26 March 2020

Strategies to reduce the transmission of airborne infectious diseases

Healthcare Sector

Introduction

The purpose of this article is to provide commentary and outline strategies to reduce the transmission of airborne infectious diseases with respect to heating, ventilation and air conditioning systems typically found in the range of buildings utilised throughout hospitals and healthcare facilities.

The article is intended to provide general guidance principles that apply specifically to the health care sector, but due to the wide range of approaches to system designs, we cannot cover every type of air conditioning system installed throughout the entire range of buildings and uses that might be encountered.

Please note that the guidance principles discussed are not engineered solutions and cannot be applied without wider consideration of all potential consequences and interfaces with related building life safety systems. We strongly recommend seeking professional advice on a building by building basis prior to implementing any of these principles.

General Information

A common method for transmission of airborne infectious diseases is via large water droplets and small water particles, which are released by an infected person when coughing, sneezing, shouting and speaking.

Shouting and speaking can produce water droplets which can travel up to 1 metre from a person. Water droplets are generally heavy, so do not readily enter most ventilation systems.

Small particles (aerosolised water droplets), typically produced when a person coughs or sneezes, can stay airborne for extended periods of time and can travel relatively long distances. These aerosols are buoyant and can be drawn into air conditioning units and ventilation systems.

Standard grade filters fitted to recirculating fan coil units or the indoor sections of typical air conditioning units can capture a portion of these aerosols. If the concentration of aerosols is high, the likelihood increases that more will pass through the filters and be re-distributed back into the occupied spaces. This transmission method has been demonstrated in small spaces with high occupant densities and high airflow rates, such as in aircraft, but there is limited evidence of this occurring within typical building air conditioning systems.

An important role of a standard air conditioning system is to introduce adequate outdoor air into the occupied spaces of a building, ensuring adequate oxygen is supplied to the building occupants and the dilution / removal of impurities released into the air by furnishings, as well as the removal of odours from respiratory functions.

Inadequate quantities of outdoor air or a lack of overall air movement means that the air within the occupied space is not removed and replaced at a sufficient rate. This allows dust particles or aerosols carrying pathogens to remain present within the space for longer, thus increasing the likelihood of contamination by direct contact or being inhaled by the occupants. This effectively increases the likely rate of transmission of airborne infectious diseases.

The strategies discussed in this document cover those which apply to common HVAC (Heating Ventilation and Air Conditioning) systems.

HVAC Based Strategies

1. Configure Air Conditioning Systems to ‘Single pass’ Full Outdoor Air

Hospitals in particular have many specialist HVAC systems, of which some are designed to handle 100% outdoor air at all times, with no provision for recirculated air. Such systems are typically utilised for isolation rooms, operating theatres, recovery rooms etc. This strategy is applicable only to plant that includes a quantity of recirculated air in the total air that is delivered into the rooms, and might typically apply to general ward blocks, offices and the like.

This is a dilution strategy which applies to central plant air handling systems that supply large volumes of conditioned air to multiple spaces / floors within a building.

The strategy is to configure the system so full outdoor air is drawn into the air conditioning system from outside, supplied to the occupied spaces and then actively removed or passively leaked out of the building directly to outside. In this arrangement no air removed from the occupied space is recirculated via the air conditioning system back into the occupied space.

The benefit of utilising full outdoor air is it reduces the opportunity to spread airborne infectious diseases throughout the building, as no recirculation occurs. The pathogen load is limited to only that being generated within each space at that time.

Side effects from manually configuring an air conditioning or ventilation system to utilise full outdoor air at all times are inevitable, as these systems are not designed to cater for full outdoor air under extreme hot or cold conditions. Side effects may include:

- Uncomfortable internal temperature and humidity levels due to the considerable increase in heating and cooling loads imposed by the high quantities of outdoor air. The systems are not designed to cope with these loads.
- The internal temperature and humidity will tend to be above that prevailing outside the building, so on very hot and/or humid days the reduction of occupant comfort may lead to complaints and a loss of staff productivity.
- Note, some central plant air conditioning systems such as those which utilise direct expansion refrigeration coils for heating or cooling the incoming air, may not be suitable for configuring to full outdoor air operation.

Specific assessment of your plant is required to determine its suitability to provide full outdoor air ventilation under a range of outdoor conditions.

2. Increase Outdoor Air Flowrates to Occupied Spaces

This is an alternative dilution strategy which applies to either central plant air conditioning systems, or distributed fan coils units type systems, with outdoor air being supplied by dedicated outdoor air systems.

If an existing air conditioning system cannot be configured to operate on full outdoor air mode, an alternative approach is to increase the flowrate of outdoor air supplied by the installed system. This is most easily accomplished by increasing the speed of the outdoor air fans, which will in turn increases the volume of outdoor air provided to each space within the building.

By increasing the outdoor air flowrate, the amount of dilution of contaminants in the occupied space is increased, so reduces the risk of transmission of airborne infectious diseases. This effect has been demonstrated in studies undertaken by the American Society of Heating, Refrigeration and Airconditioning Engineers (ASHRAE) regarding the transmission of influenza.

3. Undertake a Night Purge Cycle

This strategy can apply to all ventilation systems but may not apply to buildings with 24-hour occupancy.

A night purge cycle is where the outdoor air (and any applicable exhaust systems) are set to run continuously, even while the building is unoccupied. This purges the building with outdoor air, so replenishes all the air within the building while no contaminants are being generated within. The occupants then return to a space where very little residual contaminants remain.

Most ventilation systems can be configured to undertake a night purge system by simply changing the time-switch settings or plant schedules within a Building Management System (BMS) to make the ventilation system fans run continuously.

Provided heating and cooling functions are either disabled or setpoints relaxed during times when the building is unoccupied, this approach may even decrease energy usage of the plant. However, the maintenance frequency will need to be increased as filters will require more frequent cleaning and some plant items will require to be serviced at shorter intervals.

During the winter months, this strategy will require consideration of resulting low room temperatures, protection of sensitive equipment and freeze protection of plant.

4. Cleaning all Air Conditioning Unit and Ventilation System Filters

While standard grade air filters are ineffective against viruses, regular cleaning or replacing all air filters in the HVAC system will ensure the maximum amount of air can flow through the system, so occupied spaces receive the maximum number of air changes per hour.

To an extent, this helps to increase the dilution rate of contaminants and minimise stagnation of air within pockets of the building. Studies have demonstrated that stagnation of air in buildings increases the transmission of airborne infectious diseases, due to a reduction in the rate of removal of particles transporting bacteria or viruses. Infected particles are more readily inhaled or transmitted between the building occupants.

Filters suspected to be contaminated serving the local fan coil / indoor units, or in any recirculating ventilation systems should be replaced by new filters, with the removed filters carefully disposed of by incineration.

This also applies to washable media filters typically found in fan coil units and split system indoor units, as washing this media could expose maintenance staff to live bacteria and viruses.

Furthermore, we recommend all maintenance staff use disposable nitrile gloves and suitable face / respiratory protection when changing potentially infected filters. A high level of personal hygiene and job specific hazard analysis is also required.

5. Retrofitting HEPA Filtration in Ventilation Systems

High Efficiency Particulate Arrestance (HEPA) filters are designed to capture very small particles and are effective at capturing water droplets and aerosols. They are typically found in specialist applications such as cleanrooms, operating theatres, isolation rooms and the like.

To achieve their high levels of performance, HEPA filters utilise a fine weave of fibres causing only small gaps to exist within the filter for air to pass through them. As a result, the filters are typically considerably larger than standard efficiency filters found in commercial office applications and they require the fan and duct system to develop much higher pressures in order to drive the required volumes of air through the filters.

Consequently, unless a ventilation system has been specifically designed to cope with the high system pressures, retrofitting of HEPA filters to a standard ventilation system will overwhelm the fan and cause the system to underperform.

A typical commercial ventilation system does not include HEPA filtration and we believe it is not practical to retrofit HEPA filters to typical commercial ventilation systems as an immediate countermeasure to the transmission of airborne infectious diseases.

6. Portable Air Cleaners with HEPA filters

In-room air cleaning units contain a fan to recirculate the air within a room through prefilters and typically a HEPA grade filter to 'clean' the room air. This is an effective alternative to providing HEPA filtration within the ventilation systems.

These systems will not completely remove all particles and water droplets from the air as they can only serve a local area, but the number of residual particles available for recirculation via the in situ ventilation and air conditioning systems will be reduced, lessening the chance of transmission of infected particles & water droplets.

Availability of suitable units at short notice may be a limiting factor to this strategy.

7. Retrofitting Ultra-Violet Germicidal Irradiation in Ventilation Systems

Ultra-violet Germicidal Irradiation (UVGI) is a technique to disinfect air streams, whereby UV lamps are installed within a section of ductwork or within an Air Handling Unit. The systems generate UV-C radiation that when applied at the correct dosage, will effectively kill all bacteria and viruses which are either contained within or attached to dust particles or contained within water droplets within the air stream. This method is proven to be an effective means of disinfecting an air stream.

A requirement of this system is for the air stream to be exposed to the UV-C radiation for a specific minimum amount of 'residence' time. This typically results in the UVGI system being quite large in both cross sectional area and in length. As for HEPA filters above, if a ventilation system has not been specifically designed to accommodate a UVGI system, it can prove to be somewhat impractical to retrofit into an existing system.

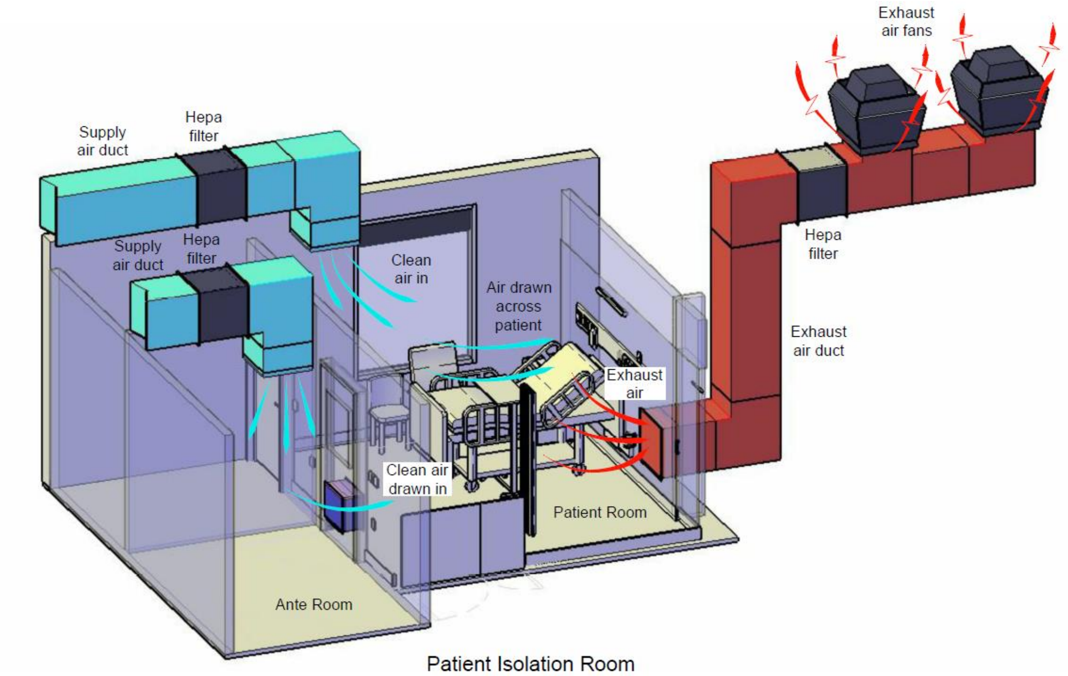
For some existing commercial air conditioning and ventilation systems, the practicalities involved will limit the ability to effectively retrofit this technology as an immediate countermeasure to the transmission of airborne infectious diseases. The application of this technology should be considered on a case-by-case basis

On the assumption that a source of clean outdoor air is available, if recirculating systems are avoided, the UV-C systems are not required to the same extent.

See also below for potential application with Isolation rooms.

Hospital Isolation Rooms

Isolation rooms, or more correctly 'negative pressure rooms' when used to manage airborne infectious diseases, are specially designed to contain the spread of airborne bacteria and viruses from infected patients.



Patient Isolation Room

The concept is relatively simple, refer schematic representation above, in that an amount of conditioned air (heated or cooled and/or humidified and filtered) is supplied into a well-sealed room, with a higher quantity of air being extracted out of the room at all times.

Consequently, a negative pressure is created within the room, so that air continuously leaks into the rooms and no contaminated air escapes from the room. When the door to the room is opened, air will rush through the door into the room.

The potentially contaminated air being drawn out of the room is cleaned by passing it through High Efficiency Particulate Arrestance (or HEPA) filters, with the cleaned air typically being exhausted vertically at high speed and at high level to maximise dilution of the discharge.

Isolation rooms are specially designed and built to a high standard with a high degree of airtightness, to ensure the negative pressure can be maintained at all times. Ease of cleaning all surfaces within the room is also a key consideration.

The operation and performance of Isolation rooms is continuously monitored by control systems and includes visual indication to the medical staff confirming that the negative pressures are being maintained at all times.

Access to isolation rooms is typically limited to medical staff who wear special protective clothing, with access closely managed by hospital staff.

It should be noted that operating theatres are not ideal for converting into negative pressure isolation rooms. Typically, theatre exhaust systems are not fitted with HEPA filters, which would allow the spread of viruses via the exhaust air systems.

A further consideration for the application of UVGI treatment using UV-C radiation, is secondary treatment of contaminated discharge air streams, such as those from isolation rooms and the like.

This would typically be in addition to HEPA filtering of contaminated discharges, resulting in a higher level of decontamination of the discharge air. This may be an effective strategy for highly infectious air discharges.

Humidity Control

The importance of controlling relative humidity to assist with limiting the transfer of airborne infections has been well researched.

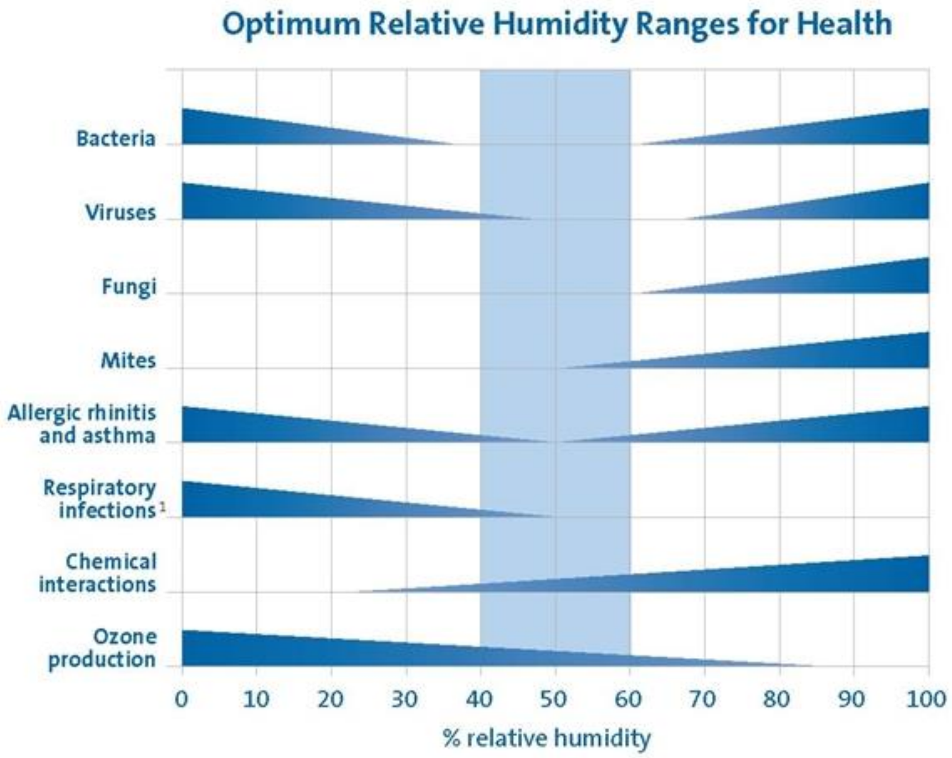
Unfortunately, the air conditioning systems for most commercial office buildings do not actively control humidity and are typically not fitted with humidifiers.

These systems typically spend significant times in cooling mode, which removes moisture at the cooling coil (dehumidification), with typical supply air temperatures of around 12°C (with the air approaching saturation). The resulting room humidity is typically around 50 – 55% once respiratory functions of room occupants are taken into account. This range fluctuates dependent upon other factors such as the condition of the ambient outdoor air, the occupant density and the presence of any moisture producing devices or plants within the spaces served.

As these 'default' humidity levels generally fall within normal comfort ranges, there is no justification for installing humidifiers for much of the year. However, during winter months, the moisture content of the outdoor air is much lower than it is for the rest of the year, and as a consequence, the conditioned air delivered to spaces is drier, with the resultant room relative humidity falling below 40% for considerable periods. This is more pronounced the drier the winter climate is and the further South the building is located within New Zealand. This has some undesirable effects from both a comfort and health perspective.

The accepted reference work on the optimum relative humidity ranges for health is published by E.M Sterling, which includes the chart reproduced below. The findings, in summary, are:

- For optimum Bacteria control, the relative humidity range has been determined to be between 40 – 60% RH.
- For optimum control of viruses, the relative humidity range has been determined to be between approximately 45 – 65% RH.
- In general, the optimal range falls in the narrow range between 40 – 60% RH, at normal room temperatures.



[1]Insufficient data above 50% RH.

E.M. Sterling, Criteria for Human Exposure to Humidity in Occupied Buildings, 1985 ASHRAE.

The reasons for this are well documented but are not repeated here as it is outside of the scope of this article.

Humidity control as a strategy is routinely included in HVAC systems serving operating theatres and the like, where the supply air is actively treated to provide a controlled room relative humidity.

In the majority of other HVAC systems, room humidity is not actively controlled although for a proportion of these systems, it may be possible to retrofit humidifiers, with the addition of humidity controls hardware and programming.

Alternatively, the addition of room humidifiers could be an option during the winter months, although practical limitations would mean that only relatively small areas could be served.

Considering the data provided in the chart above, where relative humidity control is provided for, we would recommend a control setpoint of 55 - 60% RH be set, with a proportional band of +/- 5%. This should provide an optimum relative humidity range to minimise the activity of viruses.

Be aware that the data represented in the chart was compiled in 1985, so does not include specific testing on current viral diseases.

Links and references for humidity information:

https://www.ashrae.org/file%20library/technical%20resources/covid-19/i-p_s16_ch22humidifiers.pdf

https://www.ashrae.org/file%20library/technical%20resources/covid-19/56-1.pdf

http://sterlingiaq.com/photos/1044922973.pdf

Non-HVAC Based Strategies

Non-HVAC based strategies for the control of airborne infectious diseases in the workplace typically include encouraging high levels of personal hygiene, consideration towards the wellbeing of others, high standards of workplace cleaning and the isolation of sick staff.

With respect to the current 2019-2020 Coronavirus outbreak, advice is available from the World Health Organisation and the Centers for Disease Control websites.

For specific advice within New Zealand, please refer to the following links for more information.

https://covid19.govt.nz/

https://www.health.govt.nz/our-work/diseases-and-conditions/covid-19-novel-coronavirus

Please note the advice provided by these organisations is being updated frequently as more study is undertaken on COVID-19 (Coronavirus) as the situation develops, so check for the latest advice frequently.

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