and may vary between individuals (U.S. Department of Homeland Security, 2021). The minimum diameter of aerosols on which the virus can retain its ability to replicate as well as the relative contribution of aerosols of different sizes to transmission also remain unknown. To date, there is no definitive evidence that SARS-CoV-2 can be transmitted via long-range aerosols (beyond a few metres) (Anctil et al., 2021). The risk of this type of SARS-CoV-2 transmission would increase in closed, crowded and inadequately ventilated spaces, and with prolonged exposure.

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[1] The influence of some of the principal environmental factors on the persistence or culturability of the virus is discussed in the response to a subsequent question.

TRANSMISSION THROUGH STREET FURNITURE AND ACCESSORIES

Hand contact with contaminated inanimate objects or surfaces (also called fomites) followed by contact with the mouth, nose, or eyes is another possible route of transmission of SARS-CoV-2 (Dietz et al., 2020; Kampf, Brüggemann, et al., 2020; Kanamori, Weber & Rutala, 2020; Karia et al., 2020; Norwegian Institute of Public Health [NIPH], 2020b; Public Health Ontario, 2020; CDC, 2020d; Vella et al., 2020; World Health Organization/Organisation mondiale de la Santé [WHO/OMS], 2020a).

Although there is little epidemiological evidence, organizations like the Centers for Disease Control and Prevention – CDC – and the World Health Organization – WHO (NIPH, 2020b; Public Health Ontario, 2020; CDC, 2020d; WHO/OMS, 2020a) as well as some literature reviews (Dietz et al., 2020; Kampf, Brüggemann et al., 2020; Kanamori, Weber & Rutala, 2020; Karia et al., 2020; Vella et al., 2020) have concluded that this mode of transmission of SARS-CoV-2 would be possible. The plausibility of this transmission route is supported, in particular, by experimental data. For example, an experimental study has shown that transmission of SARS-CoV-2 via contaminated surfaces to some animals was possible (Sia et al., 2020). Fomite transmission of SARS-CoV-2 is also assumed to be plausible given the frequent detection of viral RNA on surfaces in healthcare settings or in the community (Döhla et al., 2020; Fernández-de-Mera et al., 2020; Hu et al., 2020; Luo et al., 2020; Moore et al., 2021; Mouchtouri et al., 2020; Peyrony et al., 2020; Tan et al., 2020; Wu et al., 2020; Yamagishi, 2020; Ye et al., 2020; Zhou et al., 2020), especially in the immediate indoor environment (e.g.: patient rooms, cruise ship cabins) of infected individuals (Jiang et al. 2020; Kanamori, Weber, & Rutala, 2020; Peyrony et al., 2020; Yamagishi, 2020; Zhou et al., 2020). A few studies have also detected viral RNA in highly frequented outdoor areas and on frequently touched surfaces, such as street furniture in public squares and markets, bus access ramps, door handles and pedestrian crossing buttons (Abrahão et al., 2020; Harvey et al., 2020). However, it should be stressed that the presence of RNA does not necessarily imply that the virus remains culturable or infectious, a necessary condition for transmission. With regard to this, experimental studies have also shown that SARS-CoV-2 can remain culturable for up to several days after its inoculation on different types of surfaces (Biryukov et al., 2020; Fisher et al., 2020; Harbourt et al., 2020; Jang & Ross, 2020; Liu et al., 2020; van Doremalen et al., 2020; Zhou et al., 2020). However, no research team has yet succeeded in cultivating SARS-CoV-2 on surfaces under natural (non-experimental) conditions (Colaneri et al., 2020; Döhla et al., 2020; Moore et al., 2021; Ong et al., 2020; Santarpia et al., 2020; Zhou et al., 2020).

In order to reduce the risk of fomite transmission, the various surfaces of street furniture can be cleaned as usual and do not usually require disinfection. However, safe, targeted disinfection of frequently touched surfaces can be carried out (NIPH, 2020a; CDC, 2020b). For more information on surface disinfection, interested readers can consult the information sheet on this subject published by the INSPQ: *COVID-19: Surface Cleaning and Disinfection*.

What are the principal environmental parameters influencing the persistence of SARS-CoV-2 in the outdoor environment?

KEY TAKEAWAYS

- The results of laboratory studies suggest that different parameters of the outdoor environment may affect the persistence of SARS-CoV-2, in particular, temperature, humidity and solar radiation.
- High temperatures (e.g.: 70°C) could lead to degradation of the lipid envelope of coronaviruses and reduce their persistence. Conversely, colder temperatures (e.g.: 4°C) could favour their persistence.
- The relative humidity of the ambient air would affect the persistence of viruses in the environment; however, this relationship is complex and remains to be elucidated.
- Solar radiation, particularly UVC radiation, would help inactivate SARS-CoV-2 present in the environment.

Transmission of COVID-19 is modulated by multiple factors, notably behavioural, physiological and environmental factors. Results from laboratory studies (i.e., those carried out under controlled conditions) suggest that certain parameters of the outdoor environment can alter the virus' ability to replicate (i.e., its ability to reproduce itself on cell cultures under the right conditions) as well as the presence of its RNA in particles suspended in the air or deposited on inanimate surfaces (fomites). Temperature, relative humidity and the intensity of ultraviolet radiation are the principal parameters of the outdoor environment whose influence on the persistence of the SARS-CoV-2 virus has been documented in the literature. The following paragraphs summarize the knowledge derived from laboratory studies about the influence of these environmental parameters on the persistence of the SARS-CoV-2 virus (i.e., the presence of viral RNA) or on its ability to remain culturable. It should be noted that studies in controlled settings cannot fully replicate conditions observed in the natural environment; therefore, the transferability of experimental results to the outdoor environment is uncertain.

Temperature

In their literature reviews, Dietz et al. (2020), Ren et al. (2020), Aboubakr et al. (2020) and Kampf et al., (2020) point out that reaching a high temperature may trigger the degradation of the lipid envelope of coronaviruses and result in their inactivation. On the other hand, colder temperatures could contribute to their persistence. Thus, Chin et al. (2020) demonstrated, using tissue cultures incubated in the laboratory, that SARS-CoV-2 was still active at the end of their 14-day study. Moreover, SARS-CoV-2 can easily remain culturable for 7 days at 22°C. Chin et al. (2020) also demonstrated that SARS-CoV-2 culture on surfaces is optimally viable at 4°C. However, above 70°C, it takes no more than 5 minutes to deactivate the virus. In another study using inoculated food kept in freezers at -20°C and -80°C, the authors observed that SARS-CoV-2 remained culturable for up to 21 days, thus suggesting that temperatures below freezing could assist SARS-CoV-2 in remaining culturable over longer periods (Fisher et al., 2020).

In one study, the influence of temperature on the culturability of SARS-CoV-2 was assessed using samples of swine skin, paper currency (uncirculated US banknotes) and clothing (35% cotton and 65% polyester), inoculated with virus and incubated in the laboratory (Harbourt et al., 2020). In this study, SARS-CoV-2 remained culturable for 14 days on skin at 4°C, compared to no more than 96 hours at 22°C and 8 hours at 37°C (Harbourt et al., 2020). On banknotes, the virus remained culturable for 96 hours at 4°C, 8 hours at 22°C and 4 hours at 37°C, whereas on clothing samples the virus was culturable for 96 hours at 4°C, 4 hours at 22°C and 0 hours at 37°C (Harbourt et al., 2020). Another study that examined the effects of relative humidity, temperature and particle size on the ability of SARS-CoV-2 to remain culturable in a biological matrix simulating saliva deposited on non-porous surfaces also showed that the persistence of the virus decreases rapidly when humidity or temperature is increased (Biryukov et al., 2020).

Relative humidity

Unlike temperature, Casanova et al. (2010) report that the relationship between coronavirus persistence and relative humidity is not linear. The findings of the literature review by Ren et al. (2020) also highlighted the complexity of the relationship between the culturability of SARS-Cov-2 and relative air humidity. Yang, Elankumaran and Marr (2012) report that the majority of airborne viruses (with a lipid envelope) are sensitive to relative ambient humidity, but that the mechanisms responsible for this are complex and remain to be elucidated. It has been suggested that the culturability of viruses in aerosols would theoretically be minimal under conditions of average relative humidity, while it would increase when relative humidity is low or high – a U-shaped relationship (Yang, Elankumaran & Marr, 2012). This relationship could be explained by considering that viruses would be persistent under aqueous conditions (or of high relative humidity), but that the gradual evaporation of the water present in the infectious aerosols would lead to the formation of a saline solution unconducive to maintaining the viruses' culturability. The reduced persistence of viruses under conditions of intermediate relative humidity (i.e., around 50%) provides evidence of this. Once the saline solution evaporated and the residual salt crystallized (under conditions of low relative humidity, i.e., less than 50%), the viruses present in the aerosols would regain relative stability. However, the presence of proteins in the aerosolized particles could alter this relationship. Another study conducted under controlled conditions showed that the culturability of SARS-CoV-2 remains stable for 60 minutes in aerosols at relative humidity levels of 20 to 70%, given the absence of simulated sunlight (Schuit et al., 2020).

Solar radiation

Artificial UVC radiation (e.g.: from a UV lamp) is effective in inactivating SARS-CoV-2 by acting as a virucide. Although solar UVC radiation is completely absorbed by the earth's atmosphere, some authors report that the potential for virus inactivation by UVB radiation reaching the earth's surface is not negligible (Carvalho et al., 2020). However, little information is available concerning the potential for inactivation of SARS-CoV-2 by means of UVB radiation (U.S. Food and Drug Administration, 2020). Ratnesar-Shumate et al. (2020) simulated the solar light spectra at noon on a clear day, at sea level and 40°N latitude, at various times of year. They observed SARS-CoV-2 half-lives in cell culture of less than 6 minutes, and 90% of the virus was inactivated in less than 20 minutes, for all the light intensities they tested. These results are corroborated by Schuit et al. (2020). According to Carvalho et al. (2020), the potential for virus inactivation in an outdoor environment is essentially dependent on sunlight, which varies according to the region (e.g.: subtropical versus northern regions) and the season or time of year.

Do meteorological conditions and season influence the incidence of COVID-19?

KEY TAKEAWAYS

- Meteorological parameters could play a role in the transmission of COVID-19 by modulating virus persistence, physiological susceptibility to respiratory viruses and individual behaviours conducive to transmission.
- Observational studies have important limitations and do not allow us to determine whether meteorological parameters have a significant influence on the incidence of COVID-19.
- The direct effect of meteorological parameters on SARS-CoV-2 and its transmission would likely be negligible compared to individual behaviours (physical distancing, hand hygiene and respiratory etiquette).
- The impact of the seasons on the incidence of COVID-19 cannot be determined at this time.

Meteorological conditions may play a role in the transmission and incidence of COVID-19. Indeed, the incidence of some respiratory viruses, notably influenza and other human coronaviruses (HCoV-229E, HCoV-HKU1, HCoV-NL63 and HCoV-OC43), shows seasonal patterns with an upsurge of cases generally occurring during the winter season (Gaunt et al., 2010; Moriyama, Hugentobler & Iwasaki, 2020; Park et al., 2020). However, SARS-CoV and MERS-CoV (Middle East Respiratory Syndrome Coronavirus), which, like SARS-CoV-2, cause sometimes severe respiratory infections, showed limited transmission in the population and thus could not reveal clear evidence of seasonality (Al-Tawfiq & Memish, 2019; Nassar et al., 2018; National Academies of Sciences Engineering Medicine, 2020).

The mechanisms through which meteorological conditions could influence the incidence of COVID-19 involve the fact that environmental parameters could alter the persistence and culturability of the SARS-CoV-2 virus, as discussed in the previous section. Furthermore, ambient air temperature and relative humidity may alter local and systemic antiviral defence mechanisms in humans, thereby increasing susceptibility to respiratory viruses in winter (Eccles, 2002; Moriyama, Hugentobler and Iwasaki, 2020). Similarly, weather conditions and seasons may play an indirect, but likely significant, role in influencing the incidence of COVID-19 by modulating the behaviour of individuals. Indeed, when environmental conditions are harsher (e.g.: extreme cold or heat, strong winds, heavy precipitation), individuals generally spend more time indoors, which may encourage close proximity between individuals and prolonged contact. Certain times of year or particular seasonal activities, such as the beginning of the school year or the holiday season, can encourage social contact and, consequently, favour transmission of the virus (Brisson et al., 2020).

Several epidemiological studies, using ecological designs and mostly conducted in the northern hemisphere, have attempted to assess the direct influence of meteorological parameters on the number of COVID-19 cases or attributable mortalities. In rare cases, associations have been examined based on a basic reproduction rate (R0) for the virus (e.g.: Yao et al., 2020), which would be the best parameter to use to assess the direct influence of environmental variables, since it controls for the effect of prevention measures aimed at slowing the spread of the disease (Smit et al., 2020). The main meteorological parameters studied are ambient air temperature and relative humidity and, to a lesser extent, precipitation, UV radiation and wind.

The results of these ecological studies mostly indicate positive correlations or associations between temperature, relative humidity and COVID-19 incidence (Briz-Redón & Serrano-Aroca, 2020; Mecenas et al., 2020; Smit et al., 2020). These observed trends are consistent with experimental data concerning the influence of these parameters on virus persistence. However, the epidemiological results show some heterogeneity, depending on the methods used and between the countries considered. Findings from the only study focusing on Canada do not support the hypothesis that higher temperatures would reduce transmission of COVID-19 (To et al., 2021). Regarding the influence of precipitation, wind and UV radiation on transmission, epidemiological studies show inconsistent results (Briz-Redón and Serrano-Aroca, 2020).

Although the results of epidemiological studies may suggest certain trends for temperature and humidity, it is important to highlight the important methodological limitations (Briz-Redón & Serrano-Aroca, 2020; Mecenas et al., 2020; Smit et al., 2020). Notably, these studies are subject to the ecological fallacy, i.e., associations obtained from group data (i.e.: number of cases per region) may not hold at the individual level. In addition, significant factors that may confound the associations were not considered – such as population density, age structure and comorbidity of the population, poverty, access to health care and screening, as well as the public health measures in place (Mecenas et al., 2020; Smit et al., 2020). The time series used to assess the influence of the daily fluctuation of meteorological parameters on COVID-19 incidence are also subject to uncertainties related to the accuracy of daily health data. Substantial exposure errors are also plausible, particularly as the same meteorological value is generally attributed to an entire population.

Ultimately, there has not yet been a sufficiently adequate and thorough analysis of the epidemiological data to determine whether meteorological parameters have a direct effect on the incidence of COVID-19 in the population. It is assumed that the direct influence of weather on COVID-19 incidence would be negligible compared to other factors that are known to significantly modulate transmission, notably the frequency and duration of close contact as well as hand hygiene, respiratory etiquette, and the wearing of medical masks or face coverings (Jüni et al., 2020; Mecenas et al., 2020; Smit et al., 2020). Concerning the question of the seasonality of COVID-19, this cannot yet be elucidated given the limitations of the above-mentioned epidemiological studies, to which can be added an under-representation of studies conducted in the southern hemisphere, and the short lapse of time (< 1 year) since the onset of the pandemic.

Is it less risky to practice physical activities outdoors than indoors?

KEY TAKEAWAYS

- During sports activities or physical exertion, more particles (drops and aerosols) are usually emitted, and these can be transported over greater distances (beyond 2 metres).
- Practicing activities outdoors, rather than indoors, would lower the risk of transmission, particularly because of the diluting power of the ambient air.
- The application of public health recommendations, particularly physical distancing, is crucial to prevent the transmission of COVID-19 during the practice of physical activities, whether outdoors or indoors.

When people engage in activities that increase their respiratory flow, they usually emit a greater volume of air and particles (drops and aerosols). This can lead to an increase in the viral load suspended in the air or deposited on surfaces in the vicinity of the infected person, thus increasing the risk of virus transmission. In addition, during physical activity or exertion, respiratory particles are expelled at higher velocities, enabling them to be transported over greater distances. Results from laboratory studies have shown that aerosols can be dispersed over a distance greater than 2 metres if they are expelled or expectorated forcefully or if they are carried by air currents (Blocken et al., 2020a; Bourouiba, 2020; Guerrero, Brito & Cornejo, 2020; CDC, 2019). For example, a series of digital simulations involving air currents generated by walkers and runners suggest that aerosols could be propelled several metres behind them (Blocken et al., 2020b). These same simulations suggest that in the absence of wind, maintaining a distance of 5 to10 metres in the slipstream of a fast walker provides protection that is comparable to maintaining a 2-meters distance between two stationary people (Blocken et al., 2020b). It is important to note that the results generated by such simulations may not be representative of what is observed in real outdoor conditions (Asadi et al., 2020; Bourouiba, 2020). Various environmental factors will influence the propensity of potentially infectious aerosols to remain suspended in the ambient air, to disperse or to settle. In particular, the significant diluting power of the atmosphere, as well as the presence of wind, precipitation and ultraviolet radiation, could rapidly reduce the concentration of aerosols and the distance they travel in the outdoor environment, as well as the concentration of potentially infectious virus in airborne aerosols (NCCEH, 2020). However, winter conditions (especially temperatures that are generally below freezing) could favour the persistence of infectious airborne aerosols and their dispersion over longer distances.[2]

[2] The influence of some of the principal environmental factors on the persistence or culturability of the virus is discussed in the response to a previous question.

Although not specific to outdoor environments, other parameters could significantly influence the level of transmission risk during physical activity (Haut Conseil de la santé publique [HCSP], 2020a; Canadian Institutes of Health Research, 2020; CDC, 2020b). These parameters include, among others, the duration of the activity, the number of participants, the sharing of equipment (e.g.: ball, water bottle) and the physical distancing during the activity (frequency and duration of close contact). With regard to this, outdoor settings can facilitate respect for physical distancing appropriate to the context and the type of activity practiced.

The application of recommendations concerning physical distancing (≥ 2 metres), hand hygiene, respiratory etiquette and the wearing of a medical mask or face covering remain imperative in preventing the transmission of COVID-19 during the practice of sports activities, whether outdoors or indoors, and regardless of the season (Comité sur les mesures populationnelles, 2020; Gouvernement du Québec, 2020b). It is also recommended to practice certain activities, such as running, in sparsely occupied areas or in areas designated for this purpose. For more information on the practice of winter sports and recreational activities in the context of the COVID-19 pandemic, readers may consult the document *COVID-19 et saison hivernale : favoriser le transport actif et la pratique d'activités extérieures* (Bergeron et al., 2020) [in French only].

Should a face covering or medical mask be worn when outdoors?

KEY TAKEAWAYS

- The wearing of a face covering or medical mask is recommended in outdoor public spaces where it is difficult to maintain physical distancing, regardless of the outdoor temperature or season.
- For purposes of efficacy and breathability, it is recommended that the medical mask or face covering be replaced when it becomes wet, damp or frozen, which may be more frequently required in the winter and when respiratory flow is increased (e.g.: during moderate to intense physical or sports activities).

In general, in outdoor public spaces where it is difficult to maintain physical distancing (e.g.: on a commercial street), many national and international organizations recommend wearing a face covering (e.g.: a handmade fabric mask), regardless of the ambient air temperature or season (Comité sur les mesures populationnelles, 2020; Government of Canada, 2020; HCSP, 2020b; CDC, 2020c). Indeed, the wearing of face coverings represents an added measure of respiratory etiquette in crowded public spaces, including those outdoors. However, under no circumstances should the wearing of a face covering replace the contact minimization and physical distancing measures currently in effect (Groupe de travail sur la ventilation, 2021).

When used properly, a face covering or medical mask could theoretically limit, at the source, the projection of infectious particles expelled through the mouth or nose of its user when the latter exhales, speaks, sings, coughs, sneezes or increases their respiratory flow – e.g.: during moderate or intense physical effort (Comité sur les mesures populationnelles, 2020). A medical mask is a better option than a face covering, since it offers better breathability and has a greater filtration capacity, thus providing greater protection for others, as well as protection for the wearer, unlike a face covering (Davies et al., 2013; Guay et al., 2020; Leung et al., 2020; Milton et al., 2013). In brief, the usefulness of face coverings and medical masks continues to be of interest, regardless of the outdoor temperature.

Winter conditions may cause face coverings or medical masks to become damp and freeze. Indeed, in cold weather, the accumulation of moisture in the filtering material may lead to the formation of frost on the inner and outer surfaces of the face covering or medical mask. This humidity could increase viral persistence in the flow of filtered air as well as cause air leakage around the edges of the face covering or medical mask (Belkin, 1996), and cause breathing difficulties and discomfort (CDC, 2020d). Thus, although to date no data are available on the efficacy of wearing face coverings or medical masks at sub-freezing temperatures in the context of the COVID-19 pandemic, some precautions are warranted.

For purposes of comfort and efficacy, it is recommended to remove the face covering, or dispose of the medical mask, when it becomes wet, damp or frozen, and replace it with a clean, dry face covering or a new medical mask (Alberta Health Services, 2020; Government of Canada, 2020; CDC, 2020a; WHO/OMS, 2020b). This may be required more frequently in winter and when respiratory flow is increased (e.g.: during moderate to intense physical or sports activities). In addition, in very cold weather, a neck warmer made of a material like polar fleece can be worn over the face covering or medical mask to protect it from the cold.

In brief, the efficacy of the face covering or medical mask may be altered when it becomes wet or frozen and in situations where the user's respiratory flow is increased. In addition, it is recommended to wear face coverings or medical masks in outdoor spaces where physical distancing is more difficult to maintain, but not as a replacement for the latter.

For further details on the instructions for wearing face coverings or medical masks in the general population, readers can consult the INSPQ document on this subject: *COVID-19 : Port du couvre-visage ou du masque médical par la population générale* [in French only].

Does outdoor air pollution play a role in the incidence and severity of COVID-19?

Key takeaways

- Air pollution is associated with the development and exacerbation of certain pre-existing chronic conditions that are also linked to COVID-19.
- Due to significant methodological limitations, epidemiological studies do not allow us to determine whether air pollution increases the transmission or severity of COVID-19.
- The hypothesis that atmospheric particulate matter could spread the virus is implausible, as the infectious strength and the infectious dose would likely be insufficient to cause long-range infection.

Since the beginning of the pandemic, several observational epidemiological studies have been published that have assessed the relationship between air pollution and COVID-19. Some have attempted to assess the association between the number of cases or deaths attributable to COVID-19 in a given region and the daily exposure to air pollutants in that region (Adhikari & Yin, 2020; Jiang, Wu & Guan, 2020; Zhu et al., 2020). Others have looked at the relationship between COVID-19 cases and mortality in different regions and long-term exposure to air pollution, that is, before the pandemic (Conticini, Frediani & Caro, 2020; Fattorini & Regoli, 2020; Frontera, Cianfanelli, et al., 2020; Stieb et al., 2020; Travaglio et al., 2021). Finally, several of the studies published to date report a positive association between concentrations of some ambient air pollutants, such as fine particulates and nitrogen oxides, and cases and deaths attributable to COVID-19.

However, all these studies have significant methodological limitations (Heederik et al., 2020; Villeneuve & Goldberg, 2020). Briefly, they are all based on an ecological design that does not allow for causal inference, since associations obtained from aggregate data (i.e.: number of cases per region) may be inconsistent with associations observed at the individual level. The estimated exposure to air pollutants is a source of potential bias given the low geographical resolution of the data used. The identification of cases is also problematic, as some cases are asymptomatic and screening is variable over time and across jurisdictions. Various factors that may confound or modify associations have not been considered, such as the agglomeration of cases (e.g.: cases in factories or seniors' residences), access to health services, confinement and public health measures, as well as many individual characteristics, such as pre-existing chronic diseases, age, medication use, socioeconomic status, ethnicity, etc. (Heederik et al., 2020; Villeneuve & Goldberg, 2020). The results of these ecological studies raise only hypotheses that will require further study.

Despite the methodological weaknesses of the studies conducted so far, plausible mechanisms could explain a possible link between air pollution, COVID-19 incidence and mortality attributable to this disease (Heederik et al., 2020). These involve the fact that some pre-existing chronic conditions, which are associated with the risk of death from COVID-19 (e.g.: cardiovascular diseases, respiratory diseases, diabetes), are also known to be associated with long-term exposure to air pollution (Simard et al., 2020). People suffering from these chronic diseases are also known to be more sensitive to daily variations in air pollution. Thus, for these chronically ill individuals, short-term exposure to air pollution could possibly increase the risk of developing severe symptoms and dying from COVID-19 (Heederik et al., 2020).

Exposure to air pollution could also increase the risk of SARS-CoV-2 infection by altering the immune response to respiratory infections (Cao et al., 2020; Ciencewicki & Jaspers, 2007). It has also been suggested that particulate air matter may affect the persistence of the virus in ambient air and its transportation over greater distances (Frontera, Martin, et al., 2020; Martelletti & Martelletti, 2020). However, this hypothesis appears implausible; it seems unlikely that the virus would retain its infectious strength and that the infectious dose in ambient air particles would be sufficient to cause long-range infection.

Is the COVID-19 pandemic having an impact on outdoor air quality in Québec?

Key takeaway

- During the first wave in the spring of 2020, the confinement measures had a notable impact on road traffic and the concentration of some ambient air pollutants in urban areas in Québec and elsewhere in the world. However, the effect of confinement on air pollutant concentrations has since diminished.

Regional emissions (i.e., from other provinces and countries such as the United States) and local emissions (i.e., from road vehicles, industry and residential wood burning) are the main sources of air pollution in Québec. The various COVID-19 control measures implemented by public health authorities (provincially and internationally), particularly the closure of schools, industries and non-essential businesses, have led to a marked reduction in automobile, air and rail traffic, as well as in some industrial activities. For example, data collected at a station that tracks the number of vehicles travelling on the Henri-IV highway in Québec City showed that this number dropped from nearly 500,000 to less than 200,000 per week following the implementation of the confinement measures in the spring of 2020 (Gouvernement du Québec, 2020a).

In line with this finding, a decrease in the concentrations of several air pollutants was noted at the stations of the Réseau de surveillance de la qualité de l'air du Québec [Québec's air quality monitoring network] in various urban environments, particularly during the closure of schools and non-essential businesses in the spring of 2020 (Gouvernement du Québec, 2020a). Weekly nitrogen dioxide (NO_2) concentrations in the air decreased substantially beginning with the week of March 9, 2020 (Gouvernement du Québec, 2020a). The decrease in NO_2 concentrations during the confinement period is estimated to have been approximately 40% for Québec City, Montréal, Longueuil and Laval (Gouvernement du Québec, 2020a). NO_2 is one of the air pollutants emitted by the burning of fossil fuels (diesel, gasoline, coal) by road vehicles and industries. As mentioned in the previous section, short- and long-term exposure to NO_2 is associated with a variety of adverse health effects, including, among others, an increased risk of respiratory and cardiovascular morbidity and mortality (United States Government, 2016).

Elsewhere in Canada, the concentrations of air pollutants tied to road traffic have also shown similar trends (Adams, 2020). Other data, including satellite imagery covering many regions of the globe, corroborate these findings showing a decrease in average ambient concentrations of NO_2 following the closure of schools and non-essential businesses during the first wave of the pandemic (Venter et al., 2020).

However, a resurgence of NO_2 concentrations was observed from the end of April 2020 following the gradual resumption of economic activities. Moreover, concentrations of some pollutants, such as sulphur dioxide (SO_2) and ozone (O_3), do not appear to have decreased during the spring lockdown in some regions of the world (Acharya et al., 2020; Kumari & Toshniwal, 2020).

It is important to note that air pollutant levels also fluctuate naturally depending on meteorological conditions (i.e., with the presence of wind, rain, solar radiation, etc.). Consequently, in-depth analyses are required to determine the extent to which the observed decrease in air pollution may be attributable to the economic slowdown caused by the COVID-19 pandemic (Schiermeier, 2020).

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Appendix – Methodology: Rapid knowledge synthesis

1. **Cautionary note on institutional methodological**

   ✔ YES
   ☐ *If not, why not?* ______________________________

2. **Explicit formulation of the research questions covered or objectives of the synthesis**

   ✔ YES ☐ NO
   If not, why not? ______________________________

3. **Literature search strategy**

   a. ✔ Use of the COVID-19 institutional daily scientific monitoring bulletin
   b. ☐ Use of a COVID-19 institutional targeted scientific monitoring bulletin
   c. ✔ Use of the institutional grey literature monitoring bulletin

   Environmental Health scientific monitoring bulletin, up until November 23, 2020.

   d. ☐ Establishment of a specific literature search strategy (retrospective)
   e. ✔ Other

   Specify

   Grey literature research for positions of recognized organizations

4. **Use of inclusion criteria**

   ☐ YES ✔ NO

5. **Treatment of preprints**

   ✔ Their inclusion is noted ☐ Their identification is facilitated it the document

   Preprint articles were used, but were not identified as such in the document.

6. **Data extraction**

   Inclusion of evidence tables
   ☐ YES ✔ NO

7. **Assessment of the quality of the studies or the level of the evidence**

   ✔ NO
   ☐ YES

8. **Peer review**

   a. ✔ by the members of the related expert committee
   b. ✔ by members of other INSPQ COVID-19 thematic units or committees
   c. ✔ by other reviewers at the INSPQ who did not participate in the work
   d. ✔ by external reviewers (who are not from the INSPQ and who did not participate in the work)
   e. ☐ No peer review

Previous versions

Version	Date	Pages	Modifications
1.0	May 20, 2020	14	▶ Production of the information sheet COVID-19: Outdoor environment
2.0	January 7, 2021	37	▶ Updating of the information sheet based on, among other things, new knowledge concerning the transmission of the virus and issues associated with the transmission of COVID-19 in winter.

COVID-19: Outdoor environment – Question and answer document based on recent literature

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