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Ventilation risk assessment for people working at quarantine hotels and the potential for SARS-CoV-2 virus transmission

Prepared for the Department of Health, Western Australia

March 2021

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AUSTRALIA

Report Title	**Ventilation risk assessment for people working at quarantine hotels and the potential for SARS-CoV-2 virus transmission**		
Project Name			
Job Number		**Client**	**Department of Health, WA**
Report Number	112021		
Report Author	Dr Laurie Glossop – Principal Consultant, Certified Occupational Hygienist 		

DOCUMENT DISTRIBUTION

Document File Name	Document Status	Distributed to	Date distributed
Ventilation risk assessment for people working at quarantine hotels and the potential for SARS-CoV-2 virus transmission	Draft V1	[redacted] Managing Scientist Chemical Hazards (Principal Toxicologist)	8th March 2021
Ventilation risk assessment for people working at quarantine hotels and the potential for SARS-CoV-2 virus transmission	Draft V2	[redacted] Managing Scientist Chemical Hazards (Principal Toxicologist)	9th March 2021
Ventilation risk assessment for people working at quarantine hotels and the potential for SARS-CoV-2 virus transmission	FINAL	[redacted] Managing Scientist Chemical Hazards (Principal Toxicologist)	11th March 2021
Ventilation risk assessment for people working at quarantine hotels and the potential for SARS-CoV-2 virus transmission	FINAL Revised	[redacted] Managing Scientist Chemical Hazards (Principal Toxicologist)	30th March 2021

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1 Introduction

Dr Laurie Glossop, Principal Consultant and Certified Occupational Hygienist of Glossop Consultancy, was contracted by the Department of Health WA in February 2021 to risk assess the ventilation system of hotels being used for quaranting potential COVID positive returning travellers as a possible means of transmission of SARS-CoV-2 to security guards, health workers and hotel employees located or working on the quarantine floors of the hotels.

The ventilation and risk assessment of the quaratine hotels was done in conjunction with Mr Ian Harwood (Director, Mechanical Engineer F.AIRAH. Bsc (Hons), PDF Engineering). Indiviual hotel reports have been written by Ian Harwood and Laurie Glossop which are incoproated in one document by PDF Engineering.

The primary role of Dr Laurie Glossop was to assess the risk of transmission to the security gards and other personnel working in quarantine hotels. The PDF Engineering report considers the ventilation factors in isolation of other mitigating controls that influence the risk of transmission to workers and therefore may rate the hotels differently based on ventilation design and efficiency alone.

This overarching ventilation risk assessment of all the hotels puts in one document the following information:

- Hazard of COVID-19 to hotel quarantine workers.
- Hotel workers at risk.
- Variation in hotel ventilation systems.
- Risk categorising quarantine hotels currently in use.
- What can be done to lower the risk at hotels that are currently at higher risk.

2 Hazard of COVID-19 to hotel quarantine workers

This ventilation risk assessment is based on the following hazard criteria:

2.1 Transmission of COVID-19 via inhalation

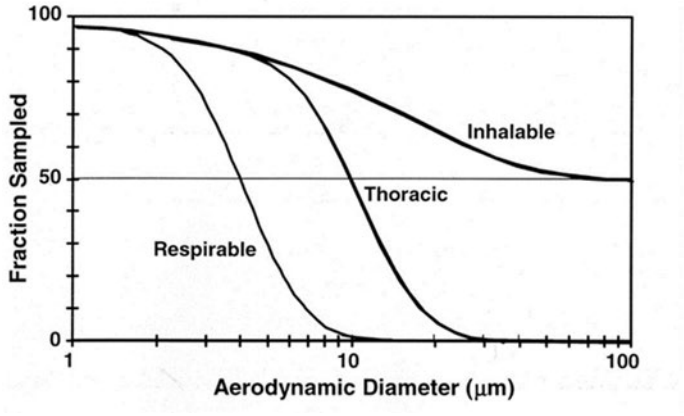
Transmission of COVID-19 occurs almost exclusively by close contact, typically within a distance of 2 metres, where inhalable size particles dominate. However, it must be remembered that when someone coughs or sneezes there are a wide range of particle sizes released, not just large particles and virions will travel greater distances.

COVID-19 transmission can occur even before a person shows symptoms, but a greater number of inhalable and respirable particles are likely when somebody has the symptoms of coughing, or sneezing. It is also known that people can transmit inhalable and respirable particles greater distances when singing, shouting or doing strenuous work activities.

Recently there is increasing evidence that a combination of respirable (aerosol) and inhalable (droplet) transmission of COVID-19 can cause infection. Respirable particles are particles that are less than 5μm in diameter and essentially never settle being kept afloat by Brownian Motion. If there is any air movement caused by air-conditioning fans or convection by heat these particles can be distributed a very long way from an infected person. A small number of inhalable particles will vaporise water before settling and become respirable particles. The WHO says the latest variants (successful mutations) of SARS-CoV-2 appear to be more infectious than the earlier variants of SARS-CoV-2 and aerosol transmission could become more important (Ref 4).

The WHO publication *Hazard Prevention and Control in the Work Environment: Airborne Dusts (Ref 1)* provides scientific definitions of particles. The American Conference of Governmental Industrial Hygienists (ACGIH), the International Organization for Standardization (ISO), and the European Standards Organization (CEN) have reached agreement on definitions of the inhalable, thoracic and respirable fractions: (ACGIH, 1999; ISO, 1995; CEN, 1993; ICRP, 1994). These definitions are:

- ***Inhalable particulate fraction*** is that fraction of a dust cloud that can be breathed into the nose or mouth.
- ***Thoracic particulate fraction*** is that fraction that can penetrate the head airways and enter the airways of the lung.
- ***Respirable particulate fraction*** is that fraction of inhaled airborne particles that can penetrate beyond the terminal bronchioles into the gas-exchange region of the lungs. Examples of dusts for which the respirable fraction offers greatest hazard include quartz and asbestos. The sampling efficiency curve for these dust fractions is presented in this graph:

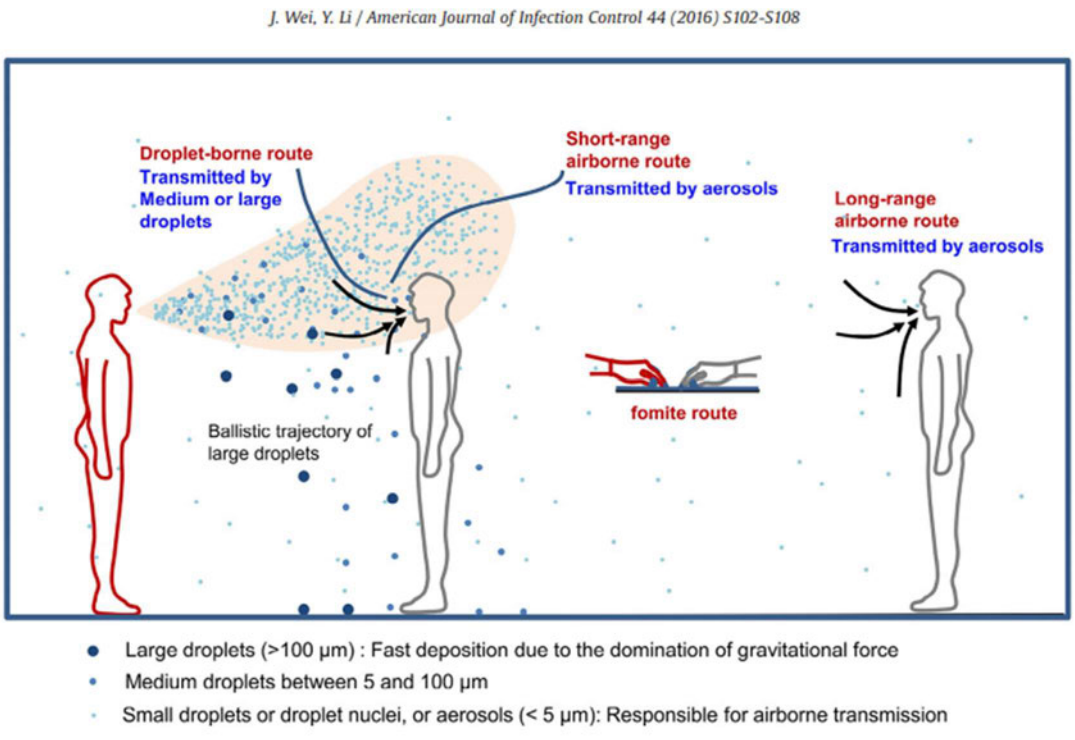


The following table provides the settling time in still air for different size particles falling from a height of 2 metres.(Ref 2):

diameter (microns)	u_t (m/s)	t
0.1	1.761×10^{-6}	315 hours
1.0	7.069×10^{-5}	7.9 hours
10	6.155×10^{-3}	5.41 minutes
100	0.463	4.32 seconds

Particles less than < 50 µm in diameter can stay suspended in air for many minutes and travel significant distances if there is air movement (Ref 7).

The following diagram by Wei (Ref 3) summarises the airborne transmission of viruses for different size particles.



2.2 Mechanical ventilation and air movement between indoor occupied spaces

The following diagram by Wei shows how virions can move out of a room into a corridor even though the room is at negative pressure. The number of virions leaving a room would be minimal and low risk. However, if a room is positive pressure, then there will be an even greater number of virions going into a corridor. Rooms for quarantining should be negative pressure or at least neutral pressure. That is large pressure differentials should be avoided, with a preference towards negative room pressurisation.

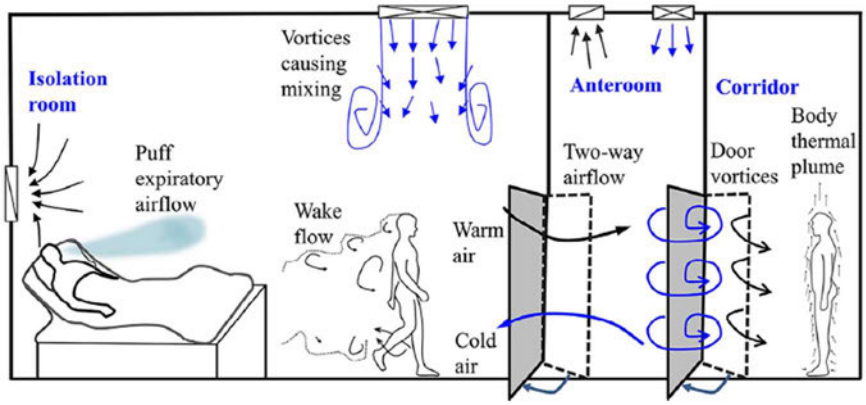


Fig 3. Droplet transport in an isolation room by expired airflow, thermal plume[51], door vortices (adapted with permission from Elsever[57]), human walking[54], 2-way buoyancy airflow, and ventilation airflow.

The WHO (Ref 8) have published the “Roadmap to improve and ensure good indoor ventilation in the context of COVID-19” have recommended at minimum requirements for “health care settings including quarantine facilities” 160 L/s/patient or 12 Air Changes per Hour where “Aerosol-generating procedures are performed and 60 L/s/patient or 6 Air Changes per Hour for a patient with COVID-19. These recommendations are for people infected with COVID-19. In nearly all non-quarantine settings the requirement for fresh air is 10L/s/person.

In a hotel environment, rooms and corridors are ventilated by air conditioning systems and there are about 1 to 3 air changes per hour of fresh air in rooms so the SARS-CoV-2 virus particles from COVID-19 positive guests can accumulate before reaching a steady state. In the quarantine hotels there was at least 10L/s/person of fresh air, which is sufficient for normal room occupation, but if a person has COVID-19 and symptoms of coughing and sneezing, then in most of the hotels they would not be achieving the WHO recommendations. This is only an issue however if other people are in the room for at least more than 15 minutes.

If a room is positive pressure to a corridor, then there will be thoracic to respirable size particles transported to the corridors and potentially other rooms when doors are opened. Some of the hotels assessed are possibly pushing about 40L/s or more air continuously from accommodation rooms into the corridors from gaps around the door, but mostly under the door where there is normally the largest gap. As the corridors are typically poorly ventilated the virions will not be diluted quickly. Factors that will likely contribute to a higher dose are lower ventilation rates in the corridor, proximity to a relatively high positive pressurised room, being in the relief air pathway, a symptomatic guest producing larger numbers of aerosols (coughing, sneezing) and/or shedding virus at a higher rate, the number of door openings, time the door is open and movement of clinical staff from a room into the corridor.

3 Hotel workers at risk

There are groups of workers in quarantine hotels who are at greatly differing risk of being infected with COVID-19:

- **Health workers** that come into close contact with COVID-19 positive guests. These workers are well aware of the hazard and risk of contracting COVID-19. There are strict infection control procedures and protective equipment required when these workers are in quarantine hotels. It is assumed that guests they visit can be COVID-19 positive and yet not showing symptoms. These workers are being exposed to both droplets and aerosols. These workers are considered to be at moderate to high risk.
- **Security guards** are at low to moderate risk of being exposed to respirable particles coming from air escaping accommodation rooms where there are COVID-19 positive guests. The closer the security guards are to COVID-19 positive guests and the longer they are present in proximity, the higher the risk of transmission because of the increased dose, especially in hotels where accommodation rooms are at positive pressure to corridors.
- **Police and other security personnel including defence forces** that attend to unruly non-compliant guests. They could be in very close proximity to COVID positive guests and there is likely to be yelling and loud speaking which will produce more particles. If they are with a person for an extended period of time their risk would be considered medium to high.
- **Hotel workers** that are delivering meals 3 times a day, collecting rubbish from rooms 3 times a day, collecting used linen about every 5 days and delivering food and equipment to guests. These workers are at low risk because of their short duration in corridors, but they are more likely to go past a room with a COVID positive guest compared to the security guards.
- **Hotel workers that work in reception** where guests are being checked in. This is likely to be low risk as guests are wearing masks and not having close contact. They are also behind Perspex screens when talking to guests which reduces the risk even further.
- **There is also a small group of external workers** who come to the hotels to perform maintenance on accommodation rooms and engineering equipment such as the Air Handling Units. The accommodation rooms all have air being exhausted typically through a bathroom grill, and this air is being released at roof level. This air could be carrying a low concentration of SARS-CoV-2 aerosols. In most quarantine hotels the outside air intakes for the AHUs are also located on the roof so some aerosols could be brought in with the outside air. This risk would be very low.

4 Variation in hotel ventilation systems

A total of 10 hotels were assessed for their ventilation systems – 9 currently used for quarantining and one new hotel that could be added to the list of quarantining hotels.

All 10 of the hotels have something different about their ventilation design and equipment used. The current 9 hotels being used vary in age from the middle of the 1970's (Mercure and Pan Pacific) through to 2020 (Novotel Murray Street) – a difference of 45 years. Over the period of 45 years there have been changes in air-conditioning design and equipment.

One important factor appears to be whether the hotels have smoke drop blades installed on accommodation entrance doors. It is our understanding that the older hotels do not have to retrospectively install such equipment. The smoke drop blades will not change whether a room is positive or negative pressure to a room, but it would certainly reduce a lot of the airflow escaping from around the door. The doors with the smoke drop blades are also well sealed around the 3 other edges of the door making them nearly airtight. This may be a criterion considered for any new quarantine Hotels.

Also, one very new hotel being considered for quarantining (Adnate in Hay Street) has the escape stairs locked magnetically which only allows opening in the situation of a fire. This would then mean you only need to secure the lift lobby area.

In regard to the 10 hotels, we found:

- 4 where the rooms are essentially negative pressure to the corridors.
- 3 where they were a mixture of positive pressure, neutral pressure and negative pressure.
- 3 hotels where the accommodation rooms are at significantly positive pressure to the corridors.

Most of the hotels have the ability to change the pressurisation of the rooms by varying the balance of air supply and relief/exhaust flow. All of the hotels had extraction/exhaust grills in the bathrooms. The exhaust location in bathrooms ensures moisture and odours are removed from the bathroom due to showering etc. and balances the introduction of outside air (fresh air) from the air supply system (AHU). This exhausted air is being released at the top of the building and is highly likely not filtered.

Nearly all of the hotels can adjust building pressure to make rooms more negative pressure, but we believe this can only be varied by about 10% or so in terms of supply and exhaust airflow.

Some of the hotels have no direct supply air ventilation of the corridors and rely on air escaping from rooms with positive pressure for ventilation. This substantially increases the risk of infection to those workers in the corridors and a small risk to guests when they open their entrance doors if there is a COVID positive guest on their level.

All the newer hotels only operate with 100% outdoor air being supplied to rooms. These hotels have Fan Coil Units (FCUs) which condition the air in the individual rooms. The FCUs re-circulate air in a room and can be as much as 90% of the air coming out of the supply air grill in the rooms.

The location of the security guards is important as to whether there is an opportunity for undiluted air to be preferentially directed from a from COVID positive guest's room to a security guard location in the corridor. Where rooms are negative pressure the risk is obviously very low, but where there is a strong positive pressure, the ventilation of corridors is important to enhance dilution of air which may have SARS-CoV-2 virions. The further a security guard is from a COVID positive guest the lower the risk because of dilution of air in the corridors. If a hotel has positive pressure rooms this greatly increases the risk to the security guards and hotel staff making deliveries.

Another factor is the release of built up droplets (inhalable) and aerosols (respirable) when guests open their doors to collect deliveries. There were different procedures between hotels about how the hotel guests were notified of the delivery. Guests being informed by a telephone call would further reduce risk to security guards and hotel workers making the deliveries as they may be able to move further away from opening doors. One challenge is keeping the food hot for guests and the longer between dropping the food and notifying the guest means food that should be hot has cooled and is unpleasant to eat. Guests do not have the ability to heat food in their rooms.

There are different procedures for dropping off deliveries and in some cases hotel workers (eg. concierge) remain in the corridor until an item is picked up. While this may be the Hotel's usual procedure during normal operation, confirmation of pickup at a secured quarantine facility can occur via the security guard, CCTV or phone call, rather than unnecessarily having additional workers present when doors are opened.

5 Ventilation transmission risk ranking for quarantine hotels currently in use

Risk ranking individual hotels by their ventilation system is not considered appropriate given the many factors attributing to the risk of infection.

In occupational hygiene it is common practice to do risk assessments and this could be for either chronic or acute occupational health risks.

It is now common practice to categorise the risks as either green (low risk), amber (moderate risk) and red (high risk). Note that these categories are based on ***relative risk*** that considers ventilation factors (air flow to corridors and room pressurisation) and the position of the security guards at the time of the assessments rather than overall risk of acquiring COVID-19. Unprotected close contact for more than 15min still represents the highest risk.

Another practice is to risk assess again after making modifications/recommendations in controls and this is usually referred to as residual risk.

The following risk categories by Laurie Glossop is for possible transmission of SARS-CoV-2 through an inhalation/air pathway in hotel quarantine. Ian Harwood may have a slightly different ranking as he does not consider the risk of exposure to security guards at the time of assessment:

Category 1 - Green Risk Hotels in alphabetical order:

- Adnate Hotel
- Hyatt Hotel
- Intercontinental Hotel
- Westin Hotel

Category 2 - Amber Risk Hotels in alphabetical order:

- Holiday Inn Hotel – South Tower and North Tower
- Novotel Murray Street Hotel
- Pan Pacific Hotel

Category 3 - Red Risk Hotels in alphabetical order:

- Four Points Hotel
- Mercure Hotel – West Tower and East Tower
- Novotel Langley Hotel

6 What can be done to reduce the probability of infections at hotels that are currently in Category 2 and 3?

Firstly, it must be understood that close contact is associated with the highest risk of transmission. Since the COVID-19 positive security guard (case 903) working at the Four Points by Sheraton Hotel, there has been an increase in infection control protocols for these workers. After assessing all the other hotels ventilation systems and the location of the security guards it is my opinion that the security guard infected at the Four Points had the highest risk of all security guards. Security guards and hotel workers entering a quarantine floor are now required to wear masks (preferably P2/N95) and eye protection. This in itself is likely to have reduced the risk of infection with SARS-CoV-2. They are also to be vaccinated, lowering the risk even further.

Further changes that could be considered at the Category 2 and 3 hotels to further mitigate risks are listed below.

1. The hotels that have accommodation rooms at positive pressure to the corridors increases the risk of transmission via the inhalation pathway. If these hotels can have their ventilation system modified to change the pressure to negative or at least neutral this would lower the risk. This may not be possible at all hotels because of the design of the ventilation system. Whether extraction systems can be increased in airflow needs to be investigated.

2. Where positive room pressure for accommodation rooms in hotels cannot be altered, security guards are not to be located in a part of the corridor where there is minimal dilution of air coming from rooms with possible COVID-19 positive guests. The security guards may have to be moved further away from these rooms.

3. Guests in adjoining rooms or directly opposite to a confirmed COVID-19 positive guests should be moved at least one room further away if at all possible.

4. Security guards move as far as away as possible (current requirement is 2 metres) from rooms when doors are being opened to collect deliveries. This can be easily achieved when doors are knocked or telephone calls to rooms to say a delivery has been made.

5. It might be possible to install a supply air grill above the location of the guards. If the air coming through the grill is cooler than the corridor air it will act as an air curtain protecting the security guard. Laurie Glossop does not know how feasible this modification would be.

6. Rooms with COVID-19 positive guests could have the supply air reduced or exhaust air increased so the room could be made more negative pressure.

7. Rooms with COVID-19 positive guests could have a HEPA filter extraction machine installed in the room to reduce the virial load which could move into the corridors. These machines make some noise which guests might find annoying.

8. CCTV is another option where the security guard might not be able to directly see all the rooms, but could be notified from CCTV monitoring that someone has left a room. Another option is that simple sensors are used along the corridor which alarm when broken. These are readily available and are used in many shops and workplaces. Obviously, these would

need to be turned off when deliveries are made. They may only be needed where there are emergency exits which cannot be monitored by security guards.

9. Another option is to not have guests in certain rooms because of security or poor ventilation in the corridor. This administrative control is relatively simple but does remove some rooms from being used for quarantining. The hotels with a red risk ranking might be amenable to this control.

7 Criteria for selecting a hotel for quarantining

After assessing the 9 current hotels being used for quarantining, the following criteria should be considered for selecting future quarantine hotels or what might be modified on existing quarantine hotels to further reduce the risk of infection of COVID-19 to security guards, health workers and hotel workers:

- Accommodation rooms are negative to neutral pressure to corridors.
- Negative pressure rooms should be sufficiently negative pressure to counteract most of the flow of air into corridors when opened.
- Supply air should only be outside air (fresh air) – this means no recirculated air in the AHU.
- Exhaust air from accommodation rooms is not recirculated and is vented to atmosphere. We believe this is the situation in all current hotels.
- Smoke drop blades on accommodation rooms – about half the hotels currently have these.
- Corridors and lobbies receive direct outside supply air.
- Windows in accommodation rooms cannot be opened.
- If accommodation rooms have a connecting door these rooms should only be used for families or only one half of the connecting rooms are used.
- All hotel rooms being used for quarantining should be checked as to whether they are positive, neutral or negative pressure to the corridors. This can be simply and quickly done by using a smoke tube by the hotel Facility Manager or mechanical staff – the results of the testing should be supplied to Department of Health and possibly audited on a random basis. We have videos of smoke tubes showing positive, neutral and negative pressure as a guide for hotels to determine what pressure the room is to the corridors.
- The testing of the pressure should be done every time a guest leaves the hotel and before a new guest occupies the room. Guests have been known to alter the air handling such as the exhaust vent in the bathroom.
- It is recommended that rooms are only cleaned at least 72 hours after guests have left. This would ensure SARS-CoV-2 has been totally inactivated.

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