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COVID-19 environmental transmission and preventive public health measures

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With new COVID-19 cases decreased to very low levels in most parts of Australia, although persisting in a number of hotspots – mainly in the state of Victoria – and increasing in some other countries such as Brazil, it is time to reflect on the effectiveness and unintended consequences of public health measures taken so far at home and overseas to prevent transmission, and to identify challenges ahead.

Extensive testing, contact tracing, and individual-case and community containment, in addition to travel bans and social distancing, have largely succeeded in curbing COVID-19 infections in Australia. Strict lockdowns prevented widespread community transmission, albeit at very high economic cost. The imposed restrictions changed daily activity patterns and behaviours that also brought improvements in other areas. Greenhouse gas emissions declined, and ambient air and potentially surface water quality improved in many cities, mainly because of reduced road traffic and industrial activity. Influenza cases were suppressed as a result of social distancing, better hand hygiene and home schooling. Some of these changes are likely to be transient, as economic and social activities are progressively increasing in most areas. However, we can draw some important public health learnings from the response to the pandemic that will help us reduce the risk of a resurgence of COVID-19 and strengthen disease prevention against a whole range of other pathogens in the long term.

Environmental transmission pathways

A better understanding of the environmental transmission pathways of COVID-19 can focus the attention of public health units on the most effective prevention methods and, importantly, reduce the risk of community transmission in different settings. Although

our current knowledge of the disease and the virus that causes it (SARS-CoV-2) is still evolving, we can learn from past coronavirus outbreaks such as the Severe Acute Respiratory Syndrome (SARS)¹ and the Middle East Respiratory Syndrome (MERS)² outbreaks, and from the course of the current pandemic in Australia and other countries.

Most coronaviruses are transmitted via respiratory droplets through the mucosal or direct inhalation route and are manifested as respiratory diseases. However, human coronaviruses show environmental resistance that makes transmission via surfaces, hands, air, water, waste and food plausible.³ In the SARS epidemic, transmission mainly occurred through direct physical contact with infected patients or by respiratory droplet spread over relatively close distances.⁴ There were also a number of well-documented clusters of infection, which led to speculation about other possible transmission pathways, including contaminated air, sewage and surfaces,⁵⁻⁷ and animal vectors.⁸ The main transmission route of COVID-19 is thought to be via the spread of respiratory droplets from coughs and sneezes and direct contact with contaminated surfaces. However, emerging evidence suggests that airborne transmission via the spread of smaller particles (called 'aerosols') from exhaled air is also possible, especially indoors.⁹⁻¹²

How far droplets and aerosols can spread depends on their size, as well as on the velocity of the respiratory jet (from coughing, sneezing, talking and breathing), and the temperature, humidity and flow of surrounding air.^{13,14} Current evidence suggests that larger (>5 microns) respiratory droplets released by coughs or sneezes settle gravitationally close to the infected individual (within approximately 1 m). Smaller droplets (≤5 microns) evaporate quickly in the air forming very small particles (called 'droplet nuclei') that can travel longer distances.

There is currently limited experimental evidence on how far these particles can travel and whether they can transmit COVID-19 under typical environmental conditions, although this is theoretically possible.^{10,11,15,16} A recent literature review has indicated that transmission of viruses is lower with physical distancing of one metre or more, with protection increasing as distance is lengthened.¹⁷

Evidence of substantial airborne transmission of COVID-19 can have profound consequences for health protection and would potentially require additional precautions, such as increased air ventilation in indoor spaces and wider community use of face masks, to reduce the risk of infection.^{18,19} The mode of transmission could also determine whether an infection starts in the upper or lower respiratory tract, which is thought to affect the severity of the disease progression.¹⁸

The effectiveness of face masks in blocking droplets and aerosols depends on the type of mask and facial fit, and the size of the aerosols. Masks rated N95 or similar are effective in blocking aerosols of at least 0.3 microns in diameter when well fitted around the mouth and nose. Surgical masks fit loosely around the mouth and nose and may allow inward leakage of smaller aerosols. A recent review of the literature suggests that face mask use could result in a large reduction in risk of COVID-19 infection, with stronger associations with N95 or similar masks compared with surgical masks.¹⁷ Even non-professional masks such as homemade cloth masks can provide certain benefits, mainly by reducing transmission from infected persons. Eye protection has also been associated with reduced infection.

Improved ventilation in indoor spaces, including public transport and nursing homes, needs to be considered as a preventive measure because it can substantially reduce the airborne time of respiratory droplets and aerosols.¹⁸ Air filtration with common domestic devices, such as portable air cleaners with high-efficiency particulate air (HEPA) filters, can remove small particles of dust or pollen that may act as carriers of SARS-CoV-2.²⁰ UV air purifiers and ozone-generating air cleaners are unlikely to be effective in suppressing airborne transmission since they need relatively long contact times to inactivate viruses. The effectiveness of air cleaners in limiting airborne transmission of COVID-19 in indoor spaces requires more evaluation.

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COVID-19 can be transmitted by touching contaminated surfaces and then a mucous membrane (eyes, mouth or nose). A key question is how long SARS-CoV-2 can survive on different surfaces. There is evidence that coronaviruses can remain infectious on inanimate surfaces like metal, glass and plastic at room temperature for up to nine days, but with progressively decreased infectivity, and for up to one day on cardboard and four hours on copper.^{3,21,22} It is plausible that in conditions involving higher temperatures (>30°C), increased humidity and more sunshine their persistence is shorter.²¹ The SARS coronavirus was detected on chairs, elevators and computers in emergency rooms and public areas of hospitals.^{23,24} Extensive surface contamination was detected in a SARS-CoV-2 outbreak centre in Singapore.²⁵ Environmental contamination of frequently touched surfaces in domestic, occupational and healthcare settings, as well as in cruise ships and planes, is therefore a potential route of transmission of COVID-19. These findings suggest that personal objects, such as mobile phones and mugs, that are exposed to respiratory droplets can potentially transmit the virus and should not be shared unless disinfected.

Hand hygiene remains critical for reducing the spread of COVID-19. Good handwashing with soap and water is effective, as well as correctly applied sanitiser gel.²⁶ The effectiveness of disinfection in inactivating the virus using a range of cleaning products on different surfaces can vary. Factors affecting the disinfection process include the type of disinfectant, its dilution, contact time, acidity/alkalinity of the product, air temperature and humidity, and interfering substances.³ In all cases, the disinfection process should include an initial cleaning step with water and detergent to remove dirt and other organic materials.

Human coronaviruses have been associated with diarrhoea and other gastrointestinal symptoms.²⁷ Some coronaviruses can potentially survive in the gastrointestinal tract, and viral shedding via faeces has been reported for COVID-19.^{1,28} The SARS coronavirus was shown to survive for at least four days in sputum, serum and faeces,³ and also in urine, but with lower infectivity.²⁹ Detection of another human coronavirus (HKU1) in stool samples from adults and children supports the idea of potential contamination via faeces.³⁰ Therefore, the risk of water or food contaminated with faecal waste should be considered as a potential pathway of transmission.^{3,31} However,

foodborne transmission is unlikely when food is properly prepared and cooked (typically at around 70°C). Importantly, transmission through food consumption did not occur in previous coronavirus outbreaks (SARS and MERS). In the COVID-19 pandemic, there are no reported cases of transmission through food consumption, although transmission through contaminated food packaging may be possible. It is unlikely that chlorinated drinking water will be affected by coronavirus in places with good water treatment infrastructure. SARS-CoV-2 has not been detected in drinking water and based on current evidence the risk to water supplies is low.³² Nevertheless, laboratory studies have shown that coronavirus could remain infectious in water contaminated with faeces for days to weeks.³³ Conventional water treatment methods based on filtration and disinfection, including chlorination and UV light, can effectively inactivate SARS-CoV-2 and other human coronaviruses.

Preventive measures and implications for public health

Public health approaches to curb the transmission of COVID-19 should continue to focus on testing, case tracing, containment, social distancing and hygiene, particularly in the absence of a new vaccine or specific treatment.³⁴ The combination of multiple measures, and their timing, have shown to achieve substantial impact on transmission. China enforced drastic public health measures, including widespread testing, extensive individual-case and community containment with social distancing, rigorous contact tracing using artificial intelligence, community use of face masks, and early lockdown of the most affected region, with notable success.¹ Early travel restrictions were highly effective in containing the epidemic in Australia.³⁵ Mandated face covering has also been shown to effectively prevent transmission in heavily affected regions in Italy and New York City.¹⁹ As COVID-19 restrictions are being progressively eased in parts of Australia, the wider use of face masks needs to be considered, particularly in crowded public places where physical distance cannot be maintained. Mass gatherings should be avoided, and home working and distant learning encouraged as they can bring long-term health and environmental benefits. Increased ventilation with air filtration needs to be considered in indoor environments, such as offices, restaurants and lecture theatres. Rigorous personal, environmental and occupational hygiene

(thorough hand washing, good cough and sneeze etiquette, and surface disinfection), as well as physical distancing, should be sustained even beyond the pandemic. A combination of these measures (Table 1) is likely to provide the best long-term protection against COVID-19 and other respiratory infections. A better understanding of SARS-CoV-2 spread and survival will be crucial in characterising the risk of transmission via different environmental pathways. Susceptibility of the virus to environmental stressors (temperature, humidity, sunlight), and interactions of COVID-19 with underlying chronic diseases (e.g. cardiorespiratory, diabetes), and environmental exposures (e.g. air pollution, respiratory allergens) need to be systematically investigated.

A better understanding of potential transmission routes and interactions with other illnesses and exposures will improve the long-term management of the pandemic. Importantly, it will enable front-line health care workers and public health responders to protect themselves and others through proportional preventive measures. It will also help public health units evaluate hypotheses for the transmission of the disease, improve individual case investigation, and implement appropriate physical distancing, environmental decontamination and personal protection and hygiene practices.

Although we still do not know how SARS-CoV-2 behaves across seasons,³⁶ the enhanced survival rate of the virus at low temperature, together with closer social interaction, may explain to some extent the rapid winter propagation of coronaviruses in parts of Asia, Europe and North America.³ The early suppression of COVID-19 in Australia has enabled health authorities to build testing, tracing and hospital capacity that will help tackle a potential resurgence of the disease. Persistent community transmission in Victoria and localised outbreaks in NSW have shown that we cannot be complacent. Strict adherence to preventive measures during the southern hemisphere winter and beyond is crucial in keeping the pandemic under control.

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Table 1: Benefits and trade-offs of public health measures for preventing COVID-19 transmission.

Measure	Benefits	Trade-offs
Testing, individual case tracing and containment (isolation and quarantine)	<ul style="list-style-type: none"> • Effective in reducing transmission while the epidemic is relatively contained • 14-day isolation is appropriate • Early case detection is crucial 	<ul style="list-style-type: none"> • Less effective if there is a large number of asymptomatic or mildly symptomatic cases, or significant pre-symptomatic transmission • Requires strict enforcement; penalties may be considered for quarantine violations
Social distancing (maintaining physical distance, closures of schools, shops, and public transport, working from home, distant learning, banning mass gatherings)	<ul style="list-style-type: none"> • Important where there is risk of community transmission • Maintaining over 1 m distance between people is considered an effective measure, with protection increasing as distance is lengthened • Reduces emissions from transport, but potentially increases emissions of pollutants from the housing sector 	<ul style="list-style-type: none"> • Many parents (including health care workers) have to stay at home to care for young children • Large impact on the economy and businesses • Impractical (e.g. food delivered should be left outside the door) • Requires strict personal adherence • Potentially reduced social interaction and physical exercise • Difficult to implement in poorer communities / informal settlements
Community containment (city/region/country lockdown, including travel restrictions)	<ul style="list-style-type: none"> • Important where there is substantial community transmission and/or many imported cases • Reduced emissions of greenhouse gases and other pollutants 	<ul style="list-style-type: none"> • Very high economic cost • Increased social isolation • Impractical in the long term • International travellers locked in • Individual human rights issues
Personal hygiene (hand washing, hand sanitiser, sneeze and cough etiquette)	<ul style="list-style-type: none"> • Effective in reducing contact and droplet transmission risk if applied appropriately • Sanitiser gel formulations based on 80% ethanol or 75% 2-propanol are very effective 	<ul style="list-style-type: none"> • Frequent use of alcohol-based hand sanitisers or chlorinated water can cause dermal irritation
Surface disinfection	<ul style="list-style-type: none"> • Effective with correct disinfectants (70% ethanol, 0.5% hydrogen peroxide or 0.1% sodium hypochlorite with 1 min contact) • A range of other cleaning products are effective (with recommended dilution and contact time) 	<ul style="list-style-type: none"> • Ecological toxicity of sodium hypochlorite ("bleach") and other disinfectants • Sodium hypochlorite might cause respiratory irritation to some individuals
Face covering, including surgical, N95 and P2 masks, and non-professional masks	<ul style="list-style-type: none"> • Well-fitted professional (surgical or N95/P2) masks offer very effective protection from respiratory droplets • Well-fitted N95/P2 masks offer very effective protection from airborne aerosols • Face covering reduces the spread of respiratory droplets from cough or sneeze in infected individuals • Widely used face covering (even non-professional masks) is effective in suppressing community transmission • Reduces transmission risk in settings where physical distance cannot be maintained • Low cost intervention 	<ul style="list-style-type: none"> • Generally uncomfortable to wear over long time periods • Masks with exhalation valves do not offer protection to those around the individual wearing the mask • They can get contaminated and need to be replaced or washed frequently • Masks may give a false sense of security • Widespread community usage of professional masks may reduce their availability to high-risk healthcare workers • Not suitable for very young children or for those who have difficulty breathing
Air ventilation/ filtration	<ul style="list-style-type: none"> • Increased natural/mechanical ventilation reduces the risk of transmission in indoor spaces • Air filtration with HEPA filters may reduce the risk of airborne transmission in indoor spaces 	<ul style="list-style-type: none"> • Significant upfront purchase and/or installation and running costs of mechanical ventilation/filtration • Potentially increased noise and security/safety concerns in relation to open windows

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