Negative air pressure system for the control and management of air-borne infection for Isolation ward

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Summary:

Background: During the pandemic situation like COVID-19 hospital environment requires specific attention to ensure healthier indoor air quality to protect healthcare workers and patients against hospital-acquired (nosocomial) infections and cross-contamination. The aim here is to recommend negative air pressure system for the control and management of hospital indoor air quality.

Method: The authors have done an extensive literature review and conducted comprehensive air quality test in different hospital using Soyabean Casein Digest agar strip test in NABL accredited lab. The Indoor Air Quality analysis was studied carefully and the results of the test are provided in this paper.

Result: Air sampling strip was observed for the presence of aerobic pathogens and microbiological contaminants which are of concern for healthcare system. Installation of negative and positive air pressure system inside the room, Air flow pattern, Monitoring methods, Safety system installed and Quality of air achieved have been well documented and reviewed in this paper. Their applications in critical environments such as isolation rooms, operating theatres and other typical units such as outpatient departments and laboratories are also considered

Conclusion: Effective mitigation measures suitable for the hospital environment have been identified. Accordingly, strategies for the implementation of a hospitals and/or isolation wards air management for reduction of biological burden are recommended. Hospital engineers, Healthcare workers and administrative staff can use this technique to manage reducing air borne infection and run their hospitals with healthier indoor air quality.

Introduction:

The severe problem of spread of coronavirus all across the world from December 2019 resulted in extreme strains and stresses on the general running of healthcare system. Generally, COVID-19 patients were needed to be accommodated in negative pressure isolation rooms on the ward according to ISHRAE and other guidelines provided by the government. It was needed for Hospital staffs, Doctors and other patients to save them from cross-contamination and Nosocomial Infection. A negative pressure theatre was considered to be more suitable than a positive pressure environment. In principle, a positive pressure operating theatre with adequate air changes could quickly eliminate the virus from the environment, and it has been shown that the risk of cross-contamination from airborne infection is low if staff are adequately protected with appropriate personal protective equipment (PPE). However, a negative pressure operating theatre offers optimal protection to personnel working in adjacent areas [1]. Hence in this paper, we have discussed the use of both positive pressure system and negative pressure system at a same time to establish an area safe and secure enough to treat patients. Over a short period, number of isolation Centre were created and it was necessary to have an negative pressure unit inside those isolation Centre. This was achieved by incorporating two strong exhaust fans next to the original exhaust system. But that caused the infected air to spread in the environment which further increased the risk of spreading virus. Hence, it was necessary to treat the air before letting it out. Many methods were incorporated to achieve the same. In the method presented in this paper, the author has studied the use of burning unit which has the temperature of about 70-85 degree Celsius, which helps in destroying the virus, bacteria and other harmful micro-organisms. This system proves to provide safety even after the pandemic crises finishes for those patients contracting similar infectious airborne diseases such as tuberculosis and severe influenza. There are various healthcare facilities and departments, such as inpatient wards,

operating theatres, intensive care units (ICUs), outpatient departments (OPDs), pharmacies, radiology departments, laboratories, etc which requires negative pressure system to be installed as each facility requires complete safety and has maximum chances where infection can be transmitted. More seriously, improper control of hospital IAQ may cause hospital-acquired (nosocomial) infections and occupational diseases. The aim of this paper is to recommend use of both positive and negative pressure system in such a manner that it reduces the chances of infection. The positive pressure system is required to complete the need of fresh air inside the OT whereas negative system helps to maintain the cycle of one-way flow pattern of air and secured environment to treat patients

Method:

Routine monitoring of airflow performance inside the experimental area was monitored through observations and/or measurements of pressure gradient, flow pattern, temperature and humidity levels. To ensure sterility in the operating theatre, routine bacterial sampling using sterile disposable plastic air samples strips filled with tryptone soy agar (TSA) and Sabouraud agar for total microbial count was performed. The plates were placed in three positions (i.e. high, low and at the air exhaust). The high position was located by the anesthesia apparatus near the operating table, 2-2.5 m above floor level; the low position was located near the operating table, 0-1m above floor level; and the air exhaust position was in front of either of the exhaust grilles. The plates were incubated at 37 C for two days and 30 C for five days for fungal and bacterial counts. A colony count of less than 30 colony-forming units (CFU)/m3 for the TSA agar and 3 CFU/m3 for the Sabouraud agar is acceptable standard in all operating theatres. This samples were than tested in NABL accredited laboratory.

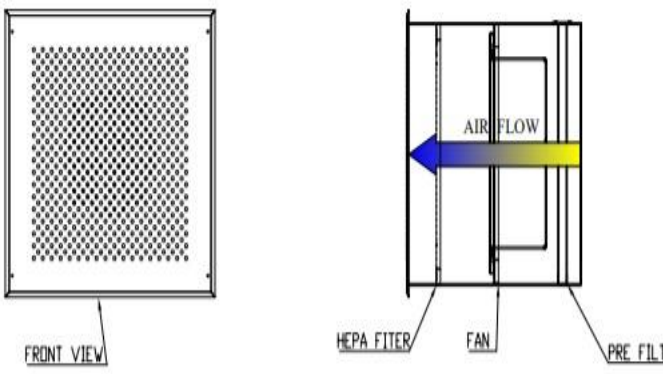

Fig.1 Negative Pressure System

Negative pressure system: The negative pressure room works on the principle of creating pressure lower than that of surroundings to allow air to flow into experimented room but not to escape from the room, as air will naturally flow from areas with higher pressure to areas with lower pressure, thereby preventing contaminated air from escaping the room. To create this negative pressure inside the room a backward curved fan (BCF) of 400 Diameter is used which has the velocity of 1500 cubic feet per minute (CFM), HEPA filter which is used in the experimented system is a mini-plate HEPA filter which has nano-particle coating (silver nitrate and keratin). Silver nitrate has bactericidal and virucidal property and keratin helps to clear VOC (volatile organic chemical) that is used to remove unwanted smell from the experimented room and absorbs gases. Finally, an ultrasonic ceramic heater is used which has the capacity to heat from 900 to 1000 degree Celsius and is controlled using air rating controller to maintain the temperature between 80 to 85 degree, In this temperature it is observed that the virus is destroyed. Thus, it fulfills requirement of disinfecting air and creating a safe indoor air quality for healthcare facility.

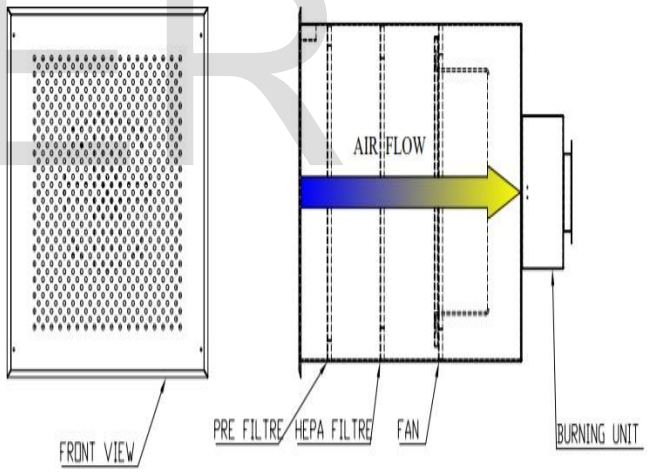

Fig. 2 Positive Pressure System

Positive Pressure System: The positive pressure room works on the principle of maintaining a higher pressure inside the treated area (experimented room) than that of the surrounding environment. This means air can leave the experimented room without circulating back in. In this way, any airborne particle that originated in the room will be filtered out. In healthcare facilities, a positive pressure room acts as a protective environment which allows staffs to keep vulnerable

patients safe from infectious disease. In the experimented system the positive pressure system helps to absorb fresh air from the environment thus, it acts as an essential unit to generate air cycles in the experimented room. this system provides good air quality inside the experimented room and creates class II (particle count less than 100) quality of air which is measured through particle count device. It has two types of filter pre filter and HEPA filter of 0.1 micron which helps to block all kinds of bacteria and a negative ion generator used to deactivate pathogens. A mini-plate HEPA filter of 0.1 micron which has a nano-particle coating of Ethanol, Hydrogen peroxide, Silver nitrate, Sodium Hypochlorite, and Keratin is used. Silver nitrate has bactericidal and virucidal property and keratin helps to clear VOC (volatile organic chemical) that is used to remove the unwanted smell from the experimented room and absorbs gases. This type of HEPA filter has an ability to trap the virus and deactivate it with the use of chemical coating on it.

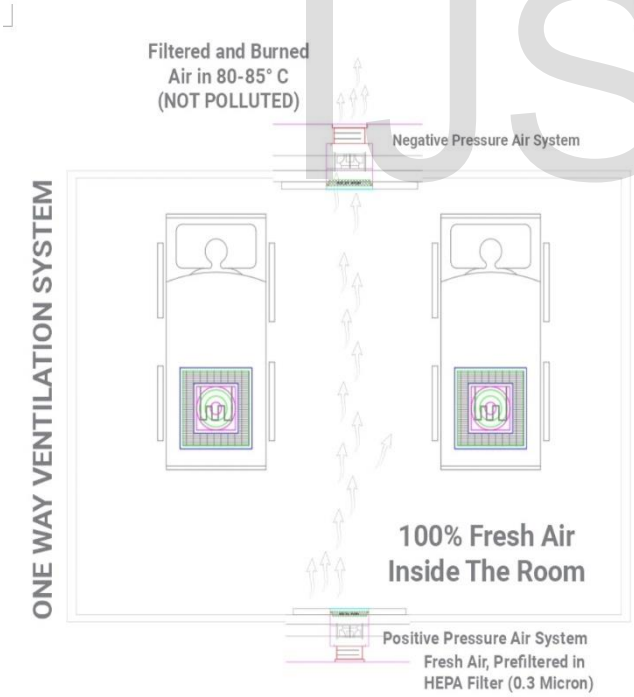

Fig. 3 layout of combination of positive and negative pressure system room

Combination of Negative and Positive pressure system room: As shown in figure 3, the negative and positive pressure system works together to create one-way ventilation system which according to ASHRAE guidelines is necessary in rooms in which COVID-19 patients are treated. The positive pressure air system takes the fresh air from the environment into the experimented room, the fresh air is prefiltered in the system using HEPA filter which has a filter size of 0.1 Micron, after filtration from the HEPA filter 100% fresh air is released in the experimented room. This way the patients in the room will get fresh air and since this is a one-way ventilation system the patients in the room are always assured to have a good Indoor air quality. This air is then passed through the negative pressure system which destroys the VOC, filters and burns the virus with the help of ultrasonic ceramic heater this reduces biological burden that means the air before leaving the experimented room is stripped off from all the virus, bacteria, etc

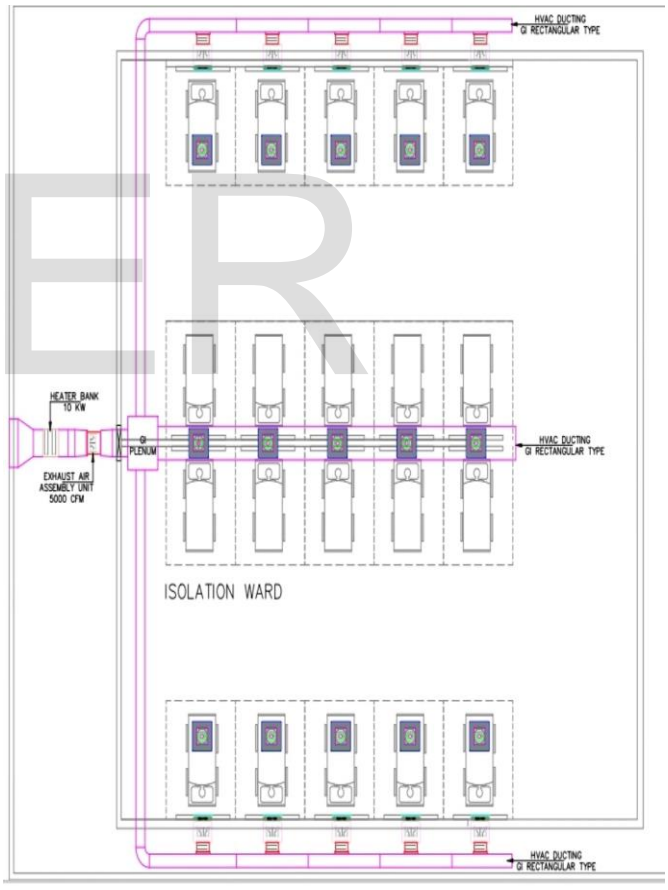

Fig.4 Telescopic Ducting system of Isolation room

Telescopic Ducting system: As given in figure 4, telescopic ducting system has a system outside the experimented (isolation room) This type of system is used when a larger area has to be covered. Ducts has its opening above each bed which is then collectively connected to exhaust air assembly unit

with 5000 CFM. The heater bank which is connected to the exhaust air assembly unit is placed outside the experimented area. This heater bank has the capacity of producing heat from 900-1000 degree Celsius. The calculation of the exhaust system and heater bank is done according to the number of duct openings provided in this experimented system.

Results:

After some months of construction, refitting, repeated performance checking and testing, most system requirements were met successfully with the exception of the checking and maintaining heat of the ultrasonic ceramic heater. This was achieved using air rating controller. Another major problem was selection of material of casing around the ceramic heater, As the area was getting heated thus rockwool type of material was used for the casing which acts as a shield against heat absorption and it also helped for sound reduction. Colony counts of less than 30 CFU/m3 for the TSA agar and less than 3 CFU/m3 for the Sabouraud agar were achieved consistently in the routine checks

Discussion:

This experiment shows the possible way in which one-way air flow system can be achieved. In this experiment it is observed that it is possible to achieved a better indoor air quality inside the healthcare facility by using the combination of Negative and positive air system in a proper way thus, decreasing the chances of Nosocomial Infection and Cross-contamination. In the situation of air-borne disease like Coronavirus it is must to take proper care and protection to avoid chances of infection and further spread of Disease. Even after the crises is over, this experiment used help the user to maintain better indoor air quality inside healthcare system.

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