Conference Agenda

15th ROOMVENT Conference

Session

IAQ2: Indoor Air Quality (IAQ) 2

Session Chair: **Minki Sung**

Presentations

Ultrafine particles: presence and generation indoors

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The particle size distributions of indoor and outdoor aerosols cover a very wide size range, from single digit nanometers to tens of micrometers. Ultrafine particles (UFP), specified as $PM_{0.1}$, have a nominal diameter (such as geometric, aerodynamic, mobility, etc.) smaller than 100 nm. The interest of their effect on human health has been steadily increasing for the following reasons:

a) Their number concentration is extremely high in many instances, e.g. more than 150 million particles per cubic centimeter of outdoor air assuming an airborne concentration of 10 µg/m^3;

b) Their deposition pattern, clearance and transportation is different compared to $PM_{2.5}$ fraction;

c) Their high surface-to-volume ratio makes them extremely effective in transmitting any toxic chemical to the human body.

Recent observations concluded that UFPs human health effects include respiratory system inflammation, cardiovascular morbidity, mortality and even DNA damages (increasing of DNA strand breaks). Studies conducted in Europe estimate that exposure to UFPs reduces from four to eight months life expectancy.

To assess the health effects of UFPs, some investigators use as an indicator central-site monitoring data of $PM_{2.5}$. However, this approach is questionable because ultrafine fraction represents only a small portion (less than 10%) of $PM_{2.5}$ mass concentration. Moreover, UFPs concentration varies in space and time much more than $PM_{2.5}$. For this reason, to assess UFP exposure, personal monitoring systems should be adopted. According to other studies, UFPs and $PM_{2.5}$ affect human health in different ways. The former accounts more for cardiovascular diseases and the latter accounts more for respiratory ones.

People spend most of their time in indoor environments. Therefore, using just outdoor particulate matter data to evaluate occupants' exposure to UFPs indoors is not appropriate.

We report available data in the scientific literature about UFP presence in indoor environments, together with the impact of outdoor pollution on UFP indoors.

Long-term and personal exposure to UFPs indoors are not well understood yet. We summarize indoor activities generating ultrafine particles and their fate. Finally, we suggest some measurement techniques and instruments suitable for expanding the available knowledge about UFP presence indoors.

Effect of Metabolic Rate Changes on Human Bioeffluents and Perceived Air Quality

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The purpose of this study was to examine the effects of metabolic rate changes on the quantity of human bioeffluents produced and resulting changes in perceived air quality. Human bioeffluents such as human skin gas and exhaled air are perceived as body odor, which is considered to contribute to deterioration of perceived air quality in buildings. Little has been reported on the relationship between metabolic rate and human bioeffluents. To improve indoor comfort, it is necessary to elucidate emission characteristics of human bioeffluents and to understand their effects on perceived air quality.

In the present study, we conducted a subject experiment. A mid-sized (1.55 m × 1.9 m × 1.9 m), air-tight stainless steel environmental chamber was used to measure the concentration of chemical substances produced by the whole body of each occupant; a subjective assessment of perceived air pollution was also obtained from respondents outside the chambers performed the sensory assessments. Each occupant performed specified physical activity at three metabolic rates as detailed below. This experiment was a pilot study; so, various conditions were tested. Occupant A's program was (1) resting 75 min → (2) 2.0 MET 75 min → (3) resting 75 min; occupant B's program was (1) resting 75 min → (2) 2.5 MET 75 min → (3) resting 75 min; the program for occupants C and D was (1) resting 60 min → (2) 2.0 MET 60 min → (3) 2.5 MET 60 min. To estimate the concentration of chemical substances, samples of the chamber air were collected with Tenax-TA and DNPH tubes and analyzed using gas chromatography-mass spectrometry and high-performance liquid chromatography.

The subjective assessment results showed that odor intensity increased, and odor tolerance decreased, as metabolic rate increased. These results showed that respondents perceived an unpleasant odor, which they attributed to body odor. Among the chemical substances detected in the chamber air, formaldehyde, acetone, acetaldehyde, and 2-ethyl-1-hexanol were higher under most occupancy conditions than when the chamber was unoccupied. These are likely to be human bioeffluents. In addition, octanal, nonanal, decanal, acetaldehyde, and hexanal were detected in excess of the olfactory threshold, and are likely to have contributed to the odor in the chamber.

In summary, the higher the metabolic level of occupants, the greater the amount of acetaldehyde, formaldehyde, and acetone emitted, and the worse the air quality was perceived to be. In addition, there was a strong correlation between acetaldehyde concentration and odor unpleasantness. In indoor environments where the physical activity level of the occupant is high, our results show that the concentration of acetaldehyde may contribute to deterioration of the perceived air quality.

Measurement of Ventilation Effectiveness of Cross-ventilation air flow Using High Response CO_2 Concentration Measuring Equipment

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In order to improve thermal environment and energy saving performance, houses and buildings that introduce natural ventilation plannedly are increasing.We want to evaluate the ventilation volume and ventilation efficiency distribution of these buildings by tracer gas method. However, experiments with conventional carbon dioxide concentration measuring devices were difficult. Although it is possible to use multiple real-time gas monitors with excellent responsiveness, these equipment are expensive and not practical. Therefore, we asked a manufacturer to make a prototype of a carbon dioxide concentration measuring device with improved responsiveness. In this paper, the responsiveness of the conventional device and the highly responsive device is confirmed first. Then, by using these devices to measure the concentration simultaneously at multiple points, the possibility of ventilation measurement were examined.

As a result, it was shown that it is possible to measure the air age as short as 20 seconds with the highly responsive device, meaning that it has the ability to measure the ventilation efficiency of ventilation. In addition, we made a prototype of a device that aims to increase the responsiveness, simply by connecting a suction pump to the conventional equipment. Although not as effective as the high-responsive devices, improvements were seen compared to the original devices. In the future, to make further changes such as the performance of the pump to look for ways to improve responsiveness.In addition, two cases were measured using the highly responsive device. The experimental procedure is as follows. We inject CO_2 into the room and use a fan to make the room a uniform concentration. At the point when it reaches the level of 2000ppm, CO_2 and the fan were stopped, and the opening was opened at the same time, and the change with time of the concentration was measured in this equipment. The first measurement verified the possibility of measuring the ventilation efficiency distribution of the ventilation airflow of a highly responsive device. In the other measurement, comparison was made between a conventional device and the highly responsive device. As a result, the possibility of measuring ventilation efficiency distribution of ventilation airflow was shown in the high response equipment. From the results of the comparison of these devices, it was also found that the trend of ventilation efficiency distribution can be seen with the conventional devices. When the results were compared in more detail, a relationship was found between the measurement results of the conventional device and the highly responsive device, and the possibility of measuring the ventilation efficiency distribution was also demonstrated with the conventional device by performing correction.

Currently, we are investigating how the wind spread from the air conditioner could be evaluated by the air age. In the future, while improving the responsiveness of conventional equipment, we would also like to improve practicality by conducting actual measurements.

On the impact of CO2 concentration in the inhaled air on the CO2 emission rate by people

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Information about metabolic CO2 emission rate by people in rooms is needed for calculation of the ventilation airflow rate as well as when the outdoor air ventilation rate in enclosed spaces have to be measured by the tracer gas technique ”Estimating Ventilation Rates using Equilibrium CO2 Analysis”, described in the ASTM D6245-2018 standard.

In both situations is used the steady state solution of the CO2 mass balance equation for the occupied space concerned. Since the uncertainty of both, required ventilation air flow rate and outdoor air ventilation rate is equal to the uncertainty of the evaluation of the production of CO2 in the space concerned the CO2 emission rate by people must be predicted as precise as possible. The standard methods (ISO 8996-2004 and ASTM D6245-2018) for evaluation of CO2 emission rate by people do not give information about the impact of CO2 concentration in the inhaled air on the CO2 emission rate by people.

Current paper presents results on the impact of CO2 concentration in the inhaled air on the CO2 emission rate by people. Thirty subjects, 15 females and 15 males, participated in the experiment. At 26 ºC the participants, feeling thermally neutral, were exposed in a small chamber to a low (800 ppm) and to a high (1700 ppm) concentration of CO_2. During the exposure period of 60 minutes the CO2 concentration in the supply and in the exhaust air was measured. The air in the chamber was well mixed. Based on the CO2 records the CO_2 emission rate for each participant was calculated at the steady-state condition inside the chamber.

At steady-state CO2 concentration of 1699±67 ppm in the inhaled air the group average CO2 emission rate was 7.29 mg/sec, while at CO2 concentration of 812±72 ppm it was 7.81 mg/sec. The result was statistically significant (p=0.0015).

AIR CHANGE EFFICIENCY IN A DORMITORY ROOM EQUIPPED WITH A COUPLED MVHR–FAN–COIL SYSTEM ON BUILDING FAÇADE

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Mechanical Ventilation with Heat Recovery (MVHR) systems are widely used in new and renovated buildings, both for Indoor Air Quality (IAQ) improvement and reduction of ventilation energy losses. In some approaches, mainly recommended for residential buildings, they are integrated to the windows frame or external façade. These systems are usually combined with a heat emitter to cover the space heating demand. The present study investigates effects of a combined MVHR system with a fan coil on IAQ characteristics of a student dormitory room undergone the energy retrofitting, through a Computational Fluid Dynamic (CFD) code. The results obtained by the numerical simulation allow assessing distributions of the airflow and temperature inside the room and investigating the IAQ parameters such as the Mean Age of the Air (MAA), local mean age of the air at exhaust vent, and Air Change Efficiency (ACE). Furthermore, the interaction between MVHR and fan coil systems and its impact on IAQ characteristics are addressed.

Exposure to metabolic CO2 in a room with mixing air distribution

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In the current practice CO_2 is used as an indicator of exposure to indoor pollutants. Standards prescribe limits for indoor CO_2 concentration and the design of ventilation flow rate is often based on the CO_2 mass balance method. Complete mixing of room air is assumed with mixing air distribution. Under this assumption, the representative room CO_2 concentration used to assess the indoor air quality and/or to control the ventilation system is measured in the exhaust air or on the walls. However, factors like air flow interaction or pollution source location affect the CO_2 concentration distribution in a room and consequently have an impact on the occupants' exposure to pollution. In this study, the CO_2 concentration in the inhaled air was investigated experimentally. The impact of heat load distribution, number and location of diffusers, and distribution of occupants, on the CO2 exposure was studied. The experiments were conducted in a room equipped with a chilled ceiling, 3 ceiling slot diffusers and heated wall panels simulating solar loads. Seven persons and a breathing thermal manikin were the source of metabolic CO_2 in the room. The CO_2 concentration in the air inhaled by the manikin was measured. The results showed that the excess CO_2 concentration in the inhaled air was up to 48% higher than at the exhaust. The heat load distribution had the biggest impact on the CO_2 exposure among the studied factors. Hence, the CO_2 concentration measured in the exhaust air or at the walls might not be the correct representative for the realistic occupants' exposure assessment. Consequently, the mass balance method appears to be not suitable for designing or controlling the ventilation flow rate. The CO_2 concentration in the air that is inhaled by occupants can exceed the limits defined in the standards, as shown in this study. Therefore, improved methods for design and control of ventilation flow rate are necessary.