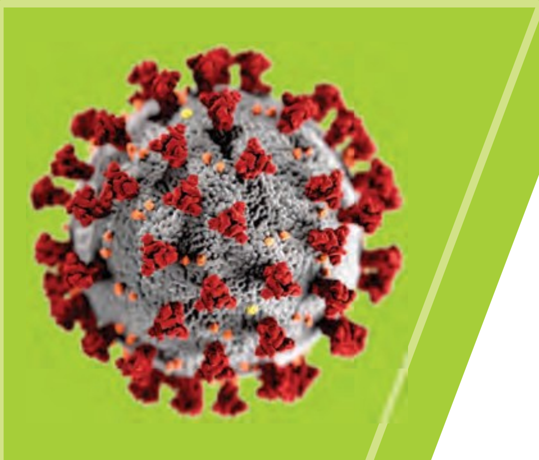
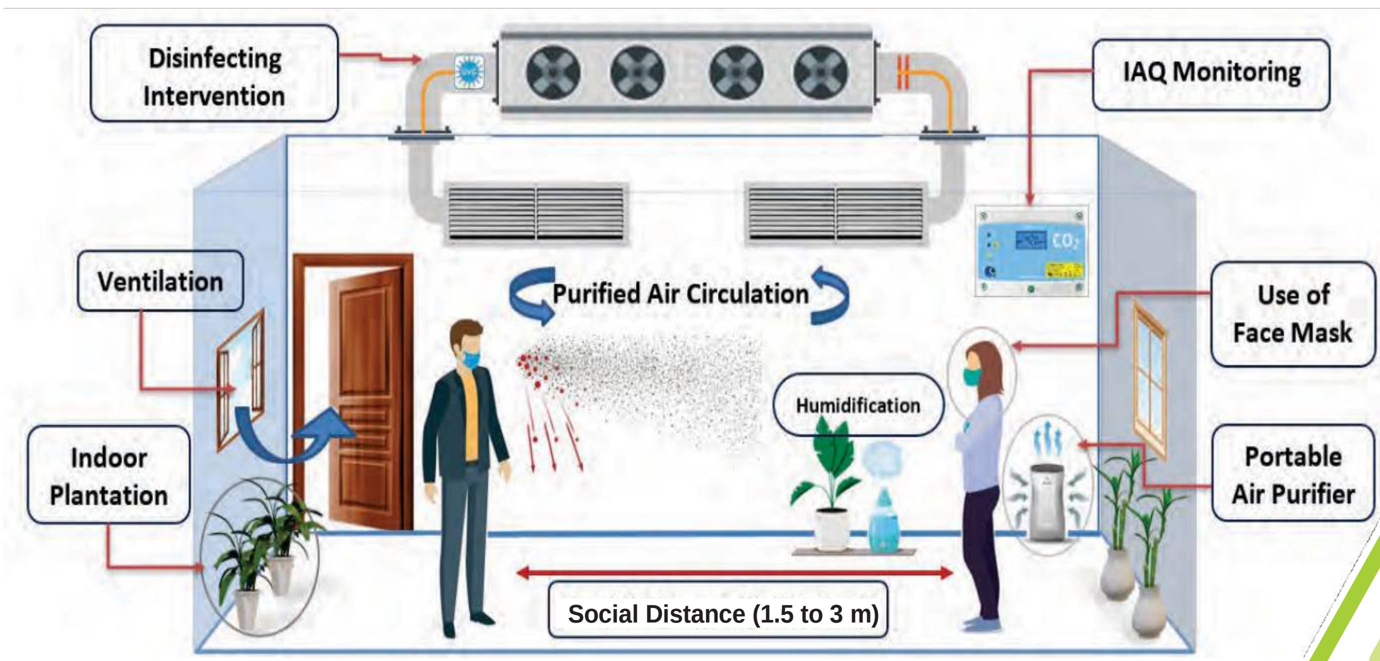


CSIR Guidelines on Ventilation of Residential and Office Buildings for SARS-Cov-2 Virus

Version 1.0 (2021)



Council of Scientific & Industrial Research (CSIR)

CSIR Guidelines

on

Ventilation of

Residential and Office Buildings

for

SARS-Cov-2 Virus

Version 1.0 (2021)

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Executive Summary

The COVID-19 pandemic, caused by the infectious SARS-CoV-2 virus, has brought into focus COVID appropriate behaviour, which includes use of masks, social distancing and air ventilation as non-pharmacological approaches to combat the spread of infection. Early in the pandemic, guidelines adopted were based on the understanding that the virus transmission occurs largely via large droplets and suggested six - feet physical distancing and disinfection of surfaces as suitable mitigative measures. Even as the debate on the mode of transmission of COVID-19 continues, there has been increasing evidence for airborne route of transmission. CSIR laboratories, CCMB and IMTECH, have examined the extent of transmission via aerosols in terms of duration and distance, and in closed door spaces apart from hospitals and demonstrated that viral particles could be detected in air even after 2 hours of exit of infected persons from a room and at distances much greater than 2 meters as well. The aerosol route of transmission is now considered to be important by WHO, REHVA, ASHRAE andby health authorities in several countries.

Droplets of different size (0.05-500 µm) loaded with viruses are generated and expelled, especially by asymptomatic and pre-symptomatic infected people during talking, singing, coughing or sneezing etc. The distance of the particles that travel away from an infected person, depends on several factors including the size of the particles, type of respiratory activity, velocity, turbulent or laminar flow, direction, temperature and humidity of the surrounding airflow etc. While, the larger particles land on surfaces; the smaller aerosol particles stay airborne for relatively longer time (up to several hours). The airborne particles, which may be inhaled by other people and eventually transmit infection, are a major risk in indoor settings.

The most effective manner of reducing the effects on any contaminant is by dilution with fresh air and thus, there is a need of a paradigm shift in ventilation from space focused design to occupant focused design. In general, the ventilation, and indoor environmental systems must focus on source control, advanced air distribution and provide healthy and comfortable micro environment to each occupant when, where and as much as needed. Looking into the minimum recommended ventilation rates of 1O litres per second per person for the SARS-CoV-2 virus like situations, the ventilation rates mentioned in National Building Code (NBC) 2016 have been modified and the recommended Air Changes per Hour (ACH) values are provided in the report for the prevailing pandemic conditions. Maintaining a social distance of 1.5m to 3.0m, adopting different disinfection solutions and purified air circulation system for good ventilation in buildings and houses are some of the major measures for decreasing viral transmission. However, it is important to note that implementing only one or two of these measures may not help in limiting the COVID-19 cases and integrating these techniques/ measures can provide a feasible solution.

Accordingly, these guidelines have been proposed for both naturally ventilated residential and office buildings, and mechanically ventilated residential and office buildings based on the scientific knowledge and engineering expertise available with CSIR. CSIR labs have also developed a variety of disinfectant solutions to ensure appropriate indoor air quality in residential and office buildings during COVID-19. The solutions developed by CSIR laboratories include a module based on UV-C light of 254 nm wavelength to deactivate the SARS-CoV-2 virus (CSIR-CSIO); indoor air purification scrubber system (CSIR-NEERI), essential oil based disinfectant solutions (CSIR-CIMAP) and unoccupied space disinfection by ozone (CSIR-CFTRI). Importantly, CSIR-IMTECH, is equipped with a Biosafety Level 3 (BSL3) facility for handling active SARS-CoV-2 wherein the effects of various decontamination solutions such as UV, Ozone, essential oils etc. on the virus viability are tested for effective and safe levels of the treatment determined for field implementation. Lastly, CSIR - CBRI, Roorkee has developed a Test Bed facility to integrate various disinfectant technologies into the HVAC ducts of buildings to validate the efficacy of these disinfectant solutions for their applications in buildings. CSIR is also engaged in implementing the UV-C air duct disinfection system in auditoriums and large conference rooms of various CSIR labs, and others, state road transport buses, etc. which will provide a relatively safer environment for indoor activities in the current pandemic.

CSIR Guidelines on Ventilation of Residential and Office Buildings during SARS-CoV-2 (COVID-19)

Background

Ventilation of buildings is important to supply fresh air for (a) the respiratory comfort of occupants, (b) to dilute indoor air for odour control, (c) to remove any products of combustion or other contaminants in air as well as (d) maintaining good indoor environmental quality [1]. To accomplish this, architects and engineers give due consideration to ventilation design as per requirements depending upon the different room sizes inbuildings in different climatic regions of the country conforming to National Building Code (NBC) of India. India is divided into five climatic zones as per NBC [1], i.e. (i) Hot- Dry, (ii) Warm - Humid, (iii) Composite, (iv) Temperate, and (v) Cold. The NBC classifies buildings into three types i.e. (a) naturally ventilated (b) mixed mode, and (c) mechanically ventilated [1].

In naturally ventilated buildings, the prime objective is to design free movement of air by orienting openings to face the direction of prevailing winds, wherein doors and windows are kept open on both windward and leeward sides to provide sufficient amount of through air flow. In normal habitable rooms devoid of any smoke generating source, the content of carbon dioxide (CO_2 in air rarely exceeds 0.5 percent to 1 percent and is, therefore, incapable of producing any ill effect. The amount of air flow required to keep the CO_2 concentration down to 1 percent is very small. The change in oxygen content is also too small under normal conditions to have any ill effects; in fact, the oxygen content may vary quite appreciably without noticeable effect on respiratory comfort if the carbon dioxide concentration is unchanged [2].

When contaminants are to be removed from air, the amount of fresh air required to dilute indoor air depends on the air space available per person and the degree of physical activity. The amount of air decreases as the air space available per person increases, and it may vary from 20 m^3 to 30 m^3 per person per hour. This would be the business as usual (BAU) scenario without considerations for airborne transmission of pathogens.

However, in COVID-19 like situations, 36m^3 per person per hour (10 liters/person/second) is recommended as specified in EN 16798-1[3]. In rooms occupied by only a small number of persons, such an air change will automatically be attained in cool weather by normal leakage around windows and other openings, and the required number of air changes per hour may easily be secured in warm weather by keeping the openings open.

The NBC [1] recommends general ventilation standards based on the required oxygen, carbon dioxide and other air quality levels and for the control of body odours when no products of combustion or other contaminants are present in the air and the values of air changes. However, looking into the minimum recommended ventilation rates of 1O liters per second per person for the SARS-CoV-2 virus like situations, the ventilation rates mentioned in NBC 2016 have been modified and the recommended ACH values are given in Table 1 for the prevailing pandemic conditions.

Indoor Design

Heating, ventilation and air conditioning (HVAC) systems are employed to achieve thermal comfort inside buildings to occupants. The indoor air management design elements also have a direct relationship with the building design. The importance of both the psychological and physiological factors in determining acceptable thermal comfort conditions should be kept in mind.

Table 1: Recommended values for ventilation rate (air changes per hour)

S. No.	Application	Air Changes per Hour (ACH) as per NBC 2016	Recommended ACH in SARS-CoV-2 Virus Scenarios
Residential Buildings			
1.	Living rooms	3-6	4-7
2.	Bedrooms	2-4	3-5
3.	Changing rooms, Bathrooms	6 - 10	8 - 12
4.	Corridors	5 -10	6 - 12
5.	Entrance halls	3-5	4-6
6.	Garages	6-8	8 - 10
7.	Kitchen, Gymnasium	6, Min	10, Min.
8.	Basement / Cellar	3-10	4-12
9.	Laundries	10 - 30	12 - 36
10.	Lavatories	6 - 15	8 - 18
11.	Toilets	6 - 10	8 - 12
12.	Isolation (Quarantine) Room	-	10 , Min.
Non-Residential Buildings			
1.	Assembly rooms, Banks	4-8	8 -10
2.	Bakeries, Dye works	20 - 30	24 - 36
3.	Billiard rooms , Hospital wards	6-8	10 - 12
4.	Cates and coffee bars, Compressor rooms, Recording studios	10 - 12	12 -15
5.	Canteens, Restaurants, Dairies, Conference rooms	8 - 12	10 -15
6.	Churches	1 - 3	10 -15
7.	Cinemas and theatres, Hair dressing saloon, Photo and X-ray dark room	10 - 15	12 -18
8.	Club rooms, Dance halls, Public house bars	12, Min	15, Min.
9.	Hospitals sterilising	15 - 25	18 - 30
10.	Hospital domestic	15 - 20	18 - 24

11.	Laboratories	6 - 15	8 - 18
12.	Lecture theatres	5 - 8	12, Min.
13.	Libraries	3-5	12, Min.
14.	Lift cars	20, Min	24, Min.
15.	Offices	6 - 10	12, Min.
16.	Paint shops (not cellulose)	10 - 20	12 -30
17.	Recording control rooms	15 - 25	18- 30
18.	School rooms	5-7	12, Min.
19.	Shops and supermarkets	8 -15	10 - 18
20.	Shower baths	15 - 20	18 - 24
21.	Stores and warehouses	3-6	4 - 8
22.	Squash courts	4, Min	6, Min.
23.	Underground vehicle parking	6, Min	8, Min.
24.	Utility rooms	15 - 30	18 - 36

Note:

It is recommended that in heavy smoking zones and/or if the room is below the ground, the ventilation rates as specified by NBC are to be increased by 50 percent.

The following four environmental parameters are considered by architects and engineers while designing the HVAC system because these are directly controllable by an HVAC system:(a) Air temperature (°C), (b) Radiant temperature (°C), (c) Air speed (m/s), and (d) Relative humidity (percent). In addition to these four environmental parameters, there are two behavioural parameters that also affect thermal comfort but are not controllable by the HVAC system and they are: (a) Activity rate (W/m2), and (b) Clothing insulation (m^2• K/W).

SARS-CoV-2 Virus(COVID-19)

Even as the debate on the extent of contribution of airborne mode to the transmission of COVID-19 continues, this route of transmission is now considered to be important by WHO, REHVA, ASHRAE and by health authorities in several countries. During breathing, talking, singing, etc. forces are generated due to rapid shearing flows, vocal cord movement, opening and closing of terminal airways. As a result, droplets of different size (0.05-500 µm) loaded with viruses are generated and expelled, especially by asymptomatic and pre-symptomatic infected people. So the air movement surrounding an infected person transports the particles. The distance of the particles travel away from the infected person depends on several factors, including size of the particles, type of respiratory activity, position of the head and the body of the person generating the particles, velocity, turbulent or laminar flow, direction, temperature and humidity of the surrounding airflow, individual differences between people with regard to respiratory activities, etc. [3-14].

At some distance, the larger particles land on surfaces (floor, furniture, body of another nearby person, etc.). The small particles stay airborne for relatively long time (up to several hours). The airborne particles may be inhaled by other people and eventually transmit infection. Results of different studies reveal that under typical indoor settings, the short range exposure occurs up to 1.5 m distance between infected and exposed persons. Above 1.5- 3.0 m distance, long-range exposure is predominant. The risk for the short-range exposure is much higher that for the long-rangeexposure [3-14].

The most effective manner of reducing the effects on any contaminant is by dilution with fresh air. Thus, ventilation is recognized as an efficient method for reducing the airborne transmission of pathogens; therefore, there is a need of a paradigm shift in ventilation from space focused design to occupant focused design. In general, the ventilation, and indoor environmental systems must focus on source control, advanced air distribution and provide healthy and comfortable microenvironment to each occupant when, where and as much as needed.

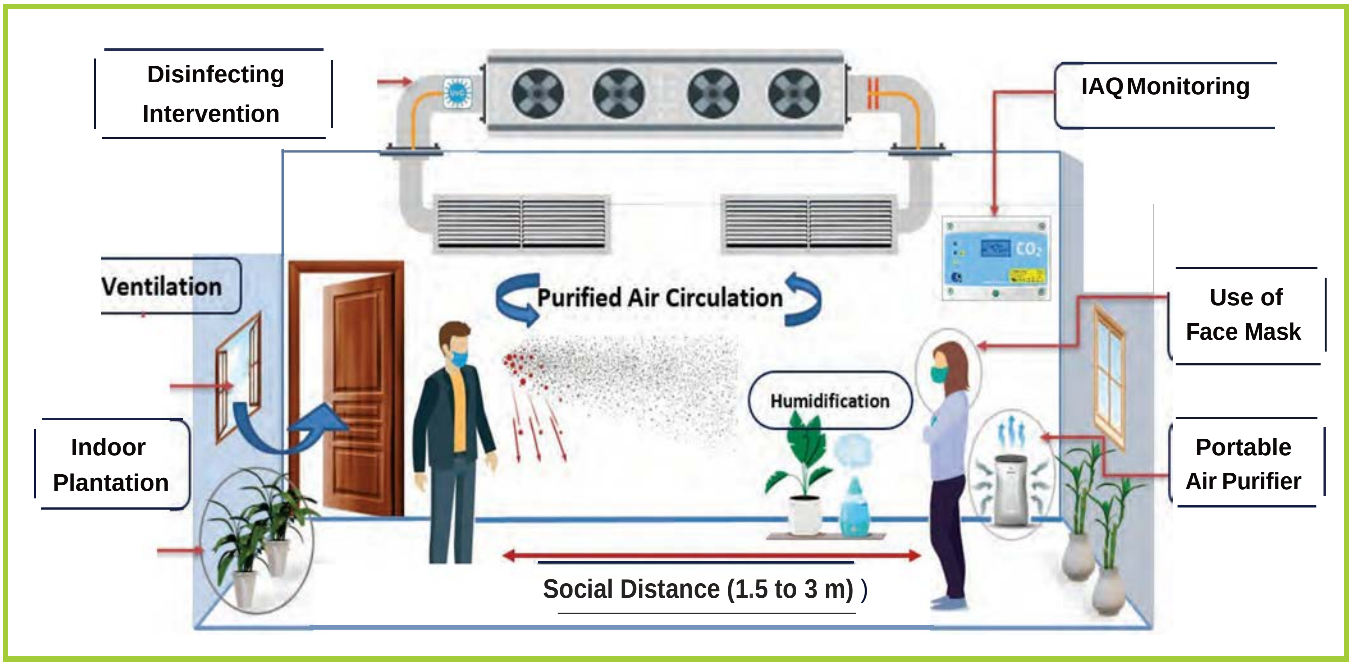


Figure 1: Schematic of maintaining a social distance, adopting disinfection solutions for good ventilation

Figure 1 shows a schematic of maintaining a social distance of 1.5m to 3.0m, and adopting different disinfection solutions and purified air circulation system for good ventilation inbuildings and houses [15].

Implementing only one or two of these measures may not help in limiting the COVID-19 cases. However, approaching these techniques or integrating these techniques / measures can account for a feasible solution.

Typesof Ventilation Systems

General ventilation involves providing a building with relatively large quantities of outside air in order to improve general environment of the building. This is achieved in one of the following ways:(a) Natural supply and natural exhaust of air; (b) Natural supply and mechanical exhaust of air; (c) Mechanical supply and natural exhaust of air; and (d) Mechanical supply and mechanical exhaust of air. Figure 2 shows a broad classificationof ventilation systems defined in various documents and standards [3-13].

Therefore, for each of these systems, different ventilation strategies and guidelines are required.

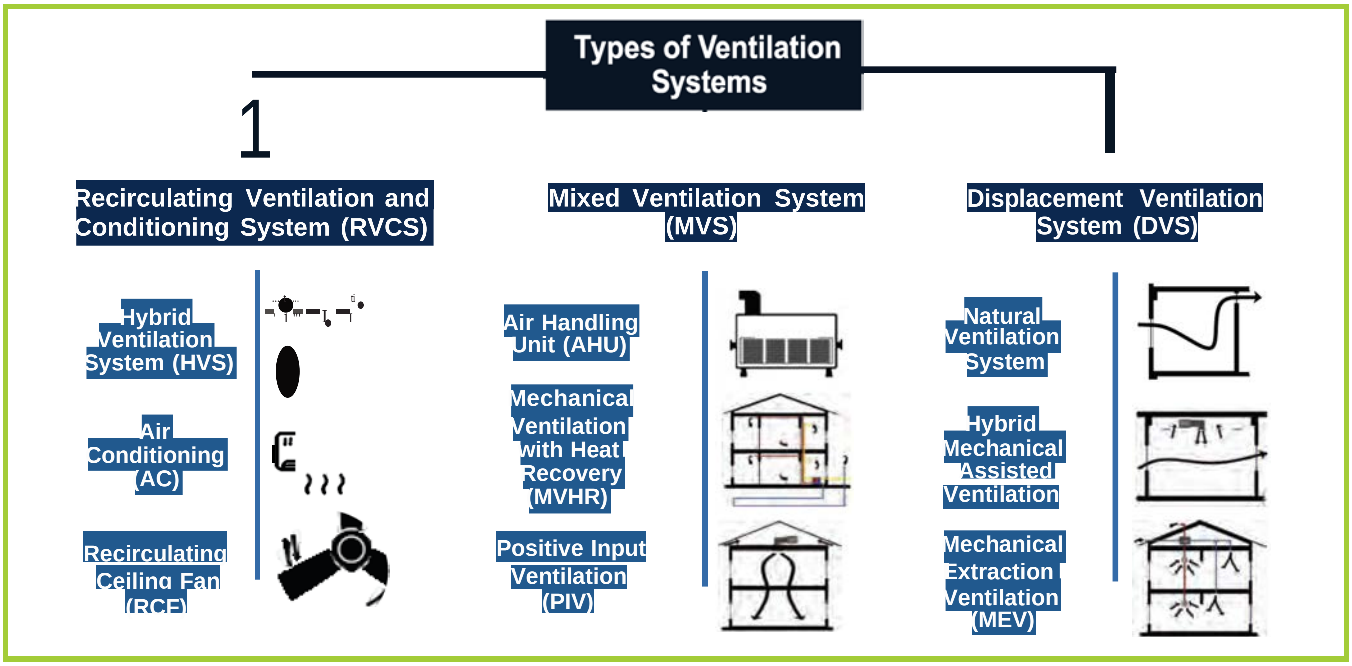


Figure 2: Types of ventilation systems

The scope of this document is limited to Mixed Ventilation System (MVS) having HVAC system with air handling units (AHUs) installed in office buildings and natural ventilation in residential and office buildings (Version 1.0).

Volume of Air Required, Evaluating Ventilation and Indices of Thermal Comfort

A comprehensive study has been carried out by CSIR to better understand the gap between the ventilation systems' functionality and the proposed requirements for SARS-CoV-2 Virus scenarios. So based on this, the general guidelines and strategies for natural ventilation as well as mechanical ventilation both in residential as well as office buildings have been formulated. Since mechanical and natural ventilation systems require different methods to evaluate the ventilation airflow rate, the following questions have been addressed before making recommendations and strategies [1 - 2, 5].

(a) To assess the minimum ventilation rate in mechanical ventilation system

As each mechanical ventilation system is designed for specific airflow rates; the technical manual or the specifications of the systems are to be verified to know the capacity of the system deployed.

(b) To estimate the minimum ventilation rate in natural ventilation system.

The rate of ventilation based on wind action can be computed using the equation (1) as defined in the NBC [1]:

$Q_w = k \times A \times V$ ……………………………………………..(1)

where,

Q_w = Rate of flow (m^3/hour)

k = Coefficient of effectiveness

(i) k = 0.1 in the case of single-sided ventilation (Figure 3 a)

(ii) k = 0.6 in the case of cross ventilation with wind perpendicular to opening (Figure 3 b)

(iii) k = 0.3 in the case of cross ventilation with wind 45^0 to opening (Figure 3 c)

A = Smallest opening area (m^2)

V = Wind speed (m/h)

Example (Delhi):

With an average outdoor wind speed of about 1.389 m/s (5 kilometre / hour) and wind incident normally on the window wall with size of opening 1.0m x 1.0m, the quantity of air flow can be calculated using the equation 1 and is as follows:

$Q = (0.6)\times(1)\times(5000) = 3000\ m^3/\text{hour} = 0.83\ m^3/\text{second}$

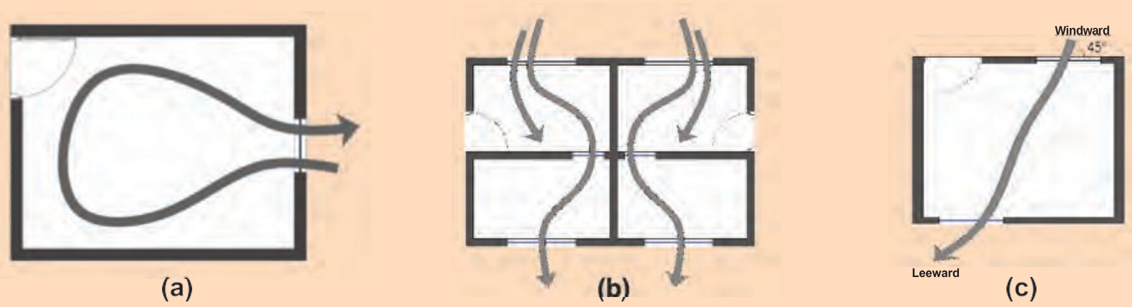


Figure 3: (a) Single-sided ventilation, (b) cross- ventilation with wind perpendicular to opening systems, (c) cross ventilation with wind 45^0 to opening.

However, in the case of provision of mosquito net/mesh = ventilation rate x 0.5 may be considered. The wind speed refers to the value at a building height at a site sufficiently away from the building without any obstructions (e.g. at an airport) as given in IS:875 [16].

(c) To evaluate the airflow direction

The airflow direction is usually assessed through a gas tracer. However, other cost-effective solutions can be used, such as incense sticks or other smoke generators – a smoke test can be used to highlight the direction of the airflow.

Tropical Summer Index (TSI)

The TSI has been developed at the CSIR- Central Building Research Institute, Roorkee [17] and is defined as the temperature of the calm air at 50% relative humidity which imparts the same thermal sensation as the given environment. Mathematically, TSI (^{0}C) is expressed as:

$$TSI = 0.308\,tw + 0.745t_9 - 2.06\,\overline{\quad + 0.841}\ldots \ldots \ldots (2)$$

where,

tw = Wet bulb temperature in °C

t_9 = Globe temperature in °C, and

V = Air speed in m/s.

Guidelines for Naturally Ventilated Office Buildings

Minimum Requirements (Prerequisite):

- Adopt the basic recommended air change schedule as per NBC 2016.
- For the SARS-COV-2, the recommended air changes shall be considered as per Table 1.
- Adopt a minimum ventilation rate of 36 m^3/person/hourof fresh air (10 liters/person/second).

General Guidelines & Strategies:

- Ensure natural ventilation rate by opening the windows as shown in Figure 3- 5.
- For single wall window room/space, use pedestal/table fan placed close to an open window or provide ventilation above the single wall window or open the door as shown in Figure 6.
- In wet area, provide proper ventilation and keep the exhaustfan on.
- In case of room with no windows, it is recommended to use air disinfection system with MERV14/F8 filter close to the occupancy area for reducing the infection.
- Ensure proper airflow pattern so that every part of room/space gets ventilated.
- Maintain direction of airflow from clean space to contaminated space.
- Provide centralized extract system/ exhaust fan for discharging contaminated air & controlling the humidity.
- The ventilators in the building must be kept open.

Air Dilution

- Areas, where the minimum air circulation is not possible, use ceiling fan/ pedestal fan/ fan coil to mix the stale air within the room.

Occupancy Ventilation

- Offices working in shifts (24x7), all the surfaces should be disinfected using any disinfectant solution after every shift. Windows shall be kept open for 15 minutes before and after each shift.
- In case of room with no windows, a standalone air disinfection system to disinfect air should be operated.

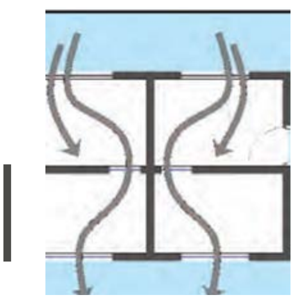


Figure 4: Cross Ventilation

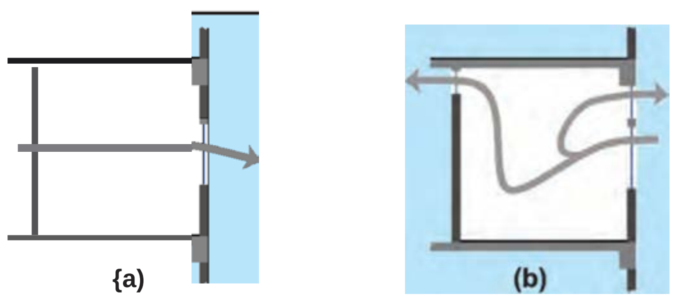


Figure 5: Good Cross Ventilation

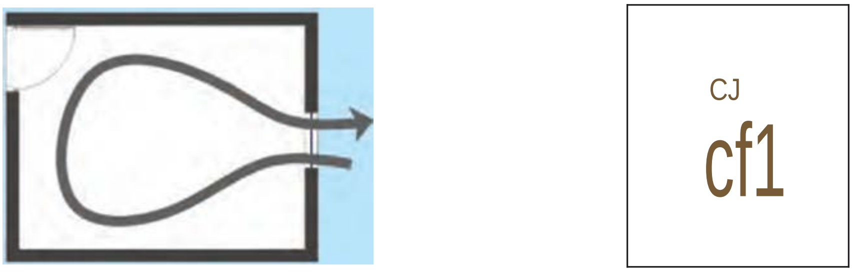


Figure 6: Details for Single-sided Ventilation

Guidelines for Mechanically Ventilated Office Buildings

Minimum Requirements (Prerequisite):

- Adopt the basic recommended air change schedule as per NBC 2016.
- For the SARS-COV-2, the recommended air changes shall be considered as per Table 1.
- Adopt a minimum ventilation rate of 36 m^3 /person/hour (10 liters/person/second).

General Guidelines & Strategies:

- Ventilation system must be achieved such that required fresh air ventilation rate must be achieved.
- Find out the exact capacity of the system and if not complied, upgrade the system to meet desired air change per hour as per Table 1.
- If existing system is unable to fulfill the required ventilation rate, then additional requirement may be met by opening windows or by providing the exhaust fans.
- In case, the system still does not meet the above requirements, then occupancy must be reduced to fulfill the required ventilation rate.
- By any means, if above requirement doesn't fulfill, then adopt suitable air disinfected solutions developed by CSIR or equivalent by adopting minimum ventilation rate.

Air Dilution

- Areas, where the minimum air circulation is possible, use ceiling fans/ pedestal fans/ fan coil to mix the stale air within the room.

Occupancy Ventilation

- In normal working conditions, space conditioning system shall be operated at least 2 hours before and after the office hours. However, after the office hours, the speed of fan may be reduced to 50%.

Temperature and Humidity

- Set the temperature between 25°C and 30°C and maintain a relative humidity between 40% and 70%.
- In warm-humid climate, the temperature may be set at 24°C - 27°C for dehumidification. In hot-dry climate, the temperature may be set at 25°C - 28°C. However, use of ceiling or pedestal fans is recommended to increase the air movement.

Air circulation of HVAC

- Find the capability of the system, if it allows to operate up to 100% fresh air and increase maximum outdoor air with suitable filters to avoid any outside dust particles (PM 2.5 / PM 10).
- If there is 100% recirculation of air, the existing filters must be upgraded with MERV14/ F8 or higher capacity filters without creating adverse effect on the air flow rates.

Heat Recovery for HVAC

- In heat recovery system, the return and supply air circulation must be separated out to avoid the carry - over of infected particles.
- In the case of air mixing, sealing should be provided and filters must be upgraded to MERV14/ F8 or higher capacity filters. Alternatively, air purification systems using calibrated Ultra-violet C or ozonation with ozone scrubbers and detectors shall be used to sanitize the air.

Guidelines for Naturally Ventilated Residential Buildings

Minimum Requirements (Prerequisite):

- Adopt the basic recommended air change schedule as per NBC 2016.
- For the SARS-COV-2, the recommended air changes shall be considered as per Table 1.
- Adopt a minimum ventilation rate of 36 m^3 /pe rson/hour (10 liters/person/second).

General Guidelines & Strategies:

- Ensure natural ventilation rate by opening the windows as shown in Figure 7-9.
- For single wall window in a room, use pedestal fan placed close to an open window or provide ventilation above the single wall window and open the door.
- In wet area (washrooms), provide proper ventilation and keep the exhaust fan on.
- In case of room with no windows, it is not recommended for use. In unavoidable cases, air disinfection system with MERV14/F8 filter, placed close to the occupancy area shall be used.
- Provide proper airflow pattern so that every part of space gets ventilated and maintain the direction of airflow from clean space to contaminated space.
- Provide centralized extract system or exhaust fan for discharging contaminated air and controlling the humidity.
- Isolation room (home quarantine) should be separate from the rest of the house/ dwelling. The airflow to the leeward side must be ensured as shown in Figure 10. If the isolation room is within the house, then it is recommended to use suitable air disinfection solutions.
- The ventilators in buildings must be kept open.

Air Dilution

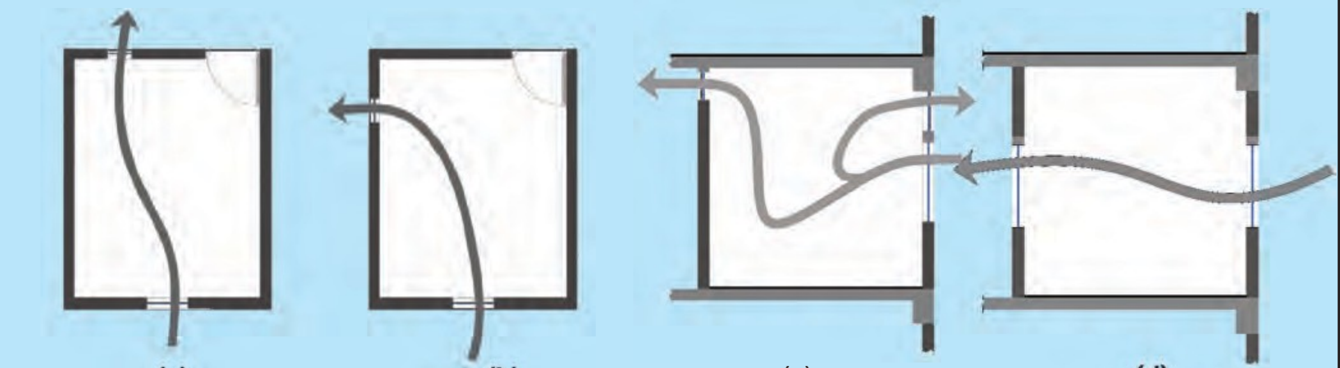
- Areas, where the minimum air circulation is possible, use ceiling fan/ pedestal fan/ fan coil to mix the stale air within the room.

Occupancy Ventilation

- The rooms occupied by guests, should be disinfected and windows must be kept open for 15 minutes.

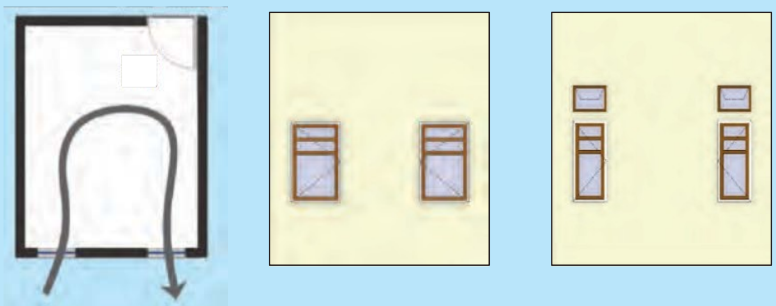
Temperature

The thermal comfort is found to lie between TSI values of 25^{0}C – 30^{0}C with optimum conditions at 27.5^{0}C temperature. However, the warmth of the environment is found to be tolerable between 30^{0}C – 34^{0}C (TSI). On the lower side, the coolness of the environment is found to be between 19^{0}C – 25^{0}C (TSI) and below 19^{0}C (TSI), it is found to be cold.



(a) (b) (c) (d)

Figure 7: Cross Ventilation



(a) (b) (c)

Figure 8: Details for two-sided ventilation in single wall

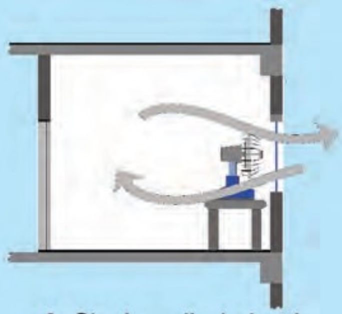


Figure 9: Single wall window in a room, use pedestal fan placed close to an open window and open the door of the room

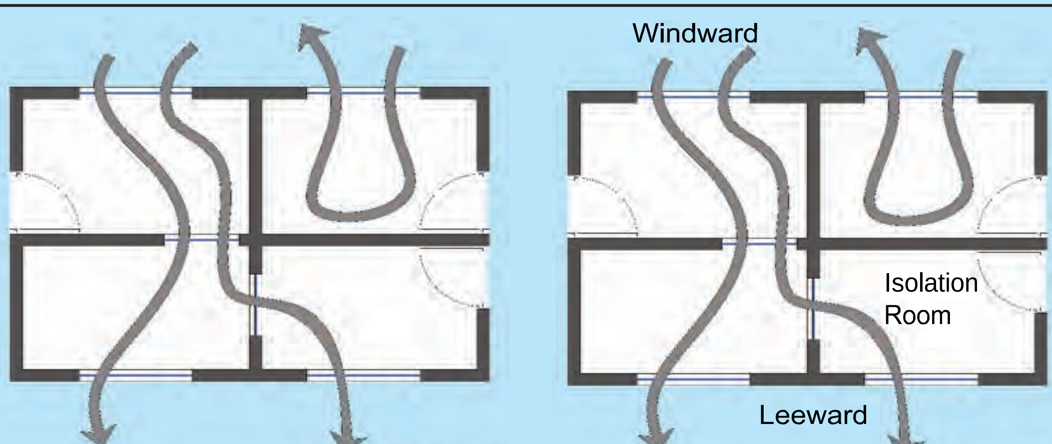


Figure 10: Ventilation for Isolation room

Guidelines for Mechanically Ventilated Residential Buildings

Minimum Requirements (Prerequisite):

- Adopt the basic recommended air change schedule as per NBC 2016.
- For the SARS-COV-2, the recommended air changes shall be considered as per Table 1.
- Adopt a minimum ventilation rate of 36 m^3/person/hour (10 liters/person/second).

General Guidelines & Strategies:

- Find out exact capacity of the system and upgrade the system to meet desired air changes per hour as given in Table 1.
- If existing system is unable to fulfill the required ventilation rate, then additional requirement must be met by opening the windows or by providing the exhaust fans.
- In case the system still does not meet the above requirements, then occupancy must be reduced or keeping a social distance of minimum 2.0 m.
- By any means, if above requirement doesn't fulfill, suitable air disinfected solutions developed by CSIR or equivalent may be adopted to comply minimum ventilation rates.
- Air circulation for the Isolation room should be separate from the rest of the house/dwelling.
- Provide separate portable space conditioners (AC) equipped with MERV14/F8 filter in the isolation room. Disinfect the entire space after isolation period is over and keep windows open for one hour at least.

Air Dilution

- Areas, where the minimum air circulation is possible, use ceiling fan/ pedestal fan/ fan coil to mix the stale air within the room.

Occupancy Ventilation

- In normal sleeping conditions, space conditioning system must be operated at least 1 hour before the use of rooms.

Temperature and Humidity

- Set the temperature at 25°C-27°C and maintain a relative humidity between 40% and 70%.
- In warm humid climate, the temperature may be set at 24°C - 27°C for dehumidification. In hot-dry climate, the temperature may be set at 25°C - 27°C. However, use of ceiling or pedestal fans is recommended to increase the air movement.

Heat Recovery for HVAC

- In heat recovery system, the return and supply air circulation must be separated out to avoid the carryover of infected particles.
- In case of air mixing, sealing should be provided and filters must be upgraded to MERV14/ F8 or higher capacity filter. Alternatively, air purification systems using calibrated Ultra-Violet C or ozonation with ozone scrubbers and detectors should be used to sanitize the air.

CSIR Disinfectant Solutions to ensure good Indoor Air Quality in Residential and Office Buildings during SARS-CoV-2 (COVID-19)

The SARS-CoV-2 Virus, responsible for the COVID-19 pandemic, transmits mainly through airborne aerosol droplets. Effective restoration of operating normalcy requires effective decontamination of air in populated closed spaces. The Council of Scientific and Industrial Research (CSIR), India, has risen to this challenge and is delivering an enhanced understanding of viral load measurement in indoor settings as well as solutions for monitoring and decontaminating such spaces. These could include auditoria, large conference rooms, cinema halls, malls, schools and even railway and metro coaches.

The disinfectant solutions developed by several CSIR laboratories are as follows:

- Central Scientific Instruments Organization (CSIO), Chandigarh has developed a module based on UV-C light of 254 nm wavelength to deactivate the SARS-CoV-2 virus;
- CSIR - National Environmental Engineering Research Institute (NEERI), Nagpur has developed indoor air purification scrubber system;
- CSIR-Central Institute of Medicinal and Aromatic Plants (CIMAP), Lucknow and CSIR-Central Food Technological Research Institute (CFTRI), Mysore have developed essential oil based disinfectant solutions.
- CSIR-Institute of Microbial Technology (IMTech), Chandigarh is equipped with a Biosafety Level 3 (BSL3) facility for handling active SARS-CoV-2. The effect of various decontamination solutions such as UV, Ozone, essential oils etc. on the virus viability are tested for effective and safe levels of the treatment determined for field implementation.
- CSIR-Central Building Research Institute (CBRI), Roorkee has developed a Test Bed facility to integrate various disinfectant technologies into the HVAC ducts of buildings to validate the efficacy of these disinfectant solutions for their applications inbuildings.

UV-C and Non - UV based Disinfectant Solutions of CSIR

(A) UV-C based Disinfectant System:

In HVAC system, bacteria, virus, spores, fungus etc. grow rapidly due to damp and dark environment. These unwanted generations will further spread in the building through air conditioning duct system making people vulnerable to infectious diseases and degrading indoor environment.

The UV-C is a non-chemical system-based method using electromagnetic ultra violet radiation in the wavelength band of 240-280 nm with no lasting by-products. Short wavelength UV-C lights are used to disinfect air, surfaces and water. It is cost-effective and user friendly standard solution for HVAC systems in buildings. UV-C eliminates 99.9% of viruses, bacteria, fungus and other bio - aerosols etc. with few seconds of contact rate / irradiation time using the 254nm UV light. UV energy attacks the DNA/RNA of a bacteria or virus, penetrating the cell membrane, breaking or modifying the DNA structure of the micro-organism. UV-Crays are highly efficient, and environmentally friendly.

(i) Benefits of using UV-C System of CSIR-CSIO, Chandigarh

- **Efficacy against indicative microbes/viruses:** Test results show 99.9% reduction of virus and bacteria infestation. The efficiency of the system is high.

- **Design based on Primary/ Secondary data with indicative microbes:** Primary data from Biosafety Level 3 (BSL 3) lab of CSIR-IMTech shows a minimum retention time of 3 seconds under controlled conditionsof 0.5mW/cm^2. The secondary data is 400mw/cm^2 and CSIR-CSIO developed with range of 205-567mw/cm^2 and also tested at CSIR-CBRI Roorkee.

- **Occupancy:** This system is applicable for both occupied and unoccupied conditions (to disinfectant both air and surfaces of any indoor environment on exposed spaces).

- **In line with guidelines/ standard:** The design is based upon the frequency and intensity of UV lighting for deactivation of virus as per ASHRAE standards.

- **USP of the Product:** The CSIR developed product is tested for 99.9% disinfection and is used as a retrofit solution to AHUs of buildings or fan coil unit (FCU) applications. All the safety norms / requirements are being followed inthe developed product.

- **Equipment size:** The size of the equipment can be designed as per requirements. Estimated equipment size at proof-of-concept stage/maturation for a model 1O'x1O'x10' (30m^3) air space is 1.5ft x 1.5ftx 1.5ft (-457mm x457mm x457mm).

- **Environmental benefits:** UV-C contributes in reducing water and energy consumption.

- **Effect on HEPA filter:** UV-C kills microbes present in air, thus air passing through HEPA filter will have low viable virus /microbes' concentration in air as compared to the other cases. Hence, HEPA 's life is increased.

- **Cost:** The cost of the product is comparatively low as compared to the other products available in the market. The estimated cost at proof-of-concept stage/maturation for a model 1O'x1O'x10' (30m^3) air space is about Rs. 10,000/-.

Therefore, the UV-C is energy efficient system, improves air flow through coils, enhances indoor air quality, requires less maintenance, easy to retrofit with any existing system having AHU ducts, and has low initial setup cost. However, it may be noted that UV-C exposure is harmful, particularly skin and eyes, capable of causing radiation burns and is carcinogenic as well.

(ii) Test Bed Facility on Technology Testing and Evaluation (TTETeF) **at CSIR-CBRI, Roorkee for HVAC Ducting System to Integrate Covid-19 Disinfection Solutions**

Various CSIR labs have developed several technologies to deactivate the SARS-CoV-2 virus. Therefore, to validate the efficacy of all these disinfectant solutions for use in buildings, CSIR- Central Building Research Institute (CBRI), Roorkee has created a Test Bed Facility on Technology Testing and Evaluation (TTETeF) in an effort to provide reliable information regarding the performance of COVID-19 disinfectant solutions integrating various disinfectant technologies including UV-C duct decontamination into the HVAC ducts of buildings. The TTETeF provides independent, quality assured performance information on different functional parameters such as air velocity, air flow rate, cooling and heating side temperature control, humidity control, mixing ratio, duct design, and computer modelling for protecting buildings, and infrastructure etc.

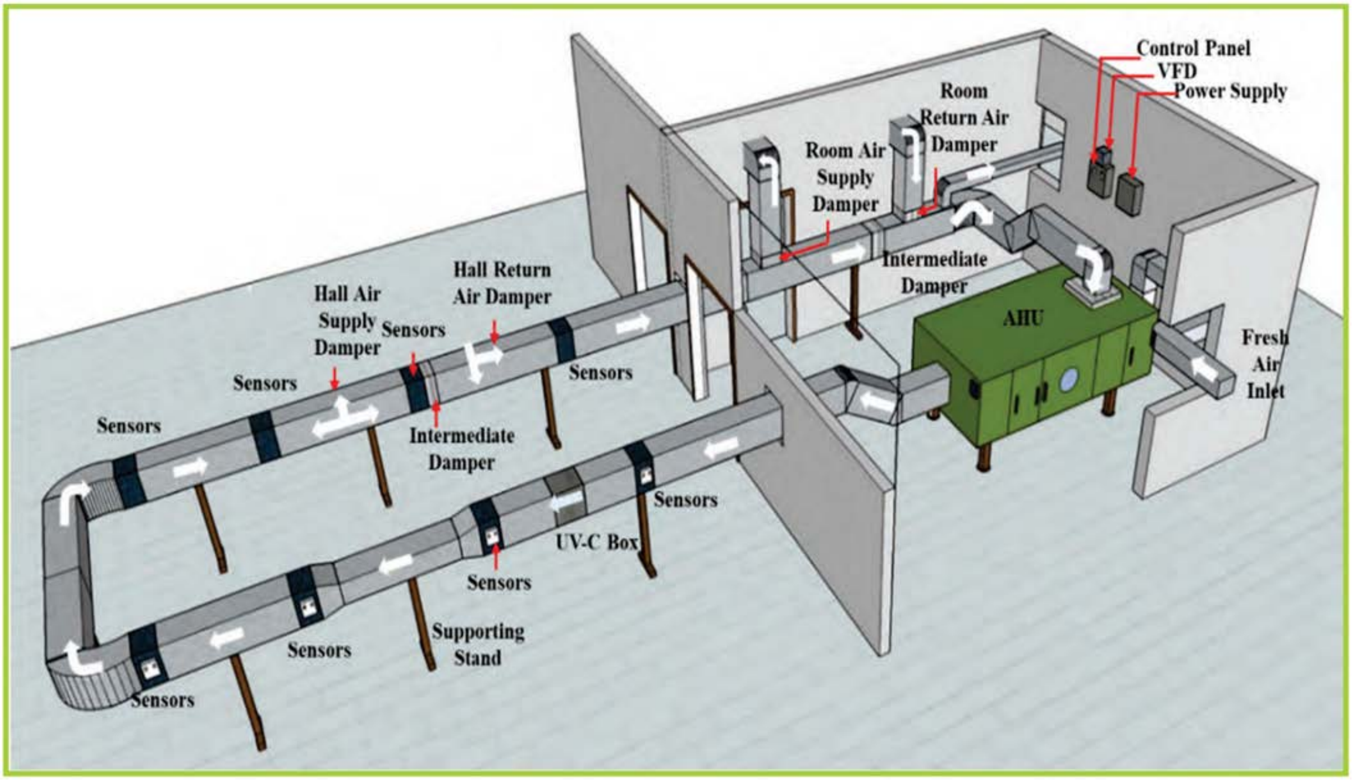


Figure 11: Schematic of the Test Bed Facility on Technology Testing and Evaluation (TIErsF) at CSIR-CBRI, Roorkee

The UV-C device is customizable and can be designed and fitted into any existing air ducts of AHU. The airborne microbes including bacteria & virus can be rendered inactive by applying controlled UV-C light. The mechanism allows users to install the light source in place easily and remove as and when required for maintenance purposes.

Figure 12: Photos of the Test Bed Facility on Technology Testing and Evaluation (TIErsF) at CSIR-CBRI, Roorkee

Table 2: Functional Parameters of the Test Bed

Control Parameters	Range
Air velocity	0 - 10 *mis*
Air flow rate	**0-2200 CFM**
Cooling side temperature control	Ambient temperature to 16°C
Heating side temperature control	Ambient temperature to 50°C
Humidity control	Ambient humidity to 95%
Mixing ratio	**0-95%**
Duct design	Modular structure

The integrated solution has been deployed in CSIR's own Auditorium at its headquarters, located at New Delhi and is being deployed in auditoria and large meeting spaces in all CSIR laboratories located in different regions of the country.

(8) Non UV-C based Disinfectant System:

There are numerous non UV based disinfectant solutions available in the market and should be used appropriately.

(i) Indoor Air Purification ScrubberforCOVID-19Impacted Areas

Two standalone units tested are available; (a) Low volume: 1.25 to 3.0 m^3/hr, and (b) Medium Volume: 20-30 m^3/hr. These consist of two columns (scrubber followed by demister) and a built-in suction device to capture known amount of indoor air for purification. Trials were carried out for its testing for dust and microbial (bactericidal) decontamination in Indoor Air Chamber of CSIR - NEERI in wet and dry mode with various scrubbing media from different CSIR Labs. Trials showed good results (60-70% avg. efficiency).

(ii) Ozone-based Air Disinfection System

An ozone-based air disinfection system has been designed, developed by CSIR- NEERI, and standardized for only closed un-occupied closed chambers and validated for various process design parameters such as ozone concentration, exposure time, temperature, relative humidity, mixing requirement and functional relationships were established. The system is validated for efficacy and safety with 5 indicative pathogens in BSL-11 Facility and residual ozone was ensured using 3S (sensors, scrubbing, sensory) method and is in-line with FDA, EPA, OSHA and CPCB guidelines. The system is water and chemical-residue-free.

(iii) Essential Oil based Disinfectant CIM-RESPCOOL

The CSIR-Central Institute of Medicinal and Aromatic Plants (CSIR-CIMAP) has developed a formulation for use in diffusers in hospital wards or even houses to sanitize air. The formulation incorporates oils from traditionally used herbs and spices. The selection of the ratio of the essential oils is based on the toxicity data of International Fragrance Association (IFRA). The formulation has been found to inhibit SARS-Cov-2 virus in culture conditions and reduces the load of other microbes when used in enclosed rooms. It has also been found to be helpful in bronchospasms and also free of any mucous membrane or skin irritation as observed in Swiss albino mice. Observational studies upon inhalation exposure in mice did not result in any abnormal behaviour even up to 72 hours and also did not alter the Hemodynamics (ECG, BP or MAP) in experimental rodent models. The formulation also has a neutralizing effect on the cytokine storm that generally follows during the pathogenesis of respiratory infections like COVID-19.

(iv) Essential Oil based Disinfectant and Fumigation System

The Essential Oil based disinfection solutions and fumigation system has been developed by CSIR-CFTRI. All the ingredients used are food grade with GRAS status. These disinfectant solutions have been tested and validated for antimicrobial efficacy, both for air and surface disinfection and bench marked with standard Hypochlorite solutions. It is also validated with indicative pathogens with $>$ 4 log reduction.

These are low-cost formulations (Rs. 40/L)/ Aerosol (Rs. 2/L). The sensory attributes are pleasant and there is no skin /eye irritation. The validation has been conducted in MoEF / FSSAI / CPCB approved lab. Additional validation with COVID-19 Virus has also been carried out at CCMB having 99% viral reduction/disinfection.

Feedback:

If you are a subject area expert or a professional dealing with the issues addressed in this document, and if you have any suggestions for improvements, feel free to contact us via: director@iip.res.in, director@cbri.res.in, director@csio.res.in, director@imtech.res.in, ashokkumar@cbri.res.in

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The Version 1.0 (2021) of the guidelines is prepared by the CSIR's Task Force on **"Devices like Wayu for indoor control of Corona Virus (Air Purifiers etc.)".**

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References:

1. National Building Code, 2016 (NBC), Bureau of Indian Standards, New Delhi.
2. IS:3362. Code of Practice for Natural Ventilation of Residential Buildings, Bureau of Indian Standards, New Delhi.
3. EN 16798-1& 2:2019: Energy performance of buildings - Ventilation for buildings - Part 1: Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics.
4. REHVA, COVID 19 Guidance, version 4.0. How to Operate HVAC and other Building Service Systems to prevent the spread of the SARS-CoV-2 Disease in Workplaces, November, 2017.
5. WHO - Roadmap to Improve and Ensure Good Indoor Ventilation in the Context of COVID-19, January, 2021.
6. ISHRAE, COVID -19 Guidance Document for Air Conditioning and Ventilation. Indian Society of Heating, Refrigerating & Air Conditioning Engineers (ISHRAE), 2020.
7. ASHRAE Standard 62.2-2019: Ventilation and Acceptable Indoor Air Quality in Residential Buildings. Atlanta.
8. ASHRAE Standard 185.1-2020: Method of Testing UV-C Lights for Use in Air-Handling Units or Air Ducts to Inactivate Airborne Microorganisms.
9. ASHRAE Standard 185.2-2020: Method of Testing Ultraviolet Lamps for Use in HVAC & R Units or Air Ducts to Inactivate Microorganismson Irradiated Surfaces.
10. ASHRAE standard 52.2-2012. Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size.
11. European standard (EN 779-2012IEN 1882:2009). Efficiency of Filters for the Ventilation of Buildings.
12. Mingyue et al. (2021). Review and Comparison of HVAC Operation Guidelines in Different Countries during COVID-19 Pandemic, Building & Environment, 2021.
13. Tom Lipinski et al.(2020). Review of Ventilation Strategies to reduce the Risk of Disease Transmission in High Occupancy Buildings, International Journal of Thermofluids, 7-8 (2020) 100045.
14. Arsen K. Melikov(2020). COVID-19: Reduction of airborne transmission needs paradigm shift in ventilation. Building and Environment, Volume 186, Dec. 2020, 107336.
15. Nehul Agarwal, Chandan Swaroop Meena, Binju P Raj, Lohit Saini, Ashok Kumar, N. Gopalakrishnan, Anuj Kumar, Nagesh Babu Balam, Tabish Alam, Nishant Raj Kapoor, Vivel Aggarwal (2021). Indoor air quality improvement in COVID-19 pandemic: Review, Sustainable Cities and Society, 70(2021) 102942.
16. IS:875 (Part 3): Wind Loads on Buildings and Structures. Bureau of Indian Standards, New Delhi.
17. Handbook on Functional Requirements of Buildings, SP:41. Bureau of Indian Standards, New Delhi.