

GUIDELINES ON VENTILATION IN THE HEALTHCARE SETTING TO REDUCE THE TRANSMISSION OF RESPIRATORY PATHOGENS

First Edition

**Ministry of Health Malaysia
&
University Malaya Medical Centre**

July 2021

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ABBREVIATIONS

ACH	Air Changes per Hour
ACMV	Air conditioning and Mechanical Ventilation System (ACMV)
AGP	Aerosol-Generating Procedures
AIIR	Airborne Infection Isolation Room
CADR	Clean Air Delivery Rate
CFM	Cubic Feet per Minute
HCW	Health Care Worker
HEPA	High-Efficiency Particulate Air
IPC	Infection Prevention and Control
MERV	Minimum Efficiency Reporting Value
OSHE	Occupational Safety, Health and Environment
UVGI	Ultraviolet Germicidal Irradiation

GLOSSARY

ACMV: Air Conditioning and Mechanical Ventilation System. The equipment, distribution systems, and terminals that provide, either collectively or individually, the processes of ventilating, or air conditioning to a building or portion of a building.

Aerosol-generating procedures (AGP): Any medical procedures that can induce the production of aerosols of various sizes (e.g. tracheal intubation, non-invasive ventilation, tracheostomy, cardiopulmonary resuscitation, manual ventilation before intubation, bronchoscopy, dental procedures).

Air changes per hour (ACH): Ventilation airflow rate (m^3/hr) divided by room volume. It indicates how many times, during 1 hour, the air volume of a space is fully replaced with outdoor air.

Air economizer: Duct and dampers arrangement with an automatic control system that together allow a cooling system to supply outdoor air to reduce or eliminate the need for mechanical cooling.

Air, exhaust: Air removed from a space and discharged to the atmosphere by means of mechanical or natural ventilation systems.

Airflow direction: The airflow direction in a building, should be from clean zones to dirty zones. The air flow direction also depends on the type and functionality of the area requirement.

Air distribution or airflow pattern: The external air should be delivered to each part of the space in an efficient manner and the airborne pollutants generated in each part of the space should be removed in an efficient manner.

Air, recirculation: A part of extracted air which is not exhausted from the building, but it is recirculated back into spaces. The air can be treated before being recirculated (thermal, air quality).

Air, Supply: Air delivered by mechanical or natural ventilation to a space, composed of any combination of outdoor air, recirculated air or transferred air.

Airborne Infection Isolation Room (AIIR): A single-occupancy room for patient care where environmental factors are controlled in an effort to minimize the transmission of those infectious agents usually spread from person to person by droplet nuclei associated with coughing or inhalation (Such rooms typically have specific requirements for controlled ventilation, air pressure, and air infiltration).

Air-handling unit (AHU): Assembly consisting of sections containing a fan or fans and other necessary equipment to perform one or more of the following functions: circulating, filtration, heating, cooling, heat recovery, humidifying, dehumidifying, and mixing of air.

Cross ventilation: Cross ventilation occurs where there are ventilation openings on both sides of the space. Air flows in one side of the building/room and out the other side through, for example, a window or door. Cross ventilation is usually wind driven.

Fan coil unit (FCU): factory-made assembly that provides the functions of air circulation, cooling, heating, or cooling and heating.

High-efficiency particulate air (HEPA): HEPA air filter classes E10 to H14 according EN 1822 or a filter with removal efficiencies of 99.97% or higher for a mass median particulate size of 0.30 μm (microns). Facilities that choose to use HEPA filters should follow the manufacturer's instructions, including on recommended cleaning and maintenance procedures for HEPA filters. Otherwise, portable air cleaners with HEPA filters can lead to a false sense of security as their performance decreases due to filter loading.

Minimum efficiency reporting value (MERV): Scaled rating of the effectiveness of air filters. The scale is designed to represent the worst-case performance of a filter when dealing with particles in the range of 0.3 to 10 micrometers.

Pressure difference: Difference between pressures measured at two points or levels in fluids or gases.

Ventilation: Ventilation is the process of supplying outdoor air to and removing indoor air from a space, for the purpose of controlling air contaminant levels, potentially accompanied by humidity and/or temperature, by natural or mechanical means.

Ventilation rate: Rate of outdoor air flow to a space, expressed in terms of volume per unit of time, either through the ventilation system or infiltration through building envelope. These are commonly expressed as cubic feet per minute (CFM) or litres per second (l/s) or cubic meter per hour (m^3/hr).

Ventilation system: A combination of appliances designed to supply interior spaces without door and/or to extract polluted indoor air.

Pressure, negative: Condition that exists when less air is supplied to a space than is exhausted from it, so the air pressure within that space is less than that in the surrounding areas. Under this condition, if an opening exists, air will flow from the surrounding areas into the negatively pressurized.

Pressure, positive: Condition that exists when more air is supplied to a space than is exhausted from it, so the air pressure within that space is greater than that in the surrounding areas. Under this condition, if an opening exists, air will flow from the positively pressurized space outward to the surrounding areas.

Split system: A two-component heating and cooling or cooling only system. The condensing unit is installed outside, the evaporator (indoor unit) is installed inside. Refrigerant lines and wiring connect them together. Generally, this system has no ventilation component and recirculates conditioned air.

1. SCOPE

- i. This document provides guidance for healthcare worker (HCW) and employers on how to improve indoor ventilation in health care facilities. It is not a standard or regulation, and it creates no new legal obligations. It contains recommendations as well as descriptions by referring to WHO's Roadmap to improve and ensure good indoor ventilation in the context of COVID-19.
- ii. This document will be updated from time to time as new evidence becomes available.

2. GUIDELINE STATEMENT

- i. Air Conditioning and Mechanical Ventilation System (ACMV) systems play an important complementary role in reducing transmission in closed indoor spaces by increasing the rate of air exchange, decreasing recirculation of air and increasing the use of outdoor air, and using adequate types of filters. Application of any new device or equipment or modifications to the AHU/ACMV should be evaluated closely to avoid unintended consequences and only adopted when supported by a safety risk assessment by experts.
- ii. Below is a general guidance on improving ventilation in the healthcare setting based on our current state of knowledge about the SARS-CoV-2 virus and its spread. The engineering and maintenance personnel must combine these recommendations with their knowledge of the type of ACMV system in the building and its purpose in the facility. Like all hazards, risk can be reduced but not eliminated.
- iii. A multidisciplinary team consisting of hospital engineers, maintenance facilities staff, Infection prevention and control (IPC) team and occupational health personnel OSHE should work together to evaluate building systems to ensure that they are operating in proper order (per design or current operational strategies), are capable of being modified to align with ACMV mitigation strategies, and to identify deficiencies that should be repaired.

3. INTRODUCTION

- i. Poor ventilation in indoor spaces is associated with the increased transmission of respiratory tract infections such as influenza, tuberculosis and rhinovirus infection.
- ii. Based on current evidence on the airborne transmission of SARS-CoV-2, inhalation at distances greater than 1-2 m from an infectious source are less likely than at closer distances. However, it can occur under certain preventable circumstances where there is higher concentration of the virus. These include:

- a. Enclosed spaces with inadequate ventilation or air handling within which the concentration of exhaled respiratory fluids, especially very fine droplets and aerosol particles, can build-up in the air space.
 - b. Increased exhalation of respiratory fluids if the infectious person is engaged in physical exertion or raises their voice (e.g., exercising, shouting).
 - c. Prolonged exposure to these conditions, typically more than 15 minutes.
- iii. In healthcare facilities the increased risk factors, such as the presence of confirmed and suspected cases, the proximity required to provide medical care, AGP potentially performed, and visitor influx, make these settings particularly vulnerable for the transmission of respiratory pathogens.
- iv. Therefore, a multi-pronged approach is needed to reduce exposure to respiratory pathogens including SARS-CoV-2 in the healthcare settings. These include strict adherence to physical distancing, wearing face masks, hand hygiene, environmental cleaning, vaccination and improvement of ventilation to reduce the risk of potential airborne spread and enable a safe working environment as well as reduce the risk of health care associated infections among HCWs, patients and visitors.

4. VENTILATION

- i. Ventilation is the intentional introduction of clean air into a space while the stale air is removed.
- ii. The aim of ventilation mitigation strategies is to help reduce viral particle concentrations. By lowering the concentration of viral particles in the confined space, it is less likely that the particles will be inhaled into the lungs; contact the eyes, nose, and mouth; or fall out of the air to accumulate on surfaces.
- iii. Good ventilation indoors reduces risk of COVID-19 and other respiratory pathogens by diluting the concentration of potentially infectious aerosols through ventilation with outside air; and filtration and disinfection of recirculated air.
- iv. Adequate ventilation in all patient care areas play a key role to help prevent and reduce infections.
- v. In medical facilities, ventilation systems are in place as an environment and engineering control for infection prevention.

5. METHODS TO VENTILATE A BUILDING

There are 3 ventilation methods:

- i. Natural

Ventilation occurring as a result of only natural forces, such as wind pressure or differences in air density, through doors, windows or other intentional openings in the building.

- ii. **Mechanical**
The active process of supplying air to or removing air from an indoor space by powered air movement components.
- iii. **Mixed-mode ventilation**
Combination of both mechanical and natural ventilation systems that provide a comfortable internal environment using different features of these systems as and when needed. For example, adding an exhaust fan in a naturally ventilated room.

6. MINIMUM REQUIREMENT FOR AIRBORNE INFECTIOUS DISEASE PATIENT'S ROOM

- i. Ideally a patient with an airborne disease should be placed in an Airborne Infection Isolation Rooms (AIIR). For details about AIIR ventilation requirement please see **Appendix 1**.
- ii. If AIIR is not available, below are the general guidance to reduce the risk of airborne pathogen transmission which includes ventilation rate requirement for the patient, strategies to improve the ventilation in the building including natural ventilation and mechanical ventilation. Besides, strategies to minimize the risk of transmission of infection, evaluation, assessment, and maintenance of existing ACMV system are covered. Lastly, monitoring of ventilation performance and complementary decentralized air cleaning methods are described.

7. MINIMUM REQUIREMENT FOR VENTILATION RATE

- i. **160 L/s/patient (hourly average ventilation rate) or 12 ACH (air changes per hour)** for airborne pathogen or / aerosol generating procedures (AGP) rooms (with a minimum of 80 l/s/patient).
- ii. **60 L/s/patient (hourly average ventilation rate) or 6 ACH (air changes per hour)** for general wards and outpatient departments.
- iii. **2.5 l/s/m³** for corridors and other transient spaces without a fixed number of patients; however, when patient care is undertaken in corridors during emergency or other situations, the same ventilation rate requirements for airborne precaution rooms or general wards will apply.
- iv. Ensure ventilation systems operate properly and provide acceptable indoor air quality for the current occupancy level for each space. The ventilation rate can be inspected through measuring the face velocity using appropriate

measurements devices as per required standards. The pressure difference, temperature and relative humidity should be monitored to ensure acceptable indoor air quality (IAQ) as per standards.

- v. For natural ventilation, the design must take into account fluctuations in ventilation rate. When natural ventilation alone cannot satisfy the recommended ventilation requirements, alternative ventilation systems, such as mixed-mode ventilation should be considered, and then if that is not enough, mechanical ventilation should be used.

8. STRATEGIES TO IMPROVE VENTILATION

8.1 STRATEGIES TO IMPROVE NATURAL VENTILATION

If the healthcare setting does not have the minimum requirement, the following strategies can be used to improve natural ventilation rate

- i. Assess the opening locations and opening surfaces. Consider potential new openings by adding or modifying windows or door dimension.
- ii. Enable cross ventilation rather than single-sided ventilation (see Figure 1 and 2).

However cross ventilation should not be implemented in specific cases such as:

- a. within a room or ward for COVID-19 suspected cases where AGP may take place and when the exhaust air is not properly managed;
- b. when the airflow is moving from a less clean to a clean area.

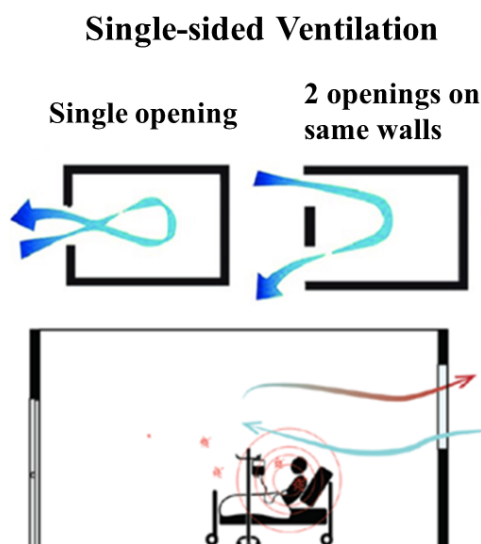


Figure 1. Example of single-sided ventilation in a patient's room.

Cross Ventilation

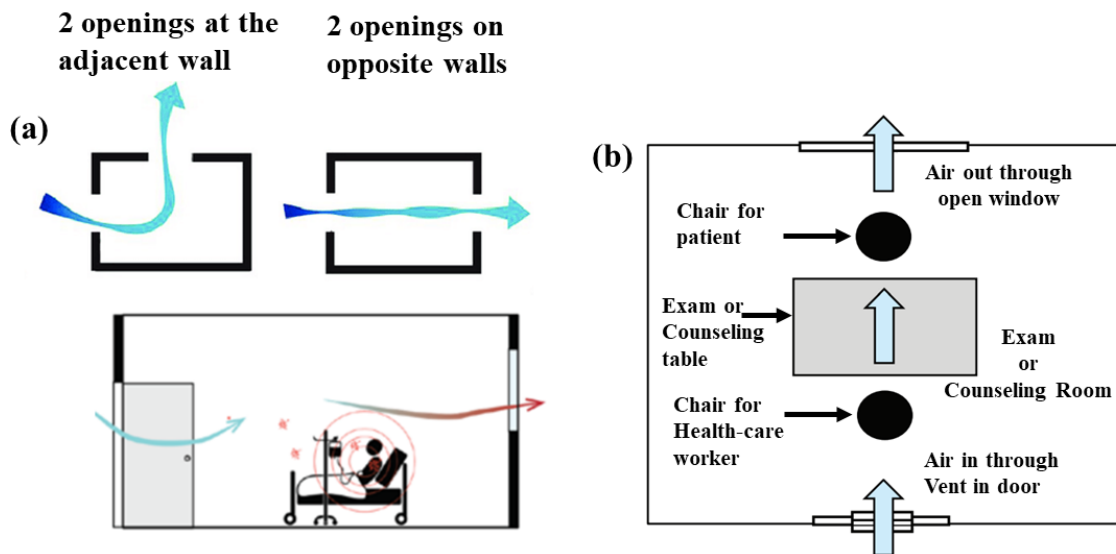


Figure 2. Ideal case of cross ventilation in (a) patient's room patient.
(b) examination/consultation room.

*Take note of the position of HCW and patient in relation to airflow.

- i. Reduce maximum room occupancy to meet the L/s/patient standard.
- ii. When natural ventilation alone cannot satisfy the recommended ventilation requirements, alternative ventilation systems, such as mixed-mode natural ventilation should be considered, and then if that is not enough, mechanical ventilation should be used. (WHO, 2009)

8.2 STRATEGIES TO IMPROVE MECHANICAL VENTILATION

If healthcare setting does not fulfil the minimum ventilation rate requirement, the following strategies can be used to improve mechanical ventilation rate

- i. Rebalance or adjust ACMV systems to increase total airflow to occupied spaces when possible. This should be based on the ACMV system capabilities.
- ii. Disable demand control ventilation (DCV) controls that reduce air supply based on temperature or occupancy. The demand control ventilation can be disabled by the facility/ engineering team. The desired ventilation rate can be adjusted manually according to the condition and requirement. However, this is heavily depending on the type of facilities.
- iii. If the system does not allow increasing the ventilation to the recommended minimum per person requirement, consider reducing the maximum room occupancy to meet the L/s/patient standard.
 - a. Measuring the face velocity of air diffusers and grilles is one of the ways to determine the amount of the air supplied by and returned to the Air Handling Unit (AHU). These values can then be used to determine the ventilation rate of a room.

- b. However, do note that further measurements, e.g., CO₂ concentration and temperature readings at certain locations near the AHU need to be done to determine the percentage of outside air (OA%). The OA% can then be used to determine the ventilation rate of a room. This method is stated in ANSI/ASHRAE/ASHE Standard 170-2021, Ventilation of Health Care Facilities.
- iv. If no other short-term strategy can be adopted, consider using a Portable air cleaner with HEPA filters. (see section 8.1)

8.3 THE AIRFLOW DIRECTION

- i. Air movement must be **from clean to less clean area (figure 3, 4, and 5)**.
- ii. The pressure difference (i.e. air flow direction) between the spaces can be checked using various methods, e.g., passive test (smoke tube test) or active test (manometer or permanent room pressure monitoring system). For details, please refer to Appendix 2.

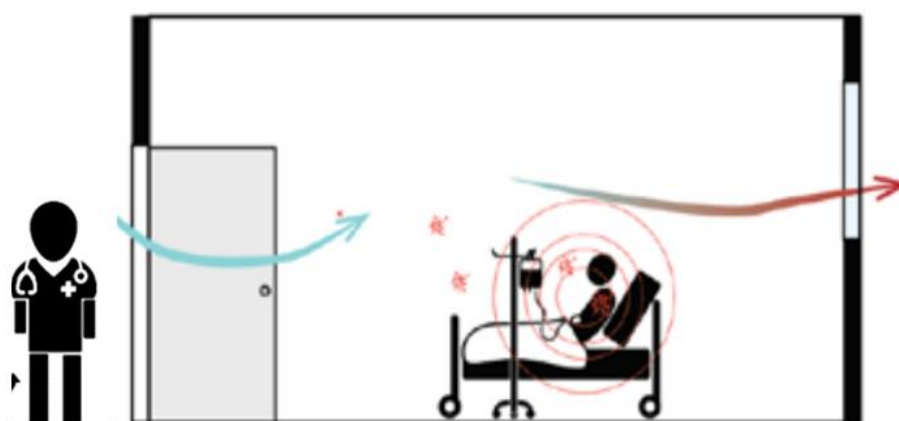


Figure 3: Airflow direction in a patient's room with natural ventilation.

8.3.1 STRATEGIES TO MINIMISE THE RISK OF TRANSMISSION OF INFECTION IN NATURAL VENTILATION

If air flow direction is not from clean to less clean area, the following strategies can be used to minimise the risk of transmission of infection.

- i. Avoid using devices that generate a strong air flow in a common area, especially streams of air going from person to person.
- ii. If a clear airflow direction is identified, modify the functional distribution of airflow directions to minimize exposure of HCWs, i.e. change the patient and staff areas in order to have negative pressure close to patient area. (see Figure 4 and 5). If necessary, installation of fans to enable clean-to-less-clean directional airflow.

a) Wall or window fans (air extractors).

1. Exhaust fans which are placed securely in a window or wall will exhaust room air to the outdoors. The exhaust fan should be placed above the head end of patient's bed ideally.
2. This will help draw outdoor air into the room via other open windows and doors without generating strong room air currents.
3. Similar results can be established in larger facilities using other fan systems, such as gable fans and roof ventilators.



Figure 4: Exhaust fan placed on the wall at the patient's head end to draw the air from clean to less clean.

b) Pedestal fan

1. Pedestal fan can be used to increase the ventilation effect of open windows and also enable clean-to-less-clean directional airflow.
2. Single direction (face not turning)
3. Avoid placing fans in a way that could potentially cause contaminated air to flow directly from one person to another
4. Place the fan as close as possible to an open window and face it towards the outside (i.e. open window). It serves to pull the room and exhaust air to the outside and remove any airborne particles in the room by blowing/ exhausting the air outside.
5. The orientation of the pedestal fan determines the airflow direction. If the fan is placed facing towards the interior of the room (i.e. facing inside) serves to pull in the outdoor air and push it inside the room.
6. The orientation of the pedestal fan should be chosen according to the desired airflow direction.
7. If there is no open window, the fan should be faced in a single direction, facing towards an unoccupied corner and wall spaces or up above the occupied zone, if possible. However, this should be avoided where possible, as this will create turbulent and recirculation flow in the building.

- iii. In rooms where AGPs are performed: add **anterooms** in order to have stricter control of airflow direction. Doors in anterooms should not be open at the same time in order to clearly separate the air between the patient room and the corridor (cleaner area). Exhaust fan may be placed on the wall/window at the patient's head end to draw the air from clean to less clean. A cost-effective solution is the use of a plastic door zipper as a partition to create an anteroom as in figure 5.

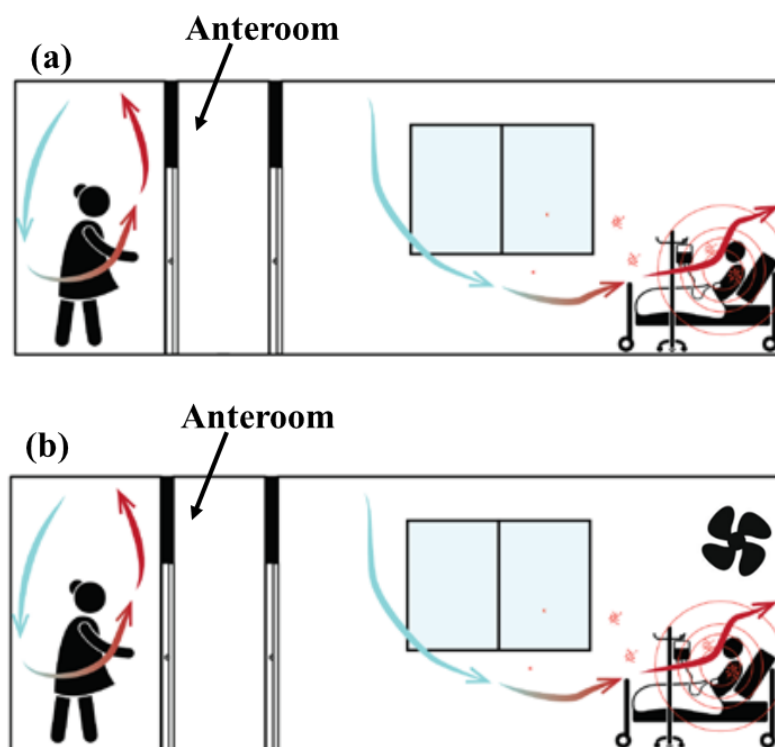


Figure 5: (a) Airflow direction in the naturally ventilated room with anteroom. (b) Airflow direction in the naturally ventilated room with exhaust fan and anteroom.

Note: **For naturally ventilated rooms**, in most cases, adding an anteroom cannot be combined with cross ventilation, therefore the minimum ventilation rate should be attained with other strategies. A cost-effective solution is the use of a plastic door zipper.

8.3.2 STRATEGIES TO MINIMISE THE RISK OF TRANSMISSION OF INFECTION IN MECHANICAL VENTILATION

If air flow direction is not from clean to less clean area, the following strategies can be used to minimise the risk of transmission of infection.

- i. In mechanically ventilated rooms, assess the opportunity to modify airflow direction, i.e. modifying the location of supply and exhaust air devices. Air enters through supply diffuser and exits through the exhaust air ducts. (see Figure 6)

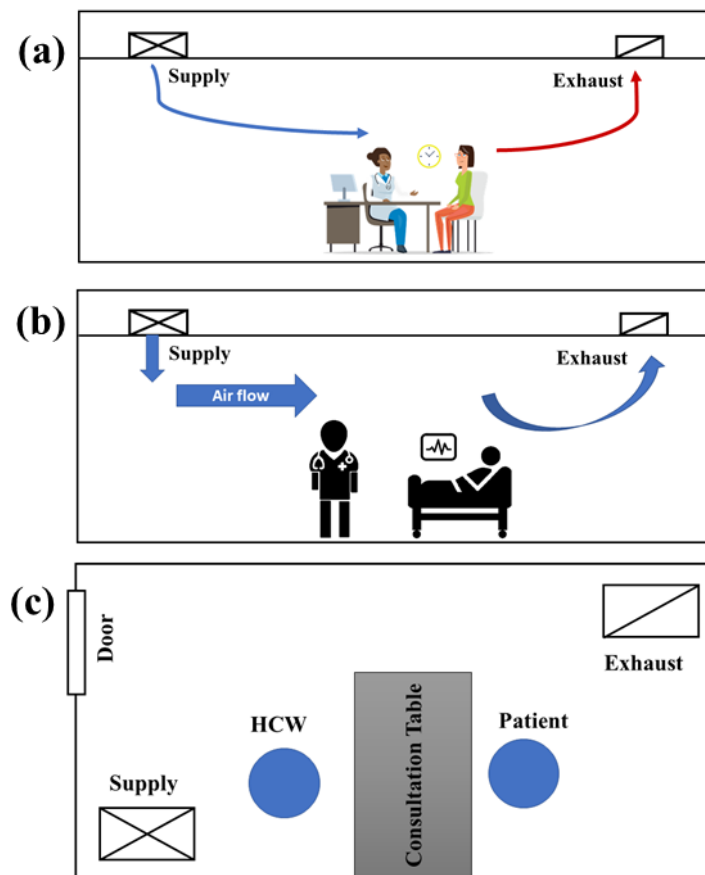


Figure 6: Air flow direction for mechanically ventilated in (a) consultation room. (b) patient's room. (c) Plan view of the consultation room.

- ii. In rooms where AGPs are performed: add **anterooms** in order to have stricter control of airflow direction. Doors in anterooms should not be open at the same time in order to clearly separate the air between the patient room and the corridor (cleaner area). Exhaust fan may be placed on the wall/window at the patient's head end to draw the air from clean to less clean. A cost-effective solution is the use of a plastic door zipper as a partition to create an anteroom as in figure 7.

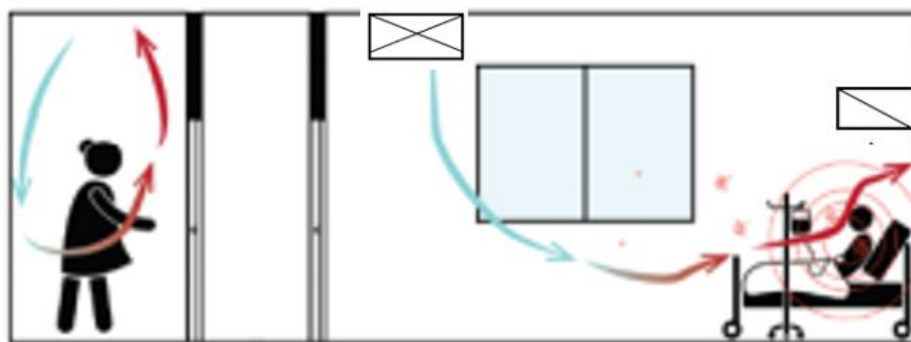


Figure 7: Airflow direction in the mechanically ventilated room with and anteroom.

8.4 EXHAUST AIR

- i. Air should be exhausted directly to the outside and away from air intake vents, people and animals in accordance with local regulations on environmental discharges.
- ii. No action is needed if the air is exhausted from the roof or at least 3 m above the adjoining roof level or ground and away from doors, occupied areas, and operable windows or areas that are normally accessible to the public or maintenance personnel.
- iii. **In naturally ventilated areas**, use of fences to avoid passage of people close to openings (windows and doors), keeping people or animals at a distance at least of 4 m. No action is needed if the air is exhausted from the roof or 2 m higher than people (i.e. due to stack effect, whirlybirds).
- iv. **For mechanically ventilated buildings/ areas:**
 - a. Fence the area near the exhaust outlet keeping people or animals at a distance of at least of 4 m and preferably 8 m horizontally from outdoor air intakes, openable windows/doors, and areas that are normally accessible to the public.
 - b. The exhaust discharge outlets shall be arranged to discharge to the atmosphere in a vertical direction and at least 3 m above the adjoining roof level or ground and away from doors, occupied areas, and operable windows or areas that are normally accessible to the public or maintenance personnel. The preferred location is above the roof level projecting upwards or horizontally away from outside air intakes. (see figure 8)
 - c. If fencing the area is not feasible, in consultation with an ACMV professional, assess the opportunity to install HEPA filters according to system capability. (see figure 9)
 - d. The exhaust duct, exhaust fan and exhaust switches shall be labelled to identify its intended purpose especially is used to exhaust the air from an airborne pathogen. (example: the label shall read "Caution- All Exhaust Duct" and the label shall be bilingual; in Bahasa Melayu and English)
- v. Outdoor air intake shall be located as high as practical, but not less than 1.8 m above ground. Air intake on the top of the building shall be located at a minimum of 0.9 m above the roof level. The area around the air intake shall be free from vegetation, waste products, or any other possible source of contamination.

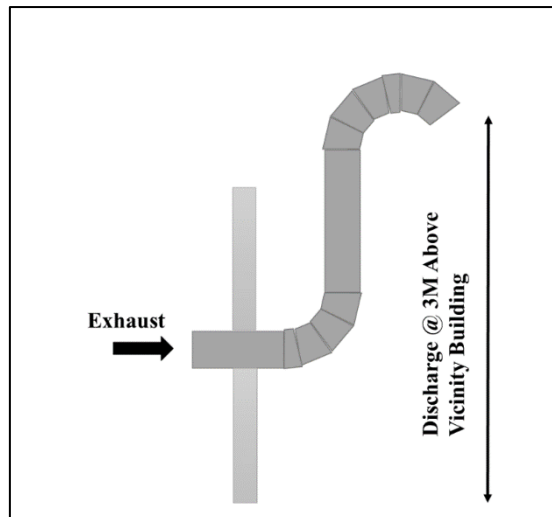


Figure 8: Exhaust discharge out should be at least 3 m above the vicinity building.

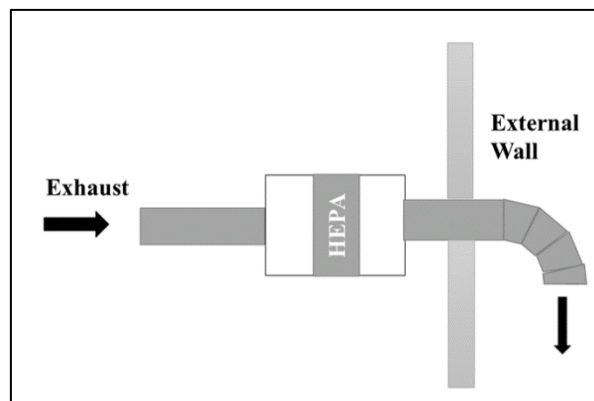


Figure 9: Installation of HEPA filter in exhaust duct if exhausted air cannot be expelled into a safe environment.

8.5 EVALUATION AND ASSESSMENT OF EXISTING AIR CONDITIONING AND MECHANICAL VENTILATION SYSTEMS WITH RECIRCULATING UNITS

8.5.1 NON-DUCTED ACMV SYSTEM

- i. Split system and fan coil units
 - a. Split system and fan coil units are the ACMV system with in room recirculation only.



Figure 10: Example of split system and fan coil unit

- b. Use of this system is **discouraged** because they provide poor filtration and contribute to turbulence, potentially increasing the risk of infection.
 - c. They do not replace ventilation in any circumstance.
 - d. **This system should be AVOIDED in rooms for COVID-19 or other airborne disease patients**, especially where AGP are performed. Using alternative systems should be considered.
 - e. It can be used only in single rooms (suspected or confirmed cases) and in shared room hosting cohorted confirmed inpatients. However, this should be avoided if possible, as without outdoor air supply or exhaust air, the split or fan coil unit will cause the recirculation of air in the room and the airborne organism will be remained in the room for a prolonged period, increasing the risk of transmission to the HCW. Furthermore, without outdoor air supply or exhaust air, the indoor air quality is very poor.
- ii. In healthcare facilities where Non-ducted ACMV systems are used and where alternative air conditioning is not available or feasible, consider the following:
 - a. creating a negative pressure relative to the corridor to reduce the potential for aerosols to escape from the room. Negative pressure can be created by installing extractor fans or devices to increase the airflow of extracted air from the room. Units should be cleaned carefully in between patients.
 - b. running the air-conditioning units at minimum velocity to reduce turbulence where AGP are performed.
 - c. ensure that direct airflows between individuals are avoided. Except for single room (suspected or confirmed cases) and shared room hosting cohorted confirmed inpatients
 - d. Open operable windows and doors at least once a day, unless outdoor air quality is poor. Air-conditioning unit should be reduced or **TURNED OFF** when doors and/or windows are opened. It should be noted that,

increasing amount of outdoor air will lead to risk of surface condensation due to increased moisture content. When the moisture content increases, there are possibilities for condensation and fungus and bacteria growth. (Figure 11)

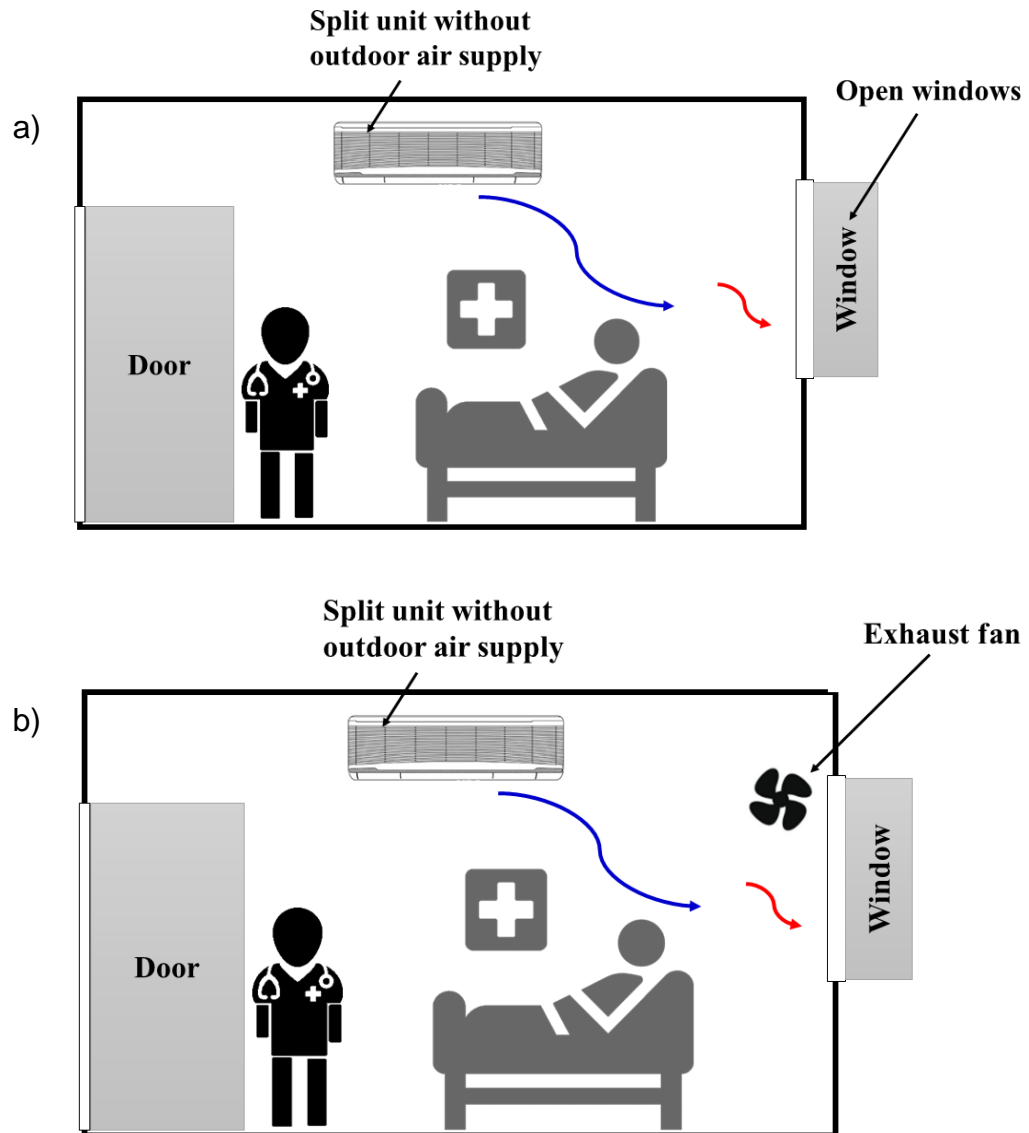


Figure 11: a) When opening the window, consider the condition of outdoor air to ensure no excess amount of humidity will affect the indoor air of the room.

b) Window is closed and exhaust fan is operated to increase ventilation inside the room

- e. Consider modifying the position of the cooling unit to direct the airflow to the less clean zone. (Figure 11)
- f. Install an extractor to control the airflow from where AGP are performed.

8.5.2 DUCTED ACMV SYSTEM

If the ducted centralised ACMV system works with recirculation mode, consider the following strategies to optimise ventilation and minimise the risk of transmission of infection:

i. Ventilation for dilution

- a. Increase the percentage of **outdoor air supply** using air economizer modes of ACMV operations, potentially up to 100%. Before increasing outdoor air, verify compatibility with ACMV system capabilities. This may be a major challenge in existing healthcare facility and wards which are not designed for 100% outdoor air, as increasing the outdoor air will affect the cooling capabilities of the ACMV system. Open outdoor air dampers to allow maximum fresh air into the building, to reduce or eliminate ACMV air recirculation.
- b. It should be noted that, increasing amount of outdoor air will lead to risk of surface condensation due to increased moisture content. When the moisture content increases, there are possibilities for condensation, fungus and bacteria growth. Hence, the humidity level should be carefully controlled and not exceed 60%RH. The facility manager shall assess the opportunity to install a dehumidification component at AHU to reduce the humidity level of the supply air.
- c. Disable demand control ventilation (DCV) controls that reduce air supply based on temperature or occupancy. The demand control ventilation can be disabled by the facility/ engineering team. The desired ventilation rate can be adjusted manually according to the condition and requirement. However, this is heavily depending on the type of facilities.

ii. Supply air

- a. Rebalance or adjust ACMV systems to increase total airflow to occupied spaces when possible. This should be based on the ACMV system capabilities.
- b. If outdoor area is highly polluted, be caution when deciding on amount of outdoor air supply to use.

iii. Return

- a. Based on the ACMV system capabilities, the facility/engineer team may consider termination of the return air feeding into the AHU and directly discharge to the atmosphere through HEPA filter.
- b. Assess the opportunity to install HEPA filters on **air return** duct according to system capability.

- c. Increased filter efficiency generally results in increased pressure drop through the filter. Ensure ACMV systems can handle filter upgrades without negative impacts to pressure differentials and/or airflow rates prior to changing filters.

iv. **Air flow direction**

- a. Air flow direction must be **from clean to less clean area** within the room.
- b. The pressure difference compare to adjacent room can be checked using various methods. (See **Appendix 2**)

v. **Air filtration**

- a. Increased filtration efficiency is especially helpful when enhanced outdoor air delivery options are limited.
- b. For air recirculation system, upgrade central air filtration to a filter that is rated at a MERV-14**/ISO ePM₁ 70-80% level or higher **at the supply end**, taking the capabilities of the ACMV systems into consideration (i.e. highest compatible with the filter rack, and seal edges of the filter to limit bypass. Except those stringent requirements as stated in ANSI/ASHRAE/ASHE Standard 170-2021. (see Appendix 3)
 - i. *Depend on the existing ACMV system capacity. The current system may operate at the optimum conditions, such retrofitting work may affect the performance of the ventilation system. The higher the MERV number, the pressure drop is larger and the fan load is also increase.
 - ii. **A MERV 14 filter is at least 75% efficient at capturing particles in the 0.3 µm to 1.0 µm size range and 90 or greater % efficient at capturing particles in the 1 µm to 3 µm size range. The typically used MERV 8 filter, which is only around 20% efficient in the 1 µm to 3 µm size range and is not rated for capture efficiency of the smaller particles. High-efficiency particulate air (HEPA) filters are even more efficient at filtering infectious particles than MERV 16 filters.
- c. If no other strategy can be adopted, consider using a Portable air cleaner with HEPA filters. (see section 8.1)

8.6 **MAINTENANCE AND OPERATION OF ACMV SYSTEM**

- i. ACMV system should be operated continuously when people are in the building.
- ii. ACMV systems included ducting should be regularly inspected, maintained and cleaned according to the manufacturer 's recommendations. All maintenance team must wear a full PPE when servicing the AHU (air circulation) or any part of the air ventilation system which cater for COVID-19 patient.
- iii. HEPA filter should be replaced according to the manufacturer's recommendation.

- iv. Any maintenance and operation shall be referred to Hospital Engineers and appointed maintenance company.

9. MONITORING OF VENTILATION PERFORMANCE

Carbon dioxide monitors

- i. Changes in CO₂ concentrations can indicate a change in room occupancy and provide information on ventilation in a given space. CO₂ sensors can act as an indicator of poor ventilation.
- ii. Limited information exists regarding a direct link associating CO₂ concentration to a risk of COVID-19 or other airborne pathogen transmission. CO₂ is co-exhaled with aerosols containing SARS-CoV-2 by COVID-19-infected people and may be used as a proxy of SARS-CoV-2 concentrations indoors.
- iii. However, CO₂ concentrations cannot predict who has SARS-CoV-2 infection and might be spreading the virus, the amount of airborne viral particles produced by infected people, or whether the ACMV system is effective at diluting and removing viral concentrations near their point of generation.
- iv. Currently there is no proven study to link the CO₂ concentration with the transmission of airborne pathogens. However, during this pandemic, national guidelines from various countries (ECDC 2020) have used CO₂ levels as a surrogate marker to provide information on the building ventilation efficacy. Technical guidelines recommend that the carbon dioxide concentration is kept below 1000 parts per million (ppm) (preferable below 800 parts per million (ppm) as recommended by CDC 2021) to ensure sufficient ventilation.
- v. There is no single CO₂ level to indicate if the indoor air space is “safe” from COVID-19, as the risk of transmission also depends on other factors such as on the type of activity in the room (i.e. talking loudly or exercising, or are they sitting quietly and reading or resting), if PPE is used (masks were used), number of people infected etc.

10. COMPLEMENTARY DECENTRALIZED AIR CLEANING METHODS

These include Portable air cleaner with HEPA filters, ultraviolet germicidal irradiation (UVGI) and other methods under **emerging technologies**. These methods are usually relatively costly, require special maintenance, and can only treat a relatively small volume of air. It may be used as a supplemental environment disinfection to inactivate SARS-CoV-2 when options for increasing room ventilation and filtration have been optimised. A convincing body of scientifically rigorous, peer-reviewed studies does not currently exist on the **emerging technologies**. Manufacturer data should be *carefully* considered and correspond with same application and occupancy scenario of your intended use. For the **emerging technologies** that produce ozone, it must comply with UL2998 and ASHRAE 62.1 as ozone build up can be harmful to humans.

ASHRAE Epidemic task force Healthcare, ASHRAE 2021.

<https://www.ashrae.org/file%20library/technical%20resources/covid-19/ashrae-healthcare-c19-guidance.pdf>

10.1 PORTABLE AIR CLEANER WITH HEPA FILTERS

If no other ventilation strategy can be adopted as described above, consider using a portable air cleaner with HEPA filters. Portable air cleaner with HEPA filters that combines a HEPA filter with a powered fan system are a preferred option for auxiliary air cleaning, especially in higher risk settings such as health clinics, vaccination and medical testing locations, workout rooms, or public waiting areas. Other settings that could benefit from portable HEPA filtration can be identified using typical risk assessment parameters, such as community incidence rates, facemask compliance expectations, and room occupant density.

- i. High Efficiency Particulate Air (HEPA) filter is at least 99.97% efficient at capturing particles 0.3 μm in size.
- ii. Can only treat a relatively small volume of air.
- iii. The overall performance of Portable air cleaner with HEPA filters, change in efficiency over time, and optimal placement has not been sufficiently investigated, and still remains challenging.
- iv. These systems do not bring in outdoor air for dilution.
- v. Depending on the type of Portable air cleaner, the filtered air discharged from the system can either be exhausted out of the room or recirculated in the room.
- vi. If the portable air filtration unit has adjustable air flow, the air flow should be selected that is appropriate to the size of the room to give the desired air changes per hour.
- vii. They are effective at cleaning air within spaces to reduce the concentration of airborne particulates and aerosol dispersion, including SARS-CoV-2 viral particles.
- viii. Portable air cleaner with HEPA filters that combine a **HEPA filter with a powered fan/blower** system to enhance air cleaning maybe used in higher risk settings which are frequently inhabited by people with a higher likelihood of having SARS-CoV-2 and/or an increased risk of getting SARS-CoV-2.
- ix. When placing Portable air cleaner with HEPA filters in a ward/ area, consider the following:
 - a. Airflow direction is from clean to less clean areas (portable air cleaner with HEPA that generates unidirectional air flow from inlet to exhaust is preferred).
 - b. Place in the areas used by people and close to people, to provide the maximum possible treatment of the source(s) of infection.
 - c. Should be operated continuously.
 - d. Portable air cleaner capacity should at least cover the gap between the minimum requirement and the measured ventilation rate by comparing the device clean air delivery rate (CADR) (m^3/hr) with the room ventilation rate.

- e. Avoid placing the device below the air conditioner diffuser as it will reduce the effectiveness of the unit which will cause turbulence flow that could cause more harm than good.
 - f. Examples of placements of Portable air cleaner with HEPA filters (figure 14-18)
 - g. Please note, that portable air cleaner with HEPA filters do not replace ventilation in any circumstance, and they do not compensate for the absence of negative air flow.
- x. Portable air cleaner should be regularly inspected, maintained and cleaned according to the manufacturer's recommendations. All maintenance team must wear a full PPE when servicing the portable air cleaner which cater for COVID-19 patient.
 - xi. Particle counters can also be used to determine the **efficacy of portable air cleaner**. This can be done by **comparing the particle count at the inlet** to the portable air cleaner **with the particle count at the output** of the portable air cleaner when the portable air cleaner is running.
 - xii. When choosing a portable air cleaner with HEPA filters, select a system that is appropriately sized for the area in which it will be installed.
 - xiii. Selection of a portable air cleaner with HEPA filters which it will be installed in a room or area is determined based on the:
 - a. Size of the room (room volume)
 - b. Existing ventilation rate in the room (ACH).
 - c. Clean Air Delivery Rate (CADR) of the portable device which is typically reported in cubic meters per hour (m³/hr) or cubic feet per minute (CFM);
 - 1. In a given room, the larger the CADR value, the faster it will clean the room air. The **smoke CADR** number on the label applies best to viral particles related to airborne pathogens.
 - 2. For Portable air cleaner with HEPA filters whose manufacturers do not provide CADR, select a Portable air cleaner with HEPA filters based on the suggested room size (m² or ft²) or the reported air flow rate (CFM) provided by the manufacturer.
 - 3. CADR should at least cover the gap between the minimum requirement and the measured ventilation rate – compare the CADR (m³/hr or CFM) with the room ventilation rate.
 - 4. For a room **with natural ventilation**, the required CADR of the portable air cleaner with HEPA filters can be calculated using the formula below.
For example, if a minimum equivalent 6 ACH is required for a room which has length of 10 ft. (3 m), width 12 ft. (3.7 m) and ceiling height 10 ft. (3 m), the calculation of the CADR (CFM) needed for this room is as follow:

$$ACH\ required = \frac{smoke\ CADR\ of\ air\ purifier\ (Cubic\ Feet\ per\ Hour)}{volume\ (ft^3)}$$

Since 1 Cubic Feet per Minute = 60 Cubic Feet per Hour,

$$ACH\ required = \frac{smoke\ CADR\ of\ air\ purifier\ (Cubic\ Feet\ per\ Minute) \times 60}{volume\ (ft^3)}$$

$$CADR = \frac{ACH\ required \times L \times W \times H}{60} CFM\ or$$

$$CADR = \frac{ACH\ required \times L \times W \times H \times 1.699}{60} (m^3/hr)$$

L: Length of room, ft.
W: Width of the room, ft.
H: Height of the room, ft.

$$CADR = \frac{6 \times 10 \times 12 \times 10}{60} CFM$$

$$CADR = 120\ CFM\ (204\ m^3/hr)$$

In this case a portable air cleaner with HEPA filters of about smoke CADR of approximately 120 CFM is needed.

5. In a **mechanically ventilated room**, the CADR should at least cover the gap between the minimum requirement and the measured ventilation rate – compare the CADR (m³/hr or CFM) with the room ventilation rate.

Example:

You require 12 ACH in a room where the existing ACMV system has 6 equivalents ACH. The room's length is 45 ft. (13.7 m), width is 20 ft. (6.1 m) and ceiling height is 9 ft. (2.7 m).

In order to meet the required 12 ACH total, the portable air cleaner needs to provide **addition 6 equivalent** ACH. The calculation of the CADR (CFM) is as follows using the above formula:

$$CADR = \frac{ACH \times L \times W \times H}{60} CFM\ or$$

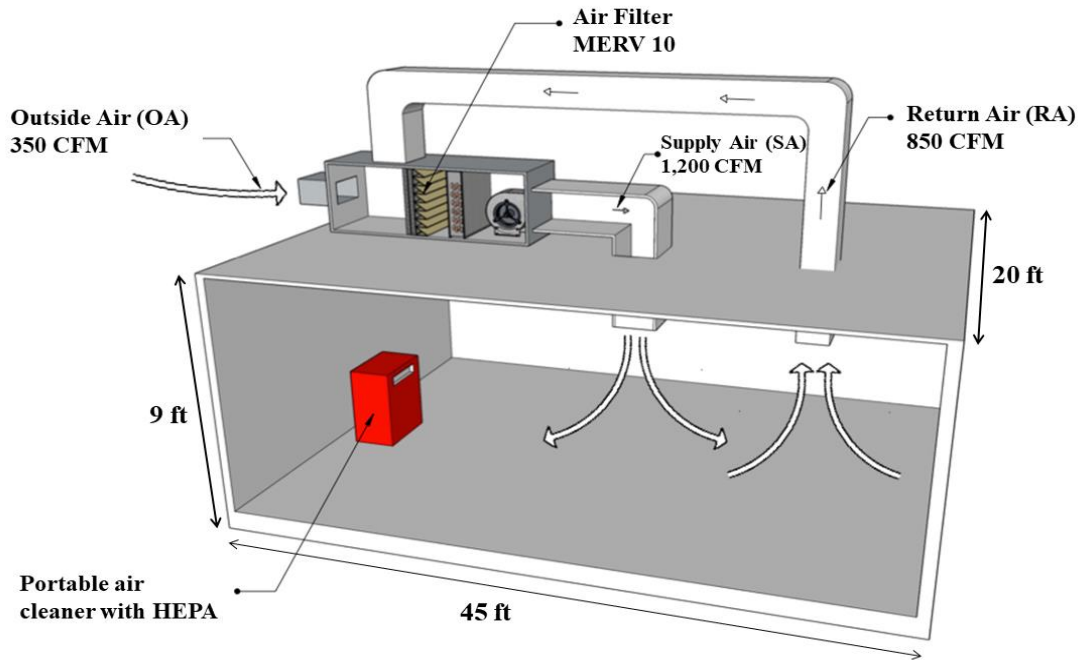
$$CADR = \frac{ACH \times L \times W \times H \times 1.699}{60} (m^3/hr)$$

$$CADR = \frac{6 \times 45 \times 20 \times 9}{60} (CFM)$$

$$CADR = 810\ CFM\ (1376\ m^3/h)$$

In this case a portable air cleaner with HEPA filters of about smoke CADR of 810 CFM is needed to achieve the 12 ACH total in the room with an existing ACMV system has 6 equivalents ACH.

6. Alternatively, the CADR can be calculated by considering the equivalent outdoor air change rate and effectiveness of filter at AHU.



Example:

A 45 ft x 20 ft (14 x 6 m) room with 9 ft (3 m) ceilings (Volume, $V = 8,100 \text{ ft}^3$ (229 m^3)) has an ACMV system with a supply airflow rate of 1,200 CFM, of which 350 CFM is outdoor air and 850 CFM is recirculated air and is filtered by MERV-10 air filter at the mixing chamber. To calculate the equivalent outdoor air of the current system, we have to determine the outdoor air equivalent air changes due to filtration, ACH_f at the AHU.

$$ACH_{OA} = \frac{60 Q_{OA}}{V} = \frac{60 \times 350 \text{ CFM}}{8,100 \text{ ft}^3} = 2.6 \text{ ACH}$$

$$ACH_{SA} = \frac{60 Q_{SA}}{V} = \frac{60 \times 1,200 \text{ CFM}}{8,100 \text{ ft}^3} = 8.9 \text{ ACH}$$

From the information and calculations above, we know that the ACH of outdoor air, ACH_{OA} is 2.6 ACH, while the ACH of supply air, ACH_{SA} is 8.9 ACH. Thus, the outdoor air equivalent ACH due to filtration, ACH_f can be determined below;

$$\begin{aligned} ACH_f &= (ACH_{SA} - ACH_{OA}) \times \text{MERV 10 nuclei droplet efficiency} \\ &= (8.9 - 2.6) \times 64.65\% = 4.07 \text{ ACH} \end{aligned}$$

Portable air cleaner capacity should at least cover the gap between the minimum requirement and the measured ventilation rate by comparing the device clean air delivery rate (CADR) with the room ventilation rate. For this example, the room is required to have 12 ACH of outdoor air. Thus, an additional equivalent ACH of outdoor air of the following amount is needed;

Air cleaner outdoor air equivalent ACH

$$= 12ACH - (ACH_{OA} + ACH_f)$$

$$= 12ACH - (2.6ACH + 4.1ACH)$$

$$= 5.3ACH$$

Therefore, the in room air cleaner device need to provide about 5.3 ACH equivalent outdoor air, which for this room the CADR of the air cleaner would need to be;

$$CADR = \frac{5.3ACH \times V}{60} = \frac{5.3ACH \times 8,100ft^3}{60} = 715.5 CFM$$

References:

1. <https://www.ashrae.org/technical-resources/building-readiness>
 2. *In room air cleaner guidance for reducing Covid19 in your space/room, ASHRAE, January-2021*
7. If a portable air cleaner with HEPA filters and the appropriate CADR number or higher is not available, select multiple units of portable air cleaner with HEPA filters with a lower CADR rating that could provide maximum coverage of the room. The unit will still provide incrementally more air cleaning than having no air cleaner at all.
 8. The fan speed should ideally meet the space noise level target of NC 30-40/35-45 dBA.

Note: Portable air cleaner with HEPA filters that use filters less efficient than HEPA filters also exist and can contribute to room air cleaning. However, they should be clearly labelled as non-HEPA units.

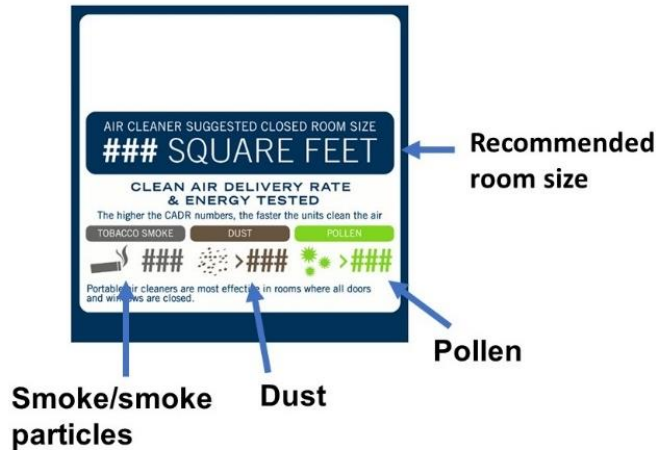


Figure 12: Example of CADR rating label.

Reference:

1. *In-room air cleaner guidance for reducing covid-19 in air in your space room*, ASHRAE 2021; <https://www.ashrae.org/technical-resources/resources>

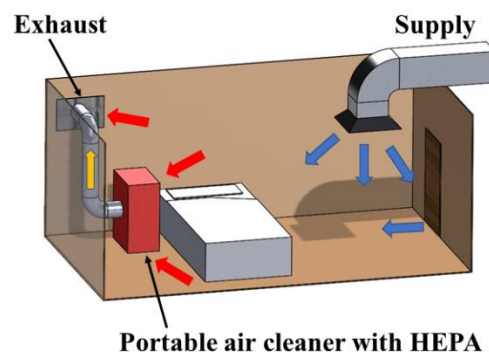


Figure 13: Example of Installing portable air cleaner with HEPA on discharge air from Room (filtered air exhausted out of the room).

There are three options for creating a temporary surge area using a portable air cleaner with HEPA as shown in Figure 14 which are known as **discharging through a window**, **discharging to an adjacent space** and **discharging to an exhaust of the air conditioning system**. These three options may be used in combination to achieve desired pressure differential. When discharging to the exhaust air conditioning system, users must be cautious with the volume of air being discharged. When discharging through a window, users must be cautious and refer to **section 8.4**.

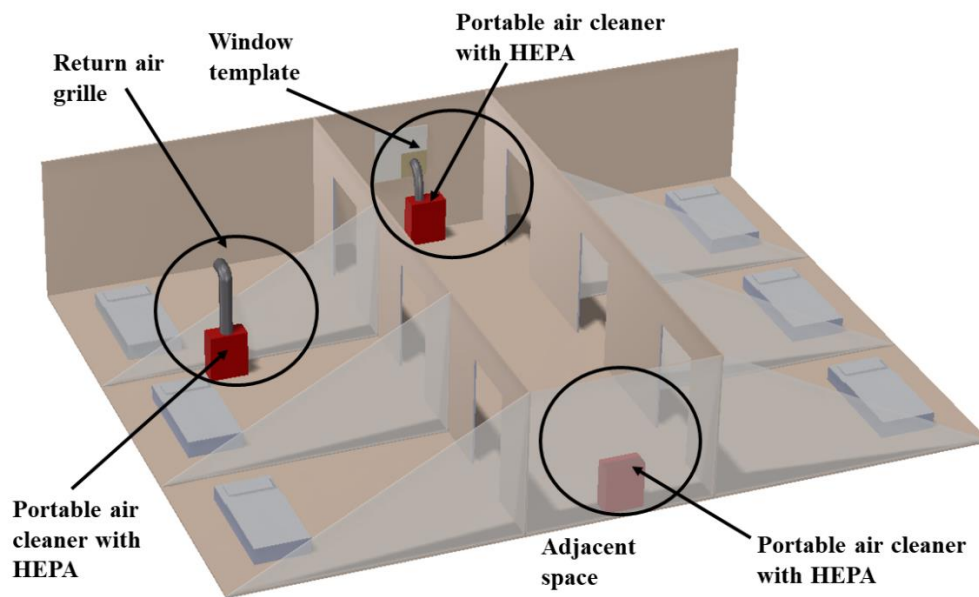


Figure 14: Example of placement of portable air cleaner with HEPA at corridor (filtered air exhausted out of the room).

Figure 15 shows the schematic of the placement of the portable air cleaner with HEPA in a two-patient isolation room. In this configuration, the occupied inner isolation zone shows the make-up air gap and portable air cleaner with HEPA exhaust and inlet position to induce directed airflow across the head of patient's bed. If the plastic curtain is installed, a PVC-framed tunnel was erected near the portable air cleaner with HEPA outlet to facilitate exhaust discharge without disrupting plastic curtains. Besides, fire sprinkler coverage needs to be considered in building the isolation curtains. Inner patient zones should not include non-ducted air conditioning system or exhaust air grilles unless they can be sealed tight.

Two bedded patient room: Side to side airflow across head of bed

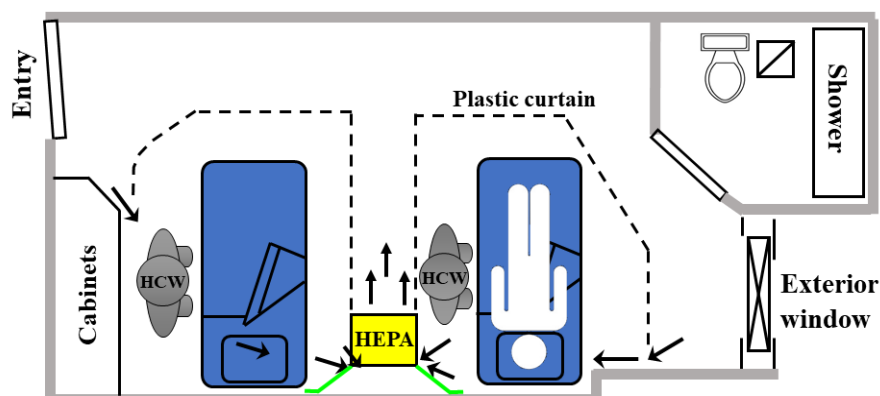


Figure 15: Example of placement of portable air cleaner with HEPA in two bedded room: side-to side airflow across head of bed (filtered air recirculated in room). (Plastic curtain may be installed for better isolation of the patient)

Note: Plastic curtain should be able to fit nearly all the way around the bed. Also, the height should be at least six inches taller than the ceiling, which allows for the plastic to be taped to the floor. For accessibility to the patient, the plastic should be at least three feet from the bed on all sides.

The portable air cleaner with HEPA should be inserted into the plastic sheeting as illustrated in Figure 16. The **plastic needs to be cut so that the portable air cleaner with HEPA unit can be fit into the space**. The intake must be within the plastic enclosure and the output must be outside the plastic enclosure. This will draw the air from the enclosure, filter it, and exhaust it to the rest of the room. This will provide an airflow that will help to isolate the patient. Once the portable air cleaner with HEPA is installed and sealed with tape, the remaining surfaces need to be sealed with tape.

The hanging plastic curtain should be taped to the floor to minimize the “leakage area” of the enclosure and provide stronger airflow and containment. **The curtain near the portable air cleaner with HEPA must be taped to the head wall**. This will also help to minimize the leakage area of the enclosure.

Turn on the portable air cleaner with HEPA. If set up correctly, the sides of the plastic will pull in which indicate that the enclosure is under negative pressure.

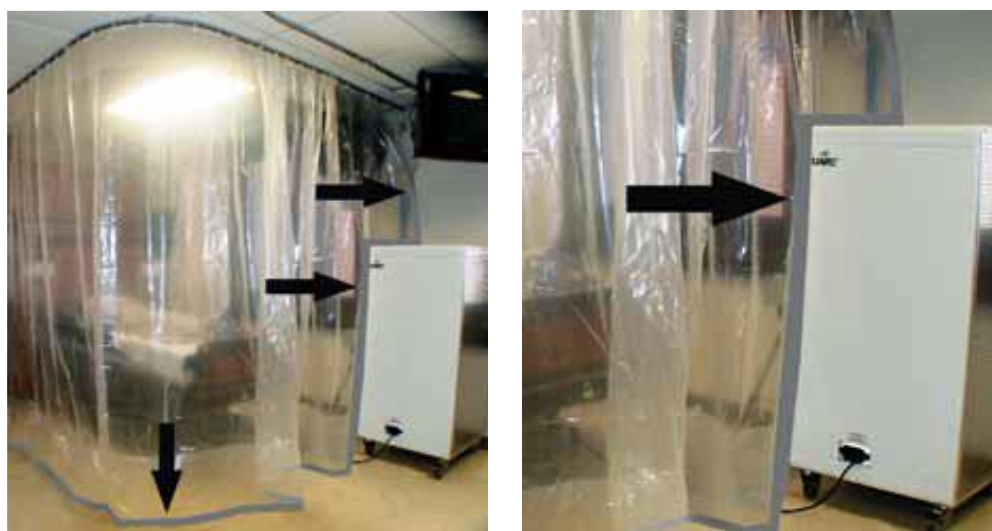


Figure 16: Example of Placement of portable air cleaner with HEPA installed in plastic air. The plastic should be taped around the portable air cleaner to provide a seal.

Figure 17 shows the schematic of the placement of the portable air cleaner with HEPA in a single patient isolation room. In this configuration, the occupied inner isolation zone shows the make-up air gap and portable air cleaner with HEPA exhaust and inlet position to induce directed airflow across the head of patient's bed.

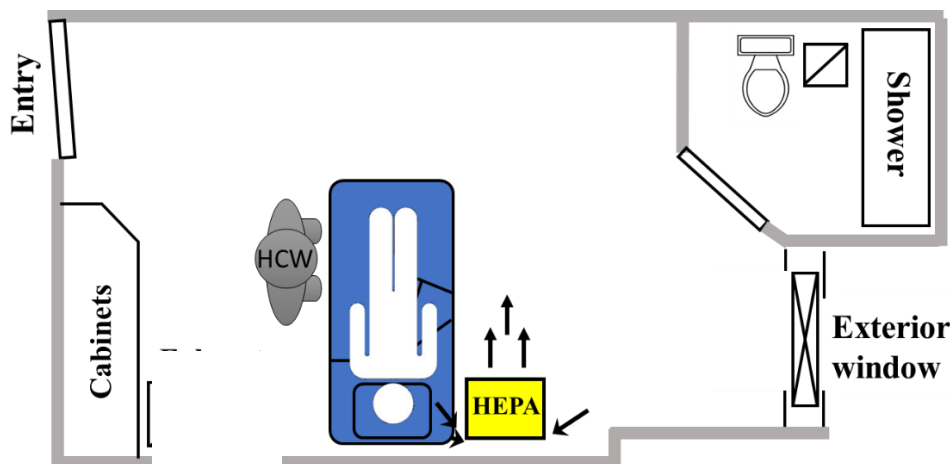


Figure 17: Example of placement of portable air cleaner with HEPA in a single patient Room: Side-to side airflow across head of bed (filtered air recirculated in room).

10.2 UVGI (Ultraviolet Germicidal Irradiation)

Ultraviolet germicidal irradiation (UVGI), is a disinfection tool that maybe used as a supplemental air cleaning measure in a healthcare setting. UVGI is effective in reducing the transmission of airborne bacterial and viral infections, but it has only a minimal inactivating effect on fungal spores. The design and sizing of effective UVGI disinfection systems as well as dosage and contact time requires specific knowledge and experience.

Seek consultation with a reputable UVGI manufacturer or an experienced UVGI system designer prior to installing UVGI systems. These professionals can assist by doing necessary calculations (dose and duration of contact), making fixture selections, properly installing the system, and testing for proper operation specific to the setting.

- i. Ultraviolet germicidal irradiation (UVGI) uses ultraviolet (UV) energy to inactivate (kill) microorganisms, including viruses, when designed and installed correctly. UV is germicidal at the range 200–320 nm, especially UV-C (200–280 nm).
- ii. The design and sizing of effective UVGI disinfection systems requires specific knowledge and experience.
- iii. Precaution:
 - a. UV-C can generate ozone and free radicals, which are hazardous to human health in closed spaces. They can produce sunburn-like skin reactions, eye and respiratory tract damage if strict safety measures are not utilized in their installation, use and maintenance.

- b. Standardised testing procedures to determine conditions to exclude the health hazards of UVGI, for potential use to reduce SARS-CoV-2 in indoor air spaces, are very limited.

iv. Types of UVGI available:

a. Upper-room UVGI systems

1. Upper-room UVGI can be used to provide air cleaning within occupied spaces
2. UVGI fixtures mounted on walls or ceilings to create a disinfection zone of UV energy that is focused up and away from people to minimize direct exposure. These fixtures disinfect air as it circulates from mechanical ventilation, ceiling fans, or natural air movement. It requires good vertical air movement in the room.
3. Its surface disinfection effects are hindered by physical obstacles to direct UVGI.
4. UVGI systems usually require a few UV fixtures to be effective. For example, a rectangular-shaped waiting room with 10–30 occupants will require 2–3 upper-air UVGI fixtures.
5. During system installation, care must be taken to control the amount of UV energy directed or reflected into the lower occupied space below levels recognized as safe as the UV energy can be hazardous to human health. Ensure UVGI manufacturers take the necessary measurements and make any required adjustments to prevent harmful UV exposures to people in the space.

b. In-duct UVGI systems

In-duct UVGI systems are installed within a ACMV system to help enhance air cleaning inside central ventilation systems. Air passes through ventilation systems and is irradiated inside before recirculation or exhaustion. These systems are designed to serve one of two purposes:

1. Coil treatment UVGI keeps ACMV coils, drain pans, and wet surfaces free of microbial growth. Coil treatment UVGI devices are not designed for disinfecting the air and should not be installed for the purposes of air disinfection.

Potential application: to reduce ACMV maintenance and improve operational efficiency; not recommended for inactivating airborne pathogens.

2. Air disinfection UVGI systems can be effective at applying intense UV energy to inactivate airborne pathogens as they flow within the ACMV duct. Air disinfection systems are often placed downstream of the ACMV coils. This location keeps the coil, drain pan, and wetted surfaces free of microbial growth and also disinfects the moving air.

Potential application: Can be used inside any ACMV system to disinfect infectious airborne pathogens.

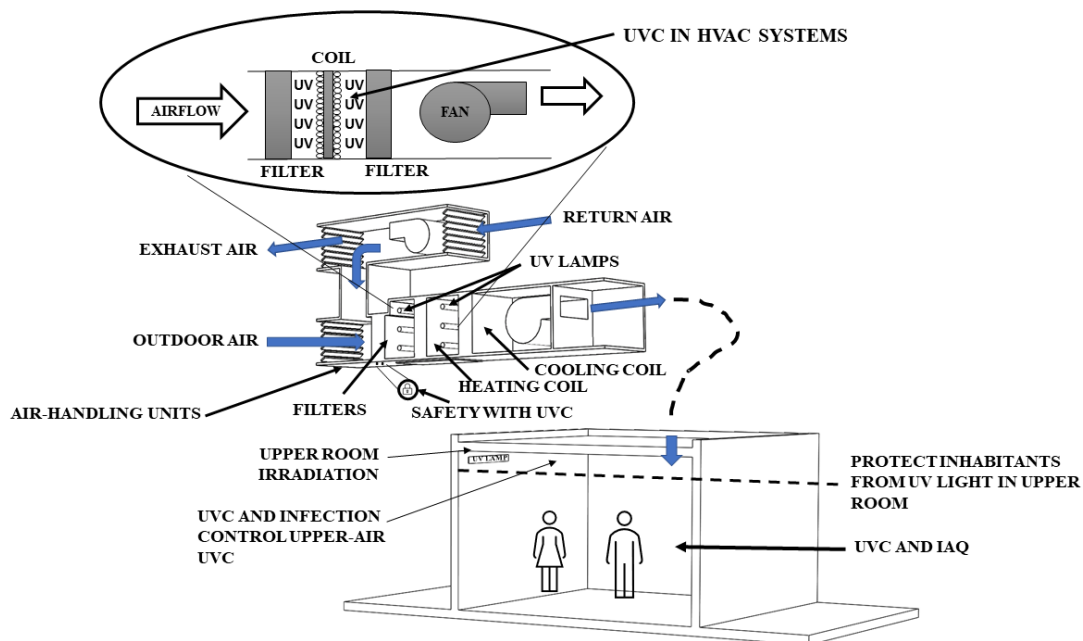


Figure 15: Potential applications of UVC to control microorganisms in air and on surfaces (ASHRAE 2009).

c. Portable UV-C for terminal room disinfection

1. May be use as additional strategy for surface disinfection after routine terminal cleaning has been done. It should not replace routine manual cleaning of healthcare environment.
2. UV-C device is typically placed in the middle of the room for terminal disinfection. However, room with bed and furniture may shadow the lights and limit the areas for effective treatment. The best is to map the intensity of light for every room to identify low reach areas for combination of treatment.
3. Important to understand the safety mechanism of the UV-C device. UV-C unit selected for terminal room disinfection, shall be equipped with a safety mechanism such as automatic turning ON after a few minutes (to allow operators to leave the area) and automatically SHUT OFF if someone ignores the physical barrier and opens the door.
4. Target micro-organism. There are hundreds of different types of microorganisms, and each has a known amount of UV-C dose required in order to achieve its deactivation to a particular % efficiency. The amount of UV-C required for different viruses, bacteria and spores varies over a very large range.

5. It is advisable to build in appropriate safety margins to account for different environmental conditions such as air flow speeds, temperature and humidity levels, number of air changes, surface soiling, lamp ageing and system configuration, etc.

11. SUMMARY OF RECOMMENDATION TO IMPROVE NATURAL VENTILATION IN HEALTHCARE SETTINGS

Ventilation rate/ number of air changes	60 L/s/patient (hourly average ventilation rate) or 6 ACH (air changes per hour) 160 L/s/patient (hourly average ventilation rate) or 12 ACH (air changes per hour) where AGP are performed
The airflow direction	Direction should be from clean to less clean. Modify the functional distribution regarding airflow directions to minimize exposure of health care workers, Avoid using devices that generate a strong air flow in a common area, especially streams of air going from person to person.
Air exhausted outside	Air should be exhausted directly to the outside away from air intake vents
Toilets	Avoid open windows in toilets to maintain the correct direction of ventilation Keep toilet ventilation in operation round the clock. Flush toilets with closed lid.
Monitoring indoor air quality	CO2 level more than 1000 ppm indicates poor indoor air quality. To minimize risk of transmission, it is important to keep the CO2 levels to as low as practically possible (preferable below 800 ppm as recommended by CDC).

12. SUMMARY OF RECOMMENDATION TO IMPROVE MECHANICAL VENTILATION IN HEALTHCARE SETTINGS

Ventilation rate/ number of air changes	60 L/s/patient (hourly average ventilation rate) or 6 ACH (air changes per hour) 160 L/s/patient (hourly average ventilation rate) or 12 ACH (air changes per hour) where AGP are performed
The airflow direction	Direction should be from clean to less clean. Modify the functional distribution regarding airflow directions to minimize exposure of health care workers, Avoid using devices that generate a strong air flow in a common area, especially streams of air going from person to person.
Air exhausted outside	Air should be exhausted directly to the outside away from air intake vents
Air recirculation	Consult ACMV professional Recirculation systems where no or too little fresh air is added are not recommended. Maximise outside air intake and reduce air recirculation as much as possible. Increase outdoor fresh air supply, potentially up to 100%, if supported by and compatible with the ACMV system Increasing amount of outdoor air will lead to risk of surface condensation and growth of fungus and bacteria. The humidity level should be carefully control not exceed 60% RH by installing dehumidification component at AHU. Non-ducted (with indoor air recirculation) convectors such as split or fan coil units is discouraged (difficult to maintain, provide poor filtration and contribute to turbulence-potentially increasing the risk of infection). MUST be avoided where AGP is performed
Filters	In recirculating central ventilation systems, install/upgrade to the most efficient filters (rated at a MERV-14 level or higher or HEPA) taking the capabilities of the ACMV systems into consideration
Air Relative humidity (RH)	AIIR: Max 60% Noncritical area: 40% to 70%

Regular airing of rooms	<p>Air common areas such as a conference room, during breaks or after the meeting when everyone has left the room.</p> <p>For example, airing is carried out by opening windows and doors wide against each other for 10 to 15 minutes after meeting.</p> <p>To discuss with the hospital engineers if this is allowed and does not cause condensation.</p>
Toilets	<p>Keeping negative pressure in toilets is recommended, as aerosol formation can occur;</p> <p>Avoid open windows in toilets to maintain the correct direction of ventilation</p> <p>Keep toilet ventilation in operation round the clock.</p> <p>Flush toilets with closed lid.</p>
Monitoring indoor air quality	<p>CO2 level more than 1000 ppm indicates poor indoor air quality. To minimize risk of transmission, it is important to keep the CO2 levels to as low as practically possible (preferable below 800 ppm as recommended by CDC).</p>
Maintenance of air filter	<p>Make sure air filters are properly sized and within their recommended service life.</p> <p>Inspect filter housing and racks to ensure appropriate filter fit and minimize air that flows around, instead of through the filter.</p> <p>All maintenance team must wear a full PPE when servicing the AHU (air circulation) or any part of the air ventilation system which cater for COVID-19 patients.</p>

13. SUMMARY OF VENTILATION SPECIFICATIONS IN SELECTED AREAS OF HEALTH-CARE FACILITIES FOR INFECTION PREVENTION AND CONTROL.

Specifications	All room (includes bronchoscopy suites)	Critical care room*	Isolation anteroom
Air pressure**	Negative	Positive, negative, or neutral	Positive or negative
Room air changes	≥6 ACH (for existing rooms) ≥12 ACH (for renovation or new construction)	≥12 ACH	≥10 ACH
Sealed***	Yes	No	Yes
Minimum filtration supply	MERV-14	MERV-14	MERV-14
Minimum filtration Exhaust	HEPA	HEPA	HEPA
Recirculation	No	No	No

If the procedure is an aerosol generating procedure, it is recommended to perform the procedure in an airborne infection isolation room or a bronchoscopy room with 12 total ACH. The room must be negative, 100% exhaust and no recirculation within the room.

* Positive pressure and HEPA filters may be preferred in some rooms in intensive care units (ICUs) caring for large numbers of immunocompromised patients.

** Clean-to-dirty: negative to an infectious patient, positive away from immunocompromised patient.

*** Minimized infiltration for ventilation control; pertains to windows, closed doors, and surface joints.

Refer to Ministry of Health Malaysia guideline- "Policies & Procedures on Infection Prevention and Control 2019"

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AIRBORNE INFECTION ISOLATION ROOMS (AIIR)

1. Introduction

Airborne Infection Isolation Rooms (AIIR) are commonly known as Negative Pressure Isolation Room as the air pressure in the patient room is more negative than the corridor/ anteroom which allows air to flow from the corridors/ anteroom (less contaminated) into the AIIR (more contaminated).

2. Airborne Infection Isolation rooms (AIIR) requirements (Figure 1 and 2)

- a. It is a single patient isolation room with en-suite bathroom. preferable with an anteroom.
- b. The minimum air change should not be less than 12ACH for new building and not less than 6ACH for existing building.
- c. The air pressure in the patient room is more negative than the corridor/ anteroom. Doors and windows must be kept closed at all time to maintain the negative pressure at all times.
- d. The Differential pressure between AIIR and corridor shall be no less than -2.5 Pa.

When an anteroom is provided, the pressure relationships shall be as follows:

- i. The patient room shall be at a negative pressure with respect to the anteroom.
 - ii. The anteroom shall be at a negative pressure with respect to the corridor.
 - iii. The bathroom shall be at a negative pressure with respect to the patient room.
- e. A display panel shall be provided to indicate if negative differential pressure is maintained. A permanently installed device and/or mechanism to constantly monitor the differential air pressure between the room and the corridor, whether or not there is an anteroom should be instituted. (Appendix 2)
 - f. Air flow direction should be from clean to less clean
 - i. The supply air flow should be from clean to less clean area.
E.g. The supply air shall be located as such that it is first passed over the HCWs and then to the patients, hence reducing the HCW's exposure to potential airborne droplet nuclei from infectious patients.
 - ii. Exhaust air vents in the patient room should be located directly above the patient bed, on the ceiling or on the wall near the head of the bed, unless it can be demonstrated that such a location is not practical.
 - iii. Air flow patterns when room is occupied by immunocompromised patient with airborne infectious disease is illustrated in figure A3

- g. Efficient air filtration type and rating should be installed at the supply and exhaust air to promote healthy indoor environment. (see Appendix 3)
 Supply side: minimum MERV 14 rating air filter
 Exhaust air: HEPA filter

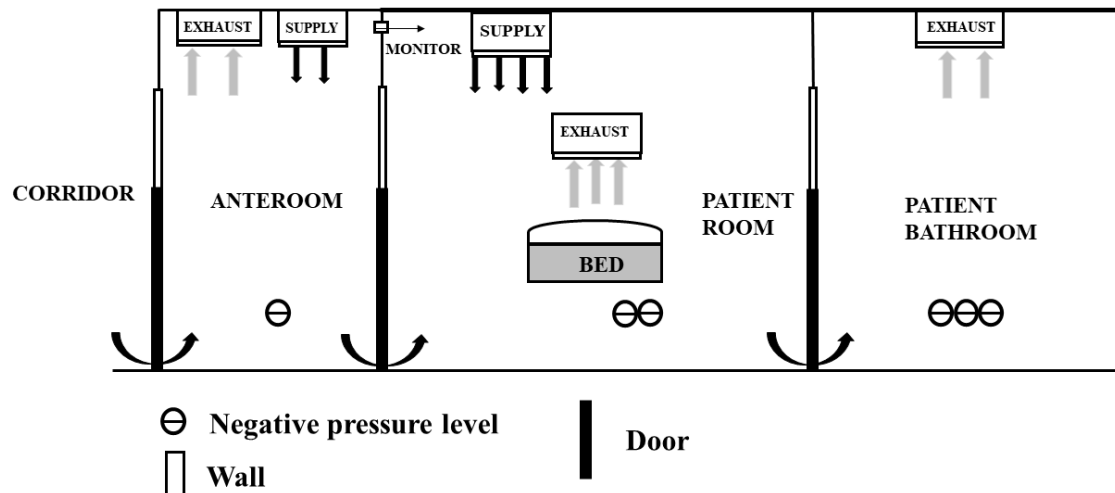


Figure A1: The air flow direction and pressure difference between the anteroom, patient room and toilet in AIIR.

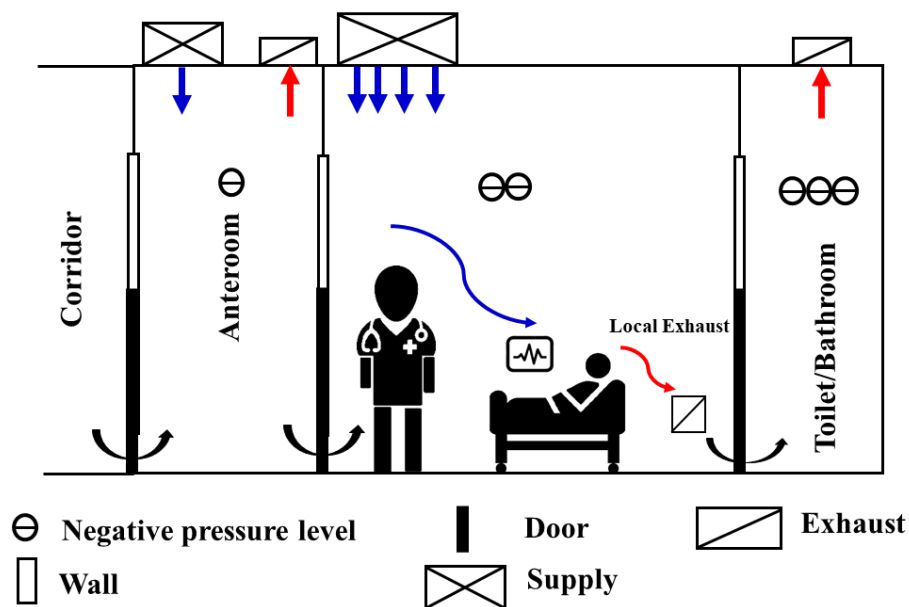


Figure A2: Air flow from clean to less clean in AIIR.

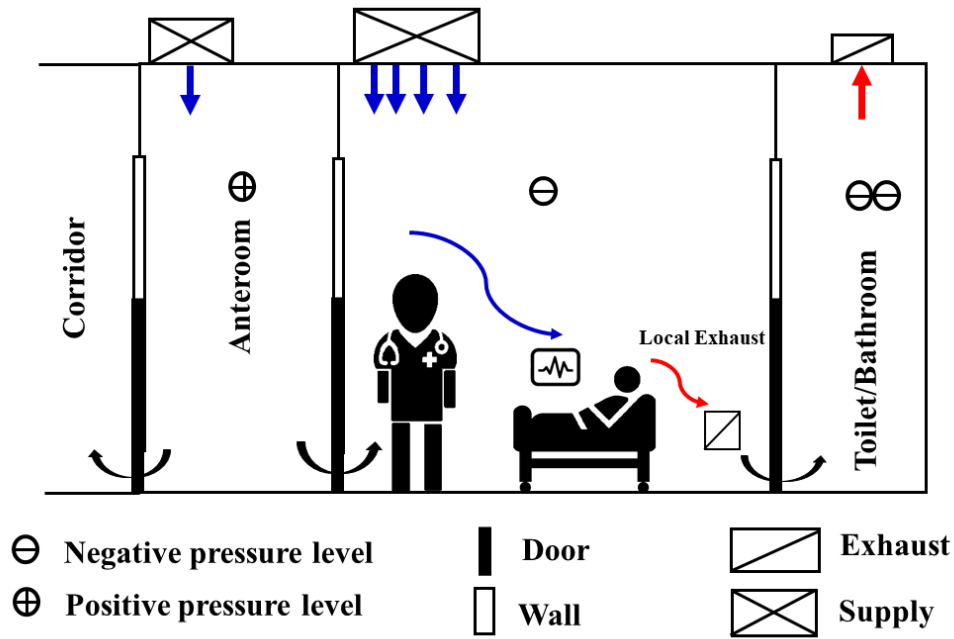


Figure A3: All and immune-compromised (patient room negative pressure and anteroom positive pressure).

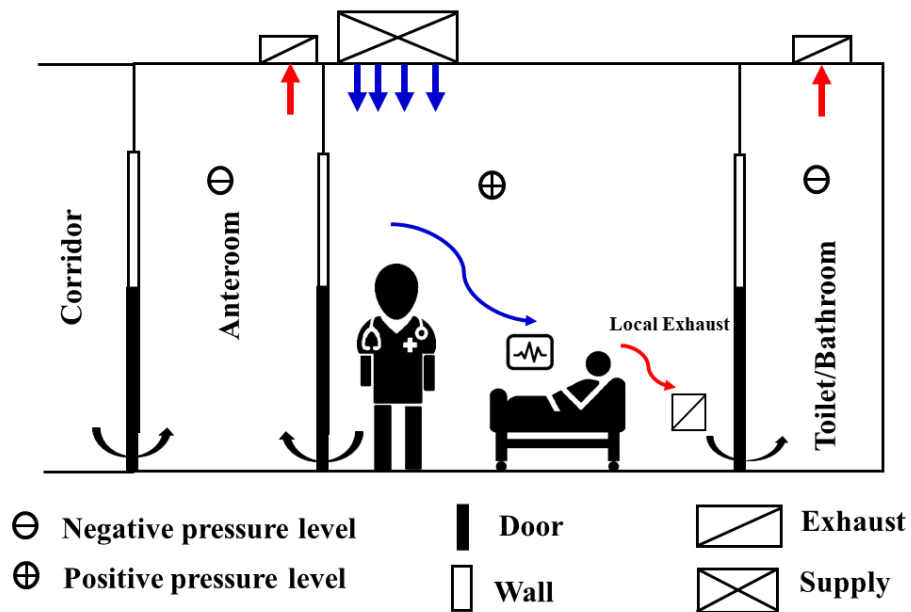


Figure A4: All and immune-compromised (patient room positive pressure and anteroom negative pressure).

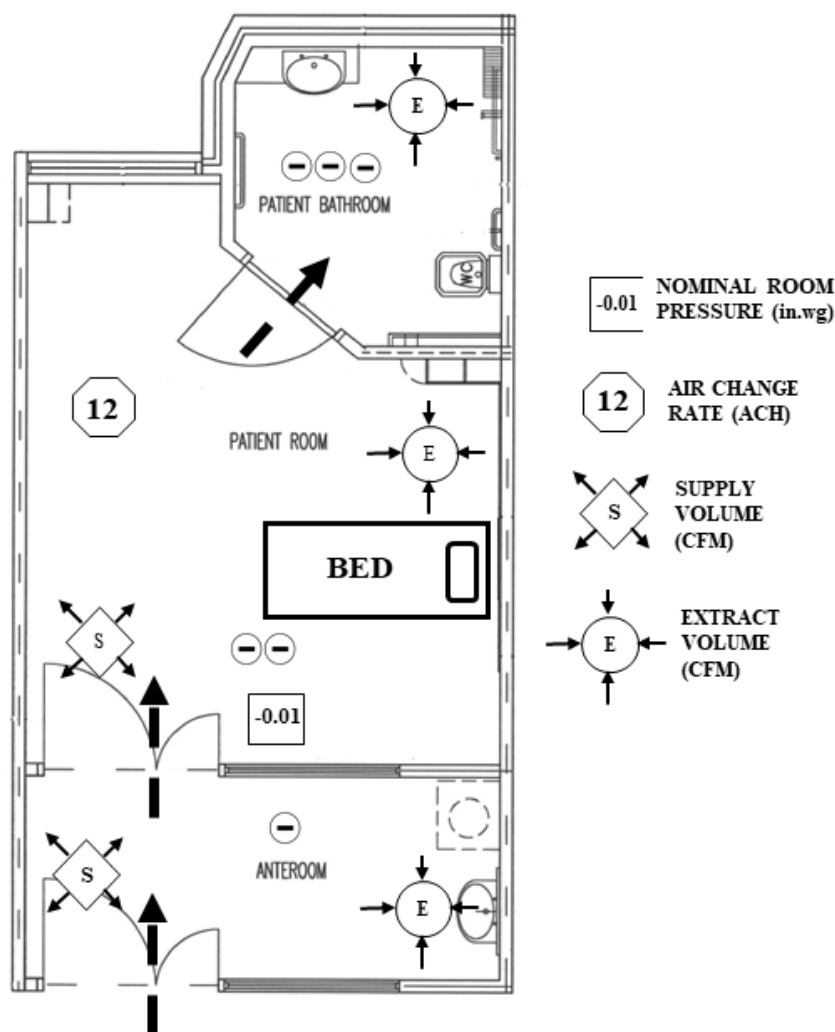


Figure A5: Plan view of the AIIR.

3. Supply and exhaust in AIIR

There are two approaches on where the air supply and exhaust air grille for the AIIR should be located.

- a. The ceiling mounted air supply is located at the centre of the room or slightly towards the entrance.
The exhaust grille is to wall mounted at a low level above the patient bed head.
- b. The ceiling mounted air diffuser is located at centre of the room or slightly towards the entrance
The exhaust grille is mounted over the patient bed head.

The first approach is preferred as it maximizes the room air mixing and contaminant removal.

- i. Outdoor air intake should be located not less than 1.8 m above ground. Air intake on the top of the building shall be located at a minimum of 0.9 m

above the roof level. The area around the air intake shall be free from vegetation, waste products, or any other possible source of contamination.

- ii. The air diffuser should be of the louvered blade type that directs air to all parts of the room, so as to ensure good mixing and minimize stagnant air; and shall be located where it is not obstructed by suspended television or surfaced light fixtures.
- iii. Supply air ducts should be independent of the building's common supply air system. If sharing of supply ducts with other isolation rooms is unavoidable, the ducts with terminal HEPA filters should be provided (figure 9)
- iv. All exhaust air from the AIIR, associated anterooms, and associated toilet rooms shall be discharged by one of the following methods:
 - 1. Directly to the outdoors away from air-intake vents, persons, and animals, in accordance local regulations on environmental discharges.
 - 2. When the recirculation of air from All rooms is unavoidable, high efficiency particulate air (HEPA) filter that removes most (99.97%) of the droplet nuclei should be installed in the exhaust duct leading from the room to the general ventilation system.
- v. The exhaust duct and exhaust fan shall be labelled to identify its intended purpose. The label shall read "Caution- All Exhaust Duct" and the label shall be bilingual; in Bahasa Melayu and English.
- vi. AIIR located at the highest floor, the air shall be exhausted directly to the outside using the ductworks at least 10 ft. (3 m) above roof level and shall be located not less than 10 ft. horizontally from any air intakes.
- vii. For the intermediate floor AIIR, the air may be exhausted directly to the outside through HEPA filter. (Figure 10)
- viii. Ultraviolet germicidal irradiation (UVGI) may be used as a supplemental engineering control in conjunction with HEPA filters at the exhaust to further enhance the cleanliness of outgoing air.

SUMMARY ON AIIR PARAMETERS

Parameter	Airborne Infection Isolation Room (AIIR)
Minimum total air changes per hour	12 ACH for new building >6 ACH for existing building
All air exhausted directly to outdoors	Yes
Minimum air changes of outdoor air per hour	2
Recirculated by means of room units	No
Air movement relationship to adjacent areas	In
Differential pressure between AIIR and adjoining areas	-2.5 Pa or -0.01 inch Wg
Design temperature, °C	22 to 26
Relative humidity, %	Max 60
Supply minimum filter efficiencies	MERV-14**
Exhaust minimum filter efficiencies	HEPA

N/R: No requirement

*Note *: Portable or fixed recirculating devices shall not be used for heating or cooling air in AIIR. Air may be recirculated within individual isolation rooms if recirculating devices with HEPA filters are used as an interim or supplement environmental controls. The supply and exhaust locations should direct clean air to areas where the healthcare workers are likely to work, across the infection source, and then to the exhaust, so that the healthcare workers are not in position between the infectious source and the exhaust location. The design of such systems should also allow for easy access for schedule preventive maintenance and cleaning.*

*** The air filtration system at the air handling units is to be made up of two filter banks. The first bank (Filter Bank No. 1) shall be placed upstream of the cooling coils so that air intake is filtered. The second filtration bank (Filter Bank No. 2) shall be placed downstream of the cooling coils and the supply fan.*

In the air handling unit for the All application, Bank No. 1 shall be fitted with a filter of a MERV 7 rating, while Bank No. 2 shall be fitted with a filter of a minimum MERV 14 rating.

Appendix 2

MONITORING OF AIR PRESSURE AND AIR FLOW IN HEALTHCARE SETTING

The pressure different (i.e. air flow direction) in the rooms and cubicles can be checked using various methods. To evaluate the actual air flow direction, the testing shall be done when the space is occupied by a patient with an airborne infection.

Monitoring the pressure in a room can be done by either:

- a. Passive test:
 - i. Simple visual qualitative tests to verify whether a room is under negative or positive pressure using the principal air flows from an area of high pressure to low pressure.
 - ii. These are used as a **preliminary screening tool** to evaluate if further investigation is needed. If room air cleaners (i.e. portable air cleaners with HEPA) are being used in the room, they should remain running.
 - iii. This test can be conducted daily to monitor the airflow direction (indicating the pressure difference) in an Airborne Isolation (negative pressure) room, if the room does not have a permanent room pressure monitoring system (e.g. Magnehelic gauge).
- b. Active test:
 - i. Manometers.
 - ii. Permanent room pressure monitoring system in AIIR.

A. PASSIVE TEST

Smoke tube kit:

In Malaysian healthcare facilities which have its own facility maintenance team, only smoke tube test is acknowledged as a valid passive test for visual air flow testing.

A smoke tube* can be used to create a smoke trail of the airflow. (*smoke tube is a tube that generates white, noncorrosive smoke on squeezing)

Hold the smoke tube parallel to the closed door, about 2 inches in front of the gap under the closed door outside the room. The smoke which will travel in the direction of airflow.

Interpreting the tests:

If the room is at a negative pressure, the smoke will travel under the door and into the room. If the room is at a positive pressure, the smoke will travel away from the door and into the corridor.



Smoke Tube Kit

Note:

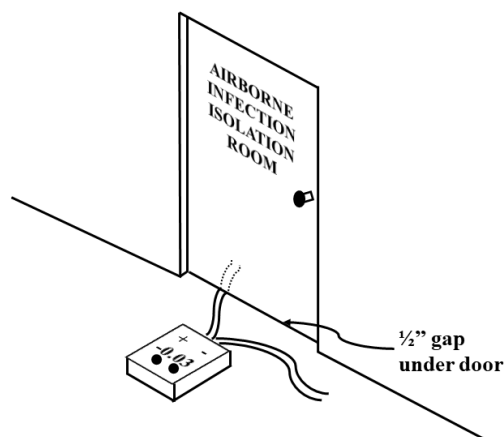
If smoke tube test is not available, as an alternative HCW can use flutter strips.

- i. Testing may be done at the door or at the window
 - Testing at Door
Hold the tip of a piece of flutter strip in front of the closed room/cubicle, approximately 1-inch above the floor, outside the cubicle/ room.
If there is no gap between the door and floor (eg. Sliding door), then slightly open door for testing.
 - Testing at window (window that opens to the outside environment)
Hold the tip of a piece of flutter strip in front of the inner side of the window (testing from inside the cubicle/ room)
- ii. Interpreting the tests:
 - If the flutter strip is pulled **towards** the room, it indicates that the room is at negative pressure and may be used for Airborne Infection Isolation.
 - If the room is at a positive pressure, the flutter strip will be blown away from the door/ window into the corridor/outside.
 - If the flutter strip is neither pulled **towards** the room or blown away, it indicates that there is no pressure difference.
- iii. Action:
If the test indicates the room is either positive or no pressure difference, the room should not be used for Airborne Infection Isolation and the HCW should inform the maintenance team to further assessment
- iv. The daily flutter strip test results should be documented on a Logbook. Example of logbook (Figure 1)
- v. If flutter strip is not available, a strip of tissue may be used by the HCW. It should be noted that proper smoke tube test is required to examine the air flow direction.

B. ACTIVE TEST

Manometer

Manometer can also be used, where one of the tubes will be placed under the door into the room and the other in the reference corridor. A display of the manometer indicates that the room is at a negative or positive pressure.



Permanent room pressure monitoring system for AIIR (negative pressure rooms)

All AIIR shall have a permanently installed device and / system to constantly monitor the differential air pressure between the room and corridor (whether or not there is an anteroom. (e.g. Magnehelic gauge or newer systems that have alarm that will be triggered when the predetermined reference pressure setting is breached).

These systems shall have wall-mounted display panels which are at eye level and the pressure difference.

The differential air pressure should be monitored daily by a dedicated HCW in the ward. Example of logbook (Figure 2).

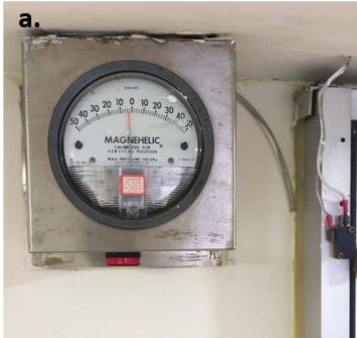
a



b



a.



b



Permanently installed device/ system to constantly monitor the differential air pressure between the AIIR and corridor a) direct took pressure monitoring system (e.g. Magnehelic gauge; b) indirect pressure monitoring system.

Airborne Infection Isolation Room (Negative Pressure)				
Daily Airflow Monitoring				
Ward: _____				
Room number: _____				
Acceptable airflow direction (indicating negative pressure): - flutter strip* will be pulled towards the room.				
Date	Time	Is air flow direction acceptable		REMARK (if the pressure not acceptable or any abnormal observation and document actions)
		Yes	No	

Figure 1: Example of logbook for dally monitoring of airflow direction in isolation room that is used for airborne infection.

* If flutter strip is not available, a strip of tissue may be used

Note: If the isolation room has a permanently installed visual monitoring devise, then flutter strip/smoke test is not necessary test

Airborne Infection Isolation Room (negative pressure)

Daily Pressure Monitoring

Ward: _____

Room number: _____

Airborne Infection Isolation Room (negative pressure)

Daily Pressure Monitoring

Ward: _____

Room number: _____

Airborne Infection Isolation Room (negative pressure)

Daily Pressure Monitoring

Ward: _____

Room number: _____

Airborne Infection Isolation Room (negative pressure)

Daily Pressure Monitoring

Ward: _____

Room number: _____

[illegible]

Figure 2: Example of logbook for dally monitoring of pressure in a AIIR that has a permanently installed visual monitoring device.

Appendix 3

AIR FILTER CATEGORY

Ref: Roadmap to improve and ensure good indoor ventilation in the context of COVID-19.
Geneva:

International standard (ISO 29463) European Standard (EN 1822)		
Filter class (ISO 29463)	Filter class (EN 1822)	Efficiency at MPPS
-	-	%
	E10	>85
ISO 15E – ISO 20E	E11	>95
ISO 25E – ISO 30E	E12	>99.5
ISO 35H – ISO 40H	HEPA – H13	>99.95
ISO 45H – ISO 50U	HEPA – H14	>99.995

International and European Standard (EN ISO 16890)		
ePM ₁ classification	ePM _{2.5} classification	ePM ₁₀ classification
0.3 µm ≤ x ≤ 1 µm	0.3 µm ≤ x ≤ 2.5 µm	0.3 µm ≤ x ≤ 10 µm
ePM ₁ (95)	ePM _{2.5} (95)	ePM ₁₀ (95)
ePM ₁ (90)	ePM _{2.5} (90)	ePM ₁₀ (90)
ePM ₁ (85)	ePM _{2.5} (85)	ePM ₁₀ (85)
ePM ₁ (80)	ePM _{2.5} (80)	ePM ₁₀ (80)
ePM ₁ (75)	ePM _{2.5} (75)	ePM ₁₀ (75)
ePM ₁ (70)	ePM _{2.5} (70)	ePM ₁₀ (70)
ePM ₁ (65)	ePM _{2.5} (65)	ePM ₁₀ (65)
ePM ₁ (60)	ePM _{2.5} (60)	ePM ₁₀ (60)
ePM ₁ (55)	ePM _{2.5} (55)	ePM ₁₀ (55)
ePM ₁ (50)	ePM _{2.5} (50)	ePM ₁₀ (50)

Composite Average Particle Size Efficiency % in Size Range μm (ASHRAE standard 52.2-2017)			ASHRAE Standard (52.2-2017)
Range E1	Range E2	Range E3	Minimum Efficiency Reporting Value
0.3 – 1.0 μm	1.0 – 3.0 μm	3.0 – 10.0 μm	MERV
$50\% \leq E1$	$85\% \leq E2$	$90\% \leq E3$	MERV 13
$75\% \leq E1$	$90\% \leq E2$	$95\% \leq E3$	MERV 14
$85\% \leq E1$	$90\% \leq E2$	$95\% \leq E3$	MERV 15
$95\% \leq E1$	$95\% \leq E2$	$95\% \leq E3$	MERV 16

Reference:

1. World Health Organization; 2021. Licence: CC BY-NC-SA 3.0 IGO
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