Conference Agenda

15th ROOMVENT Conference

Session

IAQ1: Indoor Air Quality (IAQ) 1

Session Chair: **Jianjian Wei**

Presentations

Ventilation effectiveness of alternating façade-integrated ventilation devices

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Domestic ventilation units are usually dimensioned based on the required airflow rate. However, their ability to actually exchange the room air volume is generally unknown. The presented research aims at analysing the ventilation effectiveness of alternating façade-integrated ventilation units (decentralized ventilation) experimentally. To this purpose a tracer gas analysis of a lab test case is performed. In the presented research a total of 15 tests have are carried out in a climatic chamber representing a single room equipped with two alternating façade-integrated ventilation devices with regenerative heat recovery (ZAS-D). The tests include summer, winter and intermediate supply air conditions. Further investigations are dedicated to the effect of thermal convection due to human heat dissipation on the room airflow.

The aim of the measurements is to evaluate the ventilation effectiveness under various conditions. The required analysis of the age of air is carried out by means of the concentration decay method which foresees enriching CO_2 as a tracer gas in the test room and observing its subsequent decay behaviour due to air exchange.

The global air exchange efficiency ε^a is expected to range between 0.5 for ideal mixing ventilation and the maximum 1.0 defined by ideal piston flow. The values derived from these measurements vary from $\varepsilon^a = 0.34$ to $\varepsilon^a = 0.60$ and thus indicate inadequate performance for most cases. The placement of both ventilation units in the same façade does not seem ideal, as there is a high risk of short-circuiting currents.

Recording at 17 sensor positions also provides information on spacial distribution and dynamics of the air exchange. The local air quality index $\varepsilon_{i,i}^a$ equals to 1 for ideally mixed volumes. However, almost ideal mixing ventilation, as often described in scientific literature, cannot be confirmed in this series of measurements. It can be observed that thermal convection causes an increase in inhomogeneity. Temperature differences between supply air and room air lead to thermal upward and downward forces due to density differences. As a result, the upper room volume is better ventilated in summer daytime conditions whereas the lower room volume shows better air exchange in winter conditions.

The placement of a dummy, simulating human heat dissipation, and placed half way between the ZAS-D equipped façade generates an additional vertical convection current. This increases the global air exchange efficiency to the typical value for displacement ventilation $\varepsilon^a > 0.5$. However, the improved ventilation efficiency of the measured system only affects the part of the room close to the façade equipped with the ventilation units. In contrast, the room volume further away from the ventilation units can be regarded as stagnating.

COMFORT EVALUATION CONSIDERING THERMAL AND INDOOR AIR QUALITY REQUIREMENTS OF WORKERS

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Recently, improving the energy efficiency in buildings and the workplace productivity of workers have become crucial. Workplace productivity is significantly influenced by the comfort of workers. One study categorized comfort into negative and positive comfort. However, few studies exist that evaluate the positive and negative comfort considering the thermal environment or indoor air quality. Therefore, this study aims to reveal the relationship between comfort and the thermal environment, air quality environment, and thermal and indoor air quality requirements. A survey was conducted using a questionnaire in the summer of 2018. The survey covered workers in office buildings where PMV and CO2 concentrations met the required standard. The results indicated that as workers of dissatisfied groups decreases, comfort went from "uncomfortable" to "neutral" and as workers of satisfied group increases, comfort went from “Neutral” to “Pleasantness”.

HYBRID MACHINE LEARNING FOR OCCUPANCY DETECTION

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This paper examines how qualitative information about occupancy can be obtained from smart home sensor data. For this purpose, Renson’s connected mechanical extraction ventilation units, installed in a Belgian dwelling is utilized. The mechanical extraction ventilation measures room-related parameters, such as temperature, humidity, and CO2 at the extraction point. The wide availability of data measured by sensors that monitor the indoor environment, such as CO2 levels, can be exploited to obtain information about space occupancy, which can be used for a smarter operation of ventilation systems. However, there are some challenges with using data from indoor sensors such as a.o. (1) absence of contextual information such as room volume, (2) uncertainty of the sensor position within the room, and (3) noise in the data. Occupancy detection based on sensor data using pure white- or black-box approaches is not yet feasible; as no contextual information, or labeled data is available. Therefore, a hybrid approach is developed that combines artificial neural networks and physical equations to detect occupancy. The novelty and significance of this approach are (1) the learning process performed by unsupervised learning methods, and (2) the domain-specific knowledge used to guide the learning process. Results indicate that a hybrid approach allows detecting occupancy based on sensor data while overcoming the limitations of pure white- and black-box approaches.

The use of CO2 as an indicator for indoor air quality and control of ventilation according to EN16798-1 and TR16798-2

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For many years the CO_2 level has been used as an indicator for indoor air quality in spaces where people are the dominate source of pollution. In many building regulations, the criteria for indoor air quality is specifying as an absolute level of CO_2. This is also the most common parameter to use by demand control of the ventilation system. The use is, however challenged by new research showing that the CO2 in itself as a source may influence cognitive performance of people. In the European standard dealing with indoor environmental quality EN16798-1, there are three methods listed for calculation of the design ventilation rate for acceptable indoor air quality; but they will not result in the same level of indoor air quality. One of the methods using the CO_2 concentration as criteria specifies different levels for different categories of indoor air quality. The related technical report, TR16798-2, is showing tables with recommended CO_2 levels for different type of spaces. This guideline also show how the use of air cleaning technologies may reduce the required amount of ventilation; but do not take into account the resulting increase in the CO_2 level. The present paper will discuss these issues and give recommendations for future revision of the standard and guideline in relation to the use of CO_2 as an indicator for indoor air quality.

Dispersion of Surgical Smoke in Operating Theatres with a Laminar Air Flow Field or Turbulent Mixing Ventilation

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During electro and laser surgery as well as in ultrasound applications, surgical smoke is released which poses a health risk to the surgical personnel. In this paper, the dispersion of surgical smoke was investigated. Therefore, the particle concentration in the facial region of different operating room (OR) staff members and the exhaust concentration were measured while the airflow (laminar airflow field (LAF) and turbulent mixing ventilation (TMV)) as well as the configuration (lamp positions and shapes) were varied. The investigation was performed in a research operating room test stand at Hermann-Rietschel-Institut (HRI), Technische Universität (TU) Berlin with generic person simulators.

With LAF, the surgeons were hit directly by the surgical smoke's plume in all test cases, resulting in a poor air quality. For the other staff, local air quality indices around 2 were reached in most test cases with the circular OR lamp and below 1 with the triangular lamp. Without a lamp, values above 10 were reached. With TMV, insignificant differences were found when comparing lamp positions and shapes. Local air quality indices of 0.5 (surgeons), 1.1 (scrub nurse) and 0.8 (anesthetist) were measured.

Effects of Infection Control Measures on the Concentration of Airborne Fungi and the Amount of Deposited Fungi during Construction of a Hospital

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The contamination of air and water due to renovation sites in hospitals can increase the risk of infection for immunocompromised patients. It has been reported that approximately half of the cases of healthcare-associated aspergillosis are caused by fungi contained in the dust generated during renovation work within healthcare facilities or surrounding areas. Aspergillosis is an opportunistic infectious disease that does not infect healthy individuals but infects immunocompromised patients. Because many aspergillus spores that cause aspergillosis are present in air-conditioning outlets, fungi may scatter during renovation work in a hospital, which may cause healthcare-associated infections in high-risk patients. In order to prevent this, it is necessary to take appropriate infection control measures while conducting renovation work in a hospital. Although the implementation of Infection Control Risk Assessment is required by the Centers for Disease Control and Prevention and Facility Guidelines Institute 2018, the effect of the infection control measures has not been clarified enough, and no clear evidence has been provided.

In this study, we measured airborne fungi in and around the renovation site in a hospital where containment measures, such as installation of temporary barriers and operation of exhaust fans in renovation sites and workers wearing protective clothing during construction, were implemented. We carried out the measurements at the renovation site, at a corridor in front of the temporary enclosure of the renovation site, and on a floor not undergoing renovation, to understand the effect of airborne fungi in the renovation site on a hospital close to the site. In addition, we measured the deposited fungi from protective clothes before construction and after construction, and work clothes when leaving the site after construction to understand the effects of human behavior on airborne fungi in a hospital close to the renovation site.

Regarding the concentration of the airborne fungi, it tends to increase in the order of non-construction floors, in front of temporary enclosures and in the renovation site. Airborne fungi in front of the temporary enclosures was significantly lower than in the renovation site by Welch's test ($p < 0.05$). Regarding the amount of deposited fungi on clothes, that on the protective clothes after construction was significantly higher than that before construction ($p < 0.001$). That on the work clothes was significantly less than that on the protective clothes after construction ($p < 0.001$). It shows the fungi scattered during construction adheres to the protective clothes, but hardly adhere to the work clothes.

According to the measurement results, the airborne fungi in front of temporary enclosures is significantly lower than in the renovation site. The results of the measurement of deposited fungi on the clothes suggested the effect of maintaining the cleanliness of work clothes by wearing the protective clothes during the construction work.

Therefore, it is possible to reduce infection risk effectively by the fungi containment measures in the renovation site such as the negative pressure control, the temporary enclosure and wearing the protective clothes during the construction work.

Earth Tubes - Clean-Tech Method of Improving Occupant Health and Comfort

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This paper is part of the candidate's PhD research into the use of Earth Tube Systems as a method for improving energy efficiency and indoor air quality - and exploring how far can be achieved in eliminating mechancial cooling systems altogether.

The rapid climate change recently identified in Canada, in combination with stricter energy codes, force the architectural and engineering professions to embrace new design considerations. Traditionally heating energy has been the most significant energy use across Canadian climate zones but with climate change and enhanced envelopes, the cooling energy is increasing.

This paper will explore how passive cooling approaches – including earth tubes and hybrid ventilation systems – would operate as a means of reducing energy use, lower-carbon while providing comfortable buildings. We will explore how these passive cooling methods are harnessed to enhance overall design and where traditional mechanical budgets can be re-assigned toward whole building design for maximum benefit.

The session will provide a focus on earth tube systems – how they work, particular design considerations – and a performance review of recent installations. We will also share findings from a design process where energy modeling was used to predict thermal comfort and building energy performance along with envelope and mechanical system considerations.

We will demonstrate how to incorporate an earth tube system and other passive cooling techniques - and present budget estimates, energy savings and paybacks.

Indoor Air Quality conditions within the baby beds of Day care centres: a design approach for improvement

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The indoor quality of an occupied space is extremely important for babies during their first year as their lungs are still growing and adverse conditions could affect this development. Nowadays more and more babies spent time in day care centres however, relatively little is known about the different indoor environmental conditions present in the sleeping quarters and especially inside the baby beds of day care centres. Therefore this research investigated the indoor air quality of the sleeping accommodation of day care centres as well as the conditions within the baby beds. Besides an extensive literature research actual measurements were performed in five day care centres to find out the indoor air conditions within baby beds.

Furthermore, the effects of different sleeping positions of the baby with in the baby bed was investigated by means of a measurement setup created in the laboratory. The breathing of an infant was simulated by means of a baby doll with air supply mixed with CO_2 and measured at different sensor locations for different sleeping positions. The results show an enormous increase in the CO_2 concentration (up to 4 times) depending on the sleeping position of the infant, and also show the effect of a more open crib. Clearly it showed that more attention is needed to improve the current indoor air quality situation in which babies sleep. Therefor a new design project was started to find possible ways to improve the situation. The methodology of the specific design approach, based on the Methodological Design approach will be explained. First outcomes of this project will be presented which proved that are different ways to improve the indoor air quality conditions within baby beds.

Measurements of non-uniform infection dispersal in buildings

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We present new data which illustrates how a tracer released at various points in an air-conditioned building spreads out, mixes and is ultimately ventilated. The dispersal patterns and mixing rates of the tracer are highly variable in the initial stages following release, so that very non-uniform patterns of concentration arise. However, as the mixing and dilution associated with the ventilation flow begin to dominate, the spatial variations in concentration decay and the concentration gradually wanes. Such data is key for informing models of air quality in buildings and managing challenges of infection dispersal. In particular, with airborne infection, the lack of adequate ventilation can lead to non-uniform deposition rates of contaminated airborne droplets. This may in turn lead to variable concentrations of infection on different surfaces within the space.

Influence of human respiration boundary conditions on the risk of cross infection

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Human exhalation and inhalation play important roles in the whole process of airborne cross infection, namely disseminating and receiving infectious viruses through exhalation and inhalation, respectively. Improving our understanding of the characteristics of human respiration and its influence on the risk of cross infection is thus of fundamental importance. This study intends to investigate first the magnitude and distribution of exhaled air as well as the breathing cycle period of human subjects and second the influence of pulmonary ventilation rate and breathing cycle period on the risk of cross infection. Measurements with five human subjects and a breathing thermal manikin were conducted both when they were seated and standing. Experiments with two breathing thermal manikins were then performed in a full-scale test room with mixing ventilation, in which the pulmonary ventilation rate and breathing cycle period were varied systematically. It was found that both peak flow velocity and breathing cycle period varied considerably between different subjects. A standing posture gave on average 3.4% higher and 18.9% lower exhaled airflow velocity and breathing cycle period, respectively, when compared to in a sitting posture. The influence of pulmonary ventilation rate and breathing cycle period was important only when a separation distance less than 1.0 m between the two manikins. Increasing the pulmonary ventilation rate of the exposed person greatly increased the risk of cross infection. Decreasing the breathing cycle period from the widely used ‘6 second’ value led to a considerable increase in the risk of cross infection. Standing posture resulted in a higher risk of cross infection than sitting posture. These findings imply that different control measures for short-range transmission (within 1.0 m in separation distance) should be taken when occupants have different activity levels.

Comparison of CO2 concentrations during lessons in naturally and mechanically ventilated classrooms

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Extensive one-day comfort measurements were conducted in 48 classrooms of 23 schools in Aachen and Neukirchen-Vluyn (North-Rhine Westphalia) in order to examine the status quo regarding indoor air quality, thermal comfort, room acoustics and illumination. In terms of indoor air quality and CO_2 concentrations, our field study focused on real-life conditions and considered the actual behavior of the users during lessons in spring and summer without intervention. The selection of schools included differently refurbished buildings with both natural and mechanical ventilation.

With mere window ventilation, median CO_2 concentrations up to 2590 ppm were measured. In contrast, mechanical ventilation units permanently provided hygienically well acceptable air quality with peaks below 1300 ppm CO_2. Regarding the outdoor CO_2 concentration and compared to naturally ventilated classrooms, with mechanical ventilation units the maximum and average CO_2 median concentrations per lesson were reduced by about 61% and 24%, respectively. We conclude that mechanical ventilation systems are not only well suited but essential for the provision of healthy indoor air quality in schools.