IMPACT OF INTERNAL PARTITION CURTAINS ON TEMPERATURE AND CONTAMINANT CONCENTRATION DISTRIBUTIONS IN A FOUR-BED HOSPITAL WARD WITH DISPLACEMENT VENTILATION

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Abstract

In this research, the displacement ventilation (DV) system is proposed to create a better odor environment in a hospital ward. DV is known as an efficient ventilation system, especially when the contaminant is emitted from the heat source. In the previous study, it was proven that the occupant zone of the lying or sitting person could be filled with fresh air; however, a huge amount of supply airflow rate is required to form the contaminant interface layer higher than the height of the breathing zone of the standing person. Additionally, there are internal partition curtains in the general multiple-bed wards for privacy, and it is predicted that these curtains will greatly influence air distribution in the room.

In this paper, the impact of partition curtains in a displacement ventilated hospital ward was investigated by experimental study. The measurements were carried out in a full-scale environmental chamber, which was set up as a four-bed hospital ward with partition curtains. Four person simulators and black lamps were used as heat sources, and CO_2 was emitted from the tube on the person simulator in order to simulate the odor from the body. The temperature and contaminant concentration distributions were examined under different bottom heights of curtains and the positions of supply inlets. As a result, it was figured out that the contaminant air could be exhausted more efficiently owing to the presence of the internal partition curtains. Furthermore, the room air outside the partitioned area where the contaminant source was located could be kept clean.

Keywords: Displacement ventilation, Hospital ward, Contaminant concentration distribution

1 Introduction

A hospital ward is a place where inpatients spend most of their time, and it is also a workplace for the hospital staff. Hence, an uncomfortable indoor environment would stress patients and workers, and it may affect patients' healing state and workers' productivity. Unpleasant odor from the body and bodily excretion is one of the most bothersome issues in terms of indoor air environment in hospital wards. In this research, displacement ventilation (DV) is suggested as an efficient ventilation for solving the unpleasant odor issues in a hospital ward.

Since the supplied fresh air spreads along the floor in the rooms with DV, the airflow in the rooms would be influenced by the layout or arrangement of rooms. Ahn et al. (2018) studied the ventilation and energy performance of partitioned indoor spaces with DV. Halvonová et al. (2011) probed the impact of layout and partitions on the performance of ductless personalized ventilation in conjunction with DV. From their studies, it was found that the arrangement of the room could have considerable influence on indoor environmental quality and energy consumption. Most hospital wards in Japan are multiple-bed wards, and the internal partition curtains are installed for privacy. In order to take advantage of DV properly, the influence of partition curtains on the ventilation performance of the room with DV should be investigated in advance. In this study, the impact of internal partition curtains was examined by full-scale experiments under three different positions of supply inlets and four different bottom heights of curtains.

2 Experimental Method

2.1 Experimental setup

Experiments were conducted in a full-scale experimental chamber set up as a four-bed hospital ward, with a length of 5,545 mm, a width of 5,400 mm, and a height of 2,770 mm. Fig. 1 shows the experimental arrangement and measured points. Supply air was provided through four supply inlets on the wall. The outlet was positioned on the ceiling. The total supply airflow rate was 395 m^3/h. With this supply airflow rate, the previous study confirmed that the contaminant interface is located above the sitting person's breathing zone in a four-bed displacement-ventilated ward. Four person simulators were placed on the beds, and four black lamps (lightbulbs with dark violet glass) were located near each bed to simulate the heat sources in the hospital wards such as television. The heat generations of each person simulator and black lamp were controlled at approximately 40 W and 60 W (400 W in total). An inner partition curtain was also installed for each bed. CO_2 was used to simulate the unpleasant odor in the hospital ward and was emitted from a tube sticking in a sponge on the person simulator. CO_2 flow rate was maintained at 1 L/min, and CO_2 concentration was measured using nondispersive infrared (NDIR) sensors. Temperature distribution was measured with T-type thermocouples. The data for analysing was taken after the temperature and contaminant concentration reached a steady state.

2.2 Experimental condition

Experimental conditions were presented in Table.1. The temperature and contaminant concentration were measured under three different arrangements of supply inlets: no inlet inside the curtain, one inlet inside curtain A and B (two inlets outside the curtain), and two inlets inside curtain A and B (no inlet outside the curtain). The bottom height of the partition curtain was also altered: 50, 100, 200, and 400 mm. Although the outlet was not located in the exact canter, CO_2 was emitted from bed A or C because it was assumed that the air distributions in curtain A and B, as well as curtain C and D, were not much different.

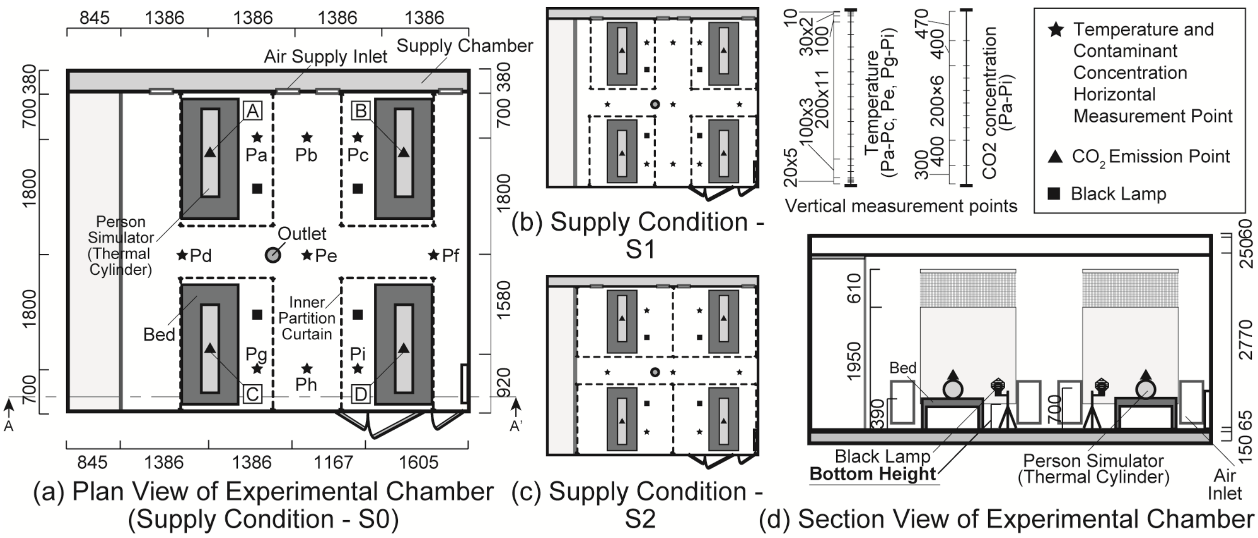

***Figure 1**. Experimental setup*

***Table 1**: Experimental conditions*

Case		*Supply condition*	*Bottom height of curtains*	*Location of CO2 emission*	
A	C	No partition curtain		A	C
S0-50-A	S0-50-C	S0(No supply inlet inside the partition curtain)	50 mm	A	C
S0-100-A	S0-100-C		100 mm	A	C
S0-200-A	S0-200-C		200 mm	A	C
S0-400-A	S0-400-C		400 mm	A	C

S1-50-A	S1-50-C	S1 (One supply inlet inside the partition curtain A and B)	50 mm	A	C
S1-100-A	S1-100-C		100 mm	A	C
S1-200-A	S1-200-C		200 mm	A	C
S1-400-A	S1-400-C		400 mm	A	C
S2-50-A	S2-50-C	S2 (Two supply inlet inside the partition curtain A and B)	50 mm	A	C
S2-100-A	S2-100-C		100 mm	A	C
S2-200-A	S2-200-C		200 mm	A	C
S2-400-A	S2-400-C		400 mm	A	C

3 Result and discussions

3.1 Contaminant concentration distribution

The concentration profiles are shown in Fig. 2 (Case A, S0, S1, S2-200-A). The air quality inside the partition curtain without a contaminant source (Pc, Pg, Pi) was as fresh as the supply air except in case S2. It indicates that the contaminated air could be removed more efficiently with partition curtains in a ward with DV. The concentration in the space between partition curtains (Pb, Pd, Pe, Pf, Ph) was also relatively low, compared with the case without curtains. Although the concentration of the upper part in the curtain with CO_2 emission was significantly high, the contaminant interface apparently formed and the lower part could be kept clean. If all supply inlets were inside the curtain (S2), the concentration tended to be high, presumably because the supplied air had to pass the curtain with CO_2 emission, and contaminant air came out from the curtain.

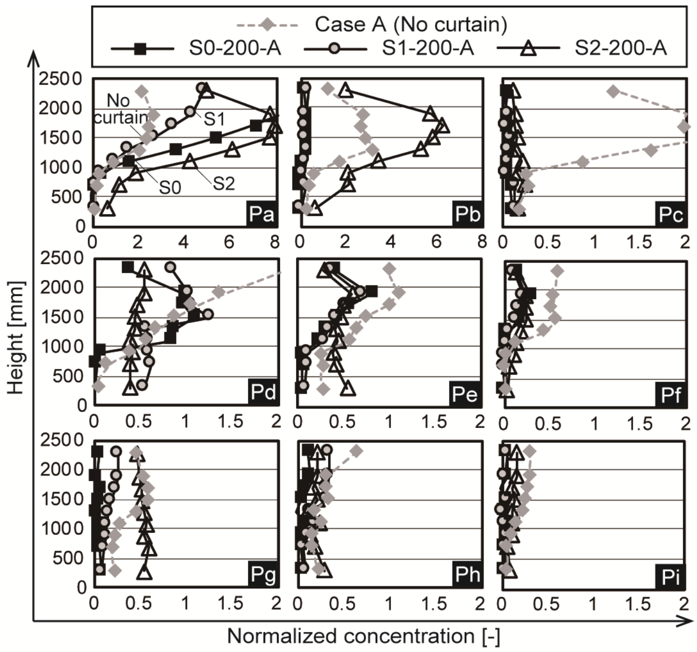

***Figure 2**. Contaminant concentration distribution (Bottom height of curtains:200mm, CO2 emission: A)*

3.2 Personal exposure and supplied airflow rate into the partition curtains

The contaminant concentrations at the height of the breathing zone are presented in Fig. 3. Personal exposure in the figure indicates the normalized contaminant concentration at the height of 1,500 mm (for standing person), 1,100 mm (for sitting person), and 700 mm (for lying person). As expected, personal exposure inside the curtain with CO_2 emission was higher than the concentration of exhaust air. However, the air quality at a height of 700 mm was still acceptable. Personal exposure in other beds was low at every height. All measured results of the case of S2 were worse than in other conditions. In the passageway, personal exposure of standing person was high when the bottom height of the curtains was 50 mm. If there is not enough space between the floor and curtain, supply air could not flow into the curtain easily especially when the curtain is close to supply inlet.

Fig. 4 shows the supplied airflow rate into the curtain with CO_2 emission. The supplied airflow rate is the total supply airflow rate divided by the normalized concentration of the upper part (1,900 mm) inside the curtain. The supplied airflow rate into curtain C is larger than curtain A in every case. Because curtain C and D are far from the supply inlet, the supply air that passed through curtain A and B was accumulated in curtain C. When the supply inlets were located in both inside and outside the curtains (Case of S1-100, 200), the supplied airflow rates into the curtain A and C were comparatively balanced.

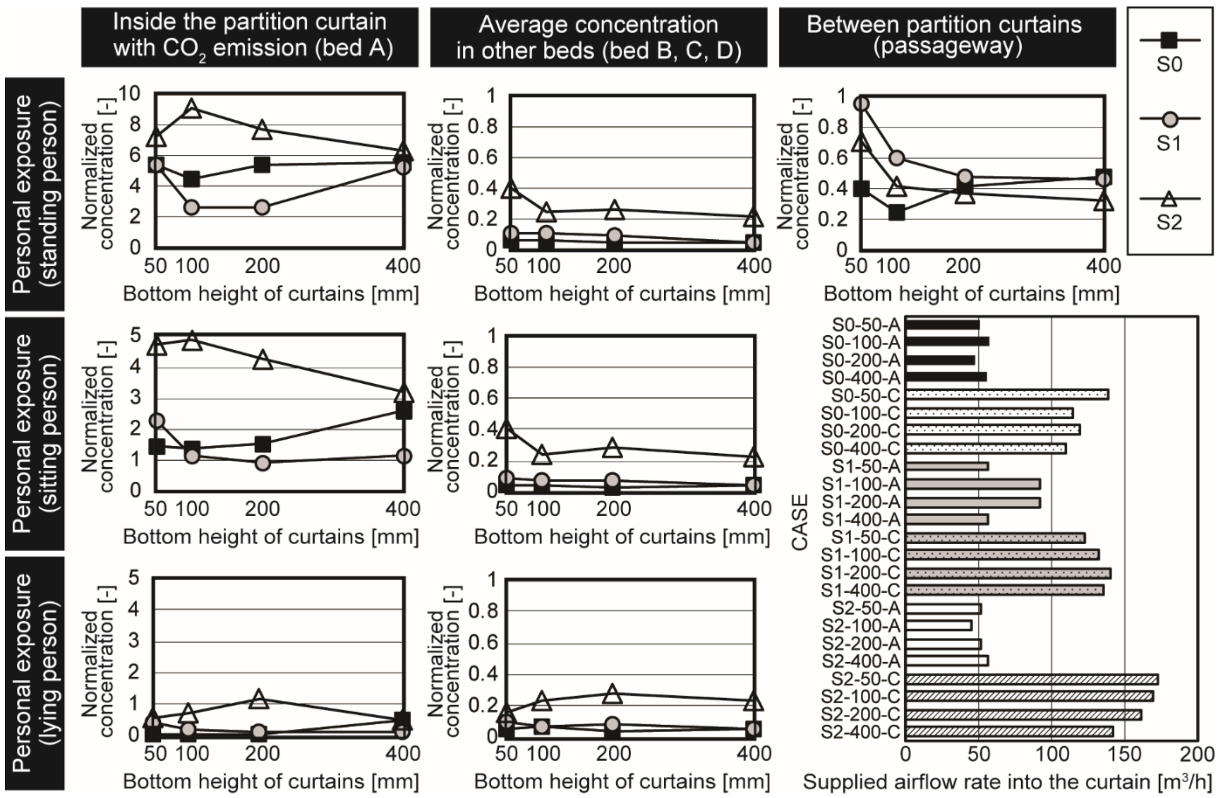

***Figure 3**. Pesonal exposure*

***Figure 4**. Supplied airflow rate*

4 Conclusion

The present study investigated the impact of the internal partition curtain in a four-bed hospital ward with DV. When the partition curtain was installed, the air quality in the ward, except inside the curtain with contaminant source, was significantly better than the case without the curtain. The internal partition curtain could have a beneficial effect on removing contaminated air in a displacement-ventilated ward efficiently. The bottom height of the curtains did not have a significant impact on the contaminant concentration as long as there was a certain space between the floor and curtains. On the other hand, the location of supply inlets considerably affected air distribution. The more varied positions of inlet and outlet should be examined using CFD analysis in the subsequent study.

5 Acknowledgment

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6 References

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