Conference Agenda

15th ROOMVENT Conference

Session

VH: Ventilation in health premises

Session Chair: **Marco Masoero**

Presentations

Performance of two supply air distribution modes in reducing the exposure to patient exhaled pathogens in hospital isolation rooms

Petri Juhani Kalliomäki[1], Julian Wei-Tze Tang[2], Matti Waris[3], Hannu Koskela[1]

[1]Turku University of Applied Sciences, Finland; [2]Leicester Royal Infirmary, University Hospitals of Leicester NHS Trust, United Kingdom; [3]University of Turku, Finland;

Use of personal protective equipment (PPE) such as masks, gloves, gowns etc. might not always provide complete protection against airborne infections (masks can be leaky or improperly worn, eyes may be unprotected etc.). Hence, sufficient room ventilation is essential to avoid cross-infection. Effective ventilation should mix and dilute the airborne contaminants emitted by any potential sources (such as patients). E.g. mixing ventilation strategies aim to induce efficient mixing and rapid dilution of airborne contaminants throughout the room. However, this method may not be optimal for protecting health care workers (HCW) from direct exposure to airborne pathogens emitted by a localized (patient) point source.

In this study, HCW exposure to patient exhaled airborne tracers was examined using a full-scale isolation room model with two air distribution modes: overhead mixing ventilation and local downward supply. The effect of different exhaust locations on HCW exposure was tested as well. Both the HCW and the patient were simulated with breathing thermal manikins. The performance of the ventilation modes was assessed using quantitative tracer gas measurements as well as qualitative smoke visualizations, velocity distribution and thermal comfort measurements.

Initial results with tracer gas experiments shows that: i) a local downward air supply performed better than the overhead mixing ventilation in limiting HCW exposure to the tracer; ii) exhaust location did not affect the exposure close to the patient. Thermal comfort was found to be better with mixing ventilation mode. Further experiments will be performed in the future to assess the effectiveness of different ventilation modes in more detail.

CFD simulation of hospital isolation room air flow patterns

Hannu Koskela[1], Petri Kalliomäki[1], Julian Wei-Tze Tang[2]

[1]Turku University of Applied Sciences, Finland; [2]Leicester Royal Infirmary, University Hospitals of Leicester NHS Trust, United Kingdom;

Health care workers (HCW) can be exposed to the infectious airborne pathogens released by the patients when working in the hospital isolation rooms. The highest exposure occurs typically close to the patient (source) where an HCW can be directly exposed to the patient's exhaled air. This is a typical situation when an HCW is giving care to a patient who is lying in a bed. The direct exposure can be reduced by controlling the airflow pattern with air distribution or local ventilation solutions. CFD simulations can be utilized in order to characterize the local airflow patterns and to find the most effective ventilation solutions.

In this study, CFD methods were used to study air flow patterns and HCW exposure to the patient exhaled air in an isolation room setup. Three different air distribution arrangements were studied: overhead mixing, local downward airflow over the patient and zonal downward airflow. Time dependent URANS was used as a computational method. In the simulations, HCW was standing next to a patient lying on a bed. The patient and the HCW were breathing though nostrils with a normal breathing cycle. The simulations were compared against experiments carried out in an identical full-scale isolation room model.

URANS predicted realistic flow patterns when compared to smoke visualizations. Also, the HCW's exposure was relatively well estimated by the URANS method. Local downward ventilation seemed to work most effectively in reduce HCW exposure. However, air velocities were high with local downward ventilation and hence it might cause draught and thermal discomfort in long term usage. Zonal downward ventilation also produced notably lower exposure compared to the mixing ventilation.

The characteristic of particle spread during open chest surgery in hospital operating room and the analysis of air flow

Akane Odagiri, U Yangai

Kogakuin University, Japan;

The operating room is one of highest air cleanliness room in a hospital. Although many countries set the standard about the surgical operating room's ventilation system, they have not discovered the best way for it.

Since 1926 the electrocautery developed by W. T. Bovie in U.S.A. has been used in many kinds of surgical operations all over the world. It is very effective to decrease the burden of a patient while cutting skin and muscle, and to stop bleeding. On the other hand, when electrocautery breaks the cell of body tissue, it produces vapor called "surgical smoke" which includes toxic substances; cell elements, blood fragments, viruses, benzene, hydrocyanic acid, formaldehyde, bio-aerosol, etc. It is reported that surgical smoke caused breast cancer. Therefore, it is necessary to take into consideration the contamination source inside a room rather than outside. In this study, in order to clarify the particle generation and its diffusion characteristic, we carried out the measurements on the airborne particles, air temperature, and relative humidity on real time during the thoracotomy operation. Furthermore, improvement of air current was also analyzed. The measurement was carried out in the operating room (class 100) of the hospital in China Shanghai.

This paper mainly describes the results of the suspended particulate concentration according to particle diameter. Fig.1 shows the profile of airborne particle concentration according to particle diameter during the thoracotomy operation. In this result, we made sure that particle occurred far than a designated figure of 100 clean class. The indoor airborne particle concentrations during an operation exceeded the cleanliness of a class 100 (Fed 209) remarkably. Electrosurgical generator and ultrasonic surgical generator are used together to the operation. In the operation which used the electrocautery, since the particle concentration of operative time 0.3-5.0μm rose notably, generation by surgical smoke was accepted. Moreover, the

airborne particles of 5.0μm or more were generated irregularly without the relation to the progress of an operation. The airborne particles of 5.0μm or more were generated from clothing etc., and relevance with a motion of medical workers was seen.

After that, we analyzed characteristics of particle spread based on the operation room of size and flow rate in this study. In consideration of the above results, same size and ventilation rate of the operating room was used for analysis of diffusion characteristic of airborne particle. computational fluid dynamics technique was used in this study. We checked air current from HEPA filter, supply air defused into operating room. However, we compare the result of same room with screen cloth that length was one meter and around of HEPA filter, we confirmed that supply air spread less than without hanging wall.

In conclusion, we find out that source of pollution is surgical smoke by the electric scalpel and that hanging wall was effective to decrease risk of breath in surgical smoke them.

Metrics for Interzonal Dispersion Assessment of Airborne SARS-CoV-2 Within Office Buildings

Prateek Man Shrestha, Jason W. DeGraw
Oak Ridge National Laboratory, United States of America;

High ventilation rate is increasingly considered as a mitigation strategy in the rapid spread of COVID-19 in existing buildings in addition to other options like UVGI and added filtration. However, this and other similar measures may also impact energy use and the efficiency of the buildings in which they are installed. Without concrete metrics, the impact of all these potential changes to the system cannot be properly assessed relative to the other impacts the measures might have, including additional energy use, added operation and maintenance costs, and reduced system life. Multizone airflow and contaminant transport simulations involving parameters such as infiltration rate, system configuration, and level of occupancy can provide critical information on relative risk distribution within a building. In this study, prototype airflow models are used to assess the degree to which ventilation-related measures can mitigate the spread of a virus like SARS-CoV-2 in a similar way that prototype energy models are used to study energy efficiency measures. A new detailed medium-sized office building prototype model is developed using the CONTAM software to represent contaminant transport in buildings like those modeled by the U.S. Department of Energy's detailed medium office prototype model. The goal of this study is to generate a set of suitable metrics that will give a whole-building picture of airborne SARS-CoV-2 virus distributions across the different zones of the building under different parameters and scenarios.

NUMERICAL STUDY ON COUGHED DROPLET DISPERSION PATTERN IN HOSPITAL WARD UNDER STRATUM VENTILATION

Yalin LU[1], Zhang LIN[2]
[1]Department of Architecture and Civil Engineering, City University of Hong Kong, Hong Kong, China; [2]Division of Building Science and Technology, City University of Hong Kong, Hong Kong, China;

Stratum ventilation provides improved indoor air quality to occupants by delivering fresh air directly to the breathing zone. This study aims to investigate the droplet dispersion pattern in a hospital ward under stratum ventilation. The motion of each droplet is tracked by applying Lagrangian approach. The evaporation of the droplet is considered. The results show that particle dispersion patterns under different air distribution are very different. After 60 s, approximately 80% of the droplets are removed from the ward under stratum ventilation. Stratum ventilation reduces the exposure risk in hospital wards by accelerating the deposition of coughed droplets and diluting the droplet concentration in the breathing zone effectively.

The potential of reduced personal exposure to airborne cross-infection in patient wards equipped with protected zone ventilation

Amar Aganovic[1], Guangyu Cao[2]
[1]Arctic University of Norway, Norway; [2]Norwegian University of Science and Technology, Norway;

The current worldwide outbreak of coronavirus (Covid-19) in 2020 reiterated the significance of hospital ventilation in infection control. Effective ventilation in general hospital wards is important for controlling the transmission of airborne infectious agents that may cause respiratory diseases. Recently, a new ventilation concept called protected zone ventilation (PZV) has been shown to have the ability to improve the quality of inhaled air in offices. The current study evaluates the PZV supply conditions under which the protection efficiency of a PZV system can be improved compared to traditional ventilation strategies while not deteriorating thermal comfort environment. The aim of this study is to choose the most efficient PZV system based on the continuation of the experimental and numerical research studies conducted by the two authors of this study. The contaminant exposure index was used to assess the risk of cross-infection. This index was evaluated based on experiments utilizing N_2O as a tracer gas to simulate the droplet nuclei exhaled by patients. Two life-size breathing thermal manikins simulated a lying infected patient and a sitting health-care worker in a small room equipped with PZV. Numerical simulation was used to evaluate the draught risk associated with certain supply conditions (velocity and temperature).The results show that the ventilation strategy is effective, but in order to comply with ISO 7730 standard for local thermal comfort the supply velocity should not exceed of 2.0 m/s. Even under such conditions, the results also showed that compared to the traditionally used mixing ventilation systems in hospital wards, the exposure risk is significantly decreased by using PZV.

Study on effective air distribution scheme in COVID-19 ICU isolation wards

Angui Li[1,2], Ying Zhang[1,2], Ou Han[1], Li'an Hou[1], Thomas Olofsson[2], Linhua Zhang[3], Wenjun Lei[3]
[1]Xi'an University of Architecture and Technology, People's Republic of China; [2]Umeå University, Sweden; [3]Shandong Jianzhu University, People's Republic of China;

The transmission of the COVID-19 has brought challenges to the indoor environment control of ICU isolation wards in hospitals. The scientific air distribution design and operation management are crucial to ensure the maximum environmental safety of medical staff. This paper aims to propose an effective air distribution scheme, the adaptive wall-based attachment ventilation, and compare it with a typical ceiling and upper sidewall air supply schemes. The ventilation efficiency is analyzed for different air distribution schemes. The influences of the negative pressure on the outlets are discussed.

Behavior of Droplets and Droplet Nuclei from Coughing Simulator in Sickroom with Displacement Ventilation

Toshio Yamanaka[1], Toshinari Taketani[2], Taisei Ihama[1]

[1]Osaka University, Japan; [2]Yasui Architects & Engineers, Inc.;

In sickroom, various odors are often generated from excrement or patients, which cause discomfort of medical workers, visitors and patients. This is one of the problems with the hospital. In order to solve this problem, the authors have suggested that the displacement ventilation be introduced to sickroom in previous papers. However, it is known that there is a possibility that displacement ventilation causes the retention of droplet nuclei expired by coughing of patient at occupied zone in the room, and the infection risk is increased in comparison with mixing ventilation. Nevertheless, this risk has not been confirmed by the experiment using droplet nuclei.

So, in this paper, the particle concentration of droplet nuclei was measured in a full-scale mock-up of four-bed ward in order to examine the distribution of concentration of droplet nuclei with different sizes. A coughing machine developed by S. Tanabe et al. was introduced to simulate the patient's coughing. Four coughing situations were simulated, that is, a standing person coughing horizontally, a sitting person coughing horizontally, a lying person coughing horizontally and a lying patient coughing upward. Salt water was used for making droplet nuclei by water evaporation after being sprayed in the room, and a particle counter was used to measure the concentration of particles of droplet nuclei made of sodium chloride. Three times of coughing were simulated with a time interval of three seconds. Supply air was filtered by HEPA filters.

In order to estimate the possibility of infection due to the inhalation of droplet nuclei, the index of local cumulative dose (LCE) was introduced. As a result, it is turned out that LCE is much higher at the upper zone than the lower zone and the order of LCE is standing person coughing horizontally, sitting person coughing horizontally, lying person coughing horizontally, and lying person coughing upward. Especially, lying person had better coughs upward in the room with displacement ventilation.