Importance of Ventilation in University Research and Education Activities

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1. INTRODUCTION

There are many situations in which the indoor air environment is important in university research and education activities. For example, various chemical substances are frequently used in university laboratories, especially in chemical laboratories. Chemicals exposure and conflagration caused by chemical experiments are important safety risk that cannot be ignored in university laboratories. Indoor air exchange equipment represented by fume hood and the general ventilation is an essential means of reducing chemical exposure in laboratories. The performance of ventilation plays an important role in improving and enhancing the indoor air environment[1][2]. Recently, the importance of ventilation has been pointed out in relation to the spread of Coronavirus infection[3]. To ensure safety and health, it is important to analyze indoor ventilation and indoor airflow scientifically and quantitatively.

Therefore, this study takes the importance of ventilation in university research and education activities as the theme, expecting to understand the ventilation performance in situations where ventilation has special significance and propose corresponding improvement measures. The specific objectives are:

a) To understand the relationship between chemical substance concentration distribution and airflow in the university laboratory;
b) To develop a local ventilation device for preventing virus spread in the lecture room.

This abstract will focus on the air environment analysis of the lecture room and consider to develop a local ventilation system, that can form an air curtain to block the droplet transmission. There have been retrospective studies proved the effect of air curtain on reducing the smoke leaking in restaurant[4] and reducing the risk of aerial infection in a model laboratory[5].

2. METHODS

2.1 Analytical method

1) <u>Computational Fluid Dynamics (CFD):</u> CFD is an analysis system for fluid flow, heat transfer and associated phenomena such as chemical reactions by means of computer-based simulation. In this study, a commercial software Flow Designer2021 was used to simulate the indoor air environment by Steady state solution and Non-steady state solution.

2) <u>Particle Image Velocimetry (PIV):</u> PIV is a class of methods that are used in fluid mechanics experiments to determine the instantaneous fields of the vector velocity by measuring the displacements of numerous fine particles that accurately follow the motion of the fluid. In this study, smoke (size: 10μm, smoke generator: KATO KOKEN) was used as the trace particle, the transmission state was recorded by a high-speed camera (K4, KATO KOKEN), and post-processed by a commercial PIV analysis software, Flow-Expert64.

2.2 Target room for analysis

This study used an actual lecture room at the University of Tokyo as the target room for analyzing the importance of ventilation and simulating the droplet-blocking effect of air curtains in university lecture rooms. The specific information of the target room refers to the Table 1.

Table 1 Boundary conditions of the target room

Boundary conditions	
Geometric size	7.95 m x 14.4 m x 3 m
Doors	2, closed
Windows	3, closed
Ventilation	16 inlets: 1.5 m x 0.02 m x 16
	8 outlets: 0.2 m x 0.2 m x 8
Ventilation speed	inlet: 1.85 m/s
	outlet: 2.78 m/s
Temperature	26 °C
Relative humidity	60%
Turbulence model	k-εmodel
Fluid type	air
Number of mesh	≒100000
CO2 exhauled by human	40 g/h
Initial concentration of co2	540 ppm
Accommodation	before pandemic: 42 students + teachers
	after pandemic: 21 students + teachers
Solution state	Steady state solution

3. RESULTS AND DISCUSSION

3.1 Air environment analysis of the lecture room

In order to understand the actual situation of ventilation in this lecture room, this study combined the boundary conditions in Table 1 to simulate the residual air age (SVE 6) and CO_2 concentration in the room. According to the boundary conditions in Table 1, it can be calculated that the ventilation frequency of the room is about 9.3 times/h, and it can meet the ventilation requirement of 30 m^3/h/person[6], which suggests that adequate ventilation condition was confirmed in this lecture room.

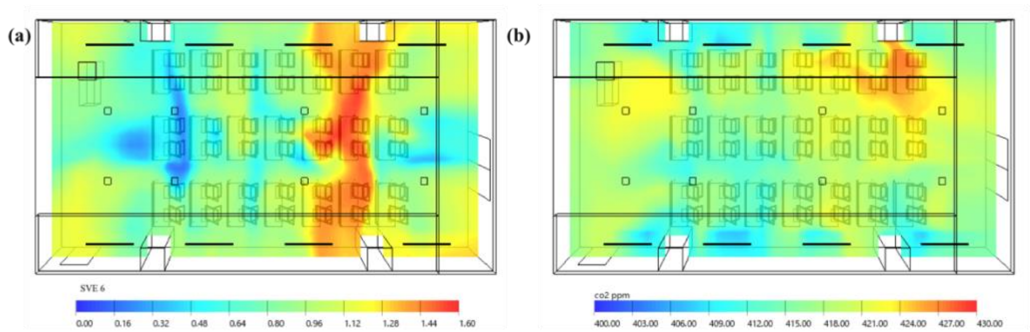

Fig. 1 Simulation results : (a) the residual air age (SVE 6); (b) CO_2 concentration distribution. (z: 1.2m)

However, through the simulation results (Fig. 1), there are different distributions of residual air age and CO_2 concentration in the room. Taking into consideration that the air environment in each part of the room is not exactly the same, such analyses on the air environment will provide effective information where to place CO_2 sensors for monitoring.

3.2 The development of a local ventilation device

(1) Overview of the air curtain

In face-to-face classes, if someone in the room exhales virus-containing droplets, it is possible that these droplets are spread to the others through airborne or aerosol transmission, it may increase the risk of “cluster” infection. In this study, it is assumed that the teacher who has the most opportunity to speak in class is the one who generated droplets. In order to minimize the chance of droplets spreading into the lecture room, this study proposed a prevention measurement by installing air curtain (Fig. 2) in the lecture room.

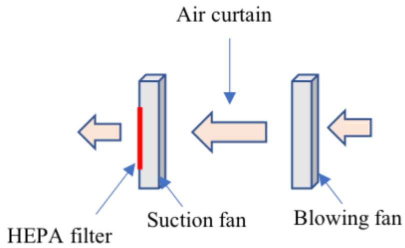

Fig. 2 Design of air curtain in this study.

Commonly, there are above-blow, below-blow, and side-blow 3 ways of air curtain blowing. This study envisaged that using two fans, one suction and the other blowing, to guide the direction of airflow, blocking the droplet transmission by forming an air barrier between the two fans. Moreover, considering to install a HEPA filter on the suction fan to filter the droplets entrapped in the air curtain.

(2) Effect of the air curtain

Considering the ability of masks for capturing large-size droplets, assuming that the teacher emits 3 μm droplets at a rate of 191droplets/s[7], simulated the blocking effect of air curtains on droplets when only mechanical ventilation is available in the lecture room.

Assumed that one class lasting 1h45min, air curtain activated before class in 5 minutes and the teacher started to generate droplets from 6 min. Fig. 3-1 shows the droplet diffusion mode at 110 min when the end of the class. Fig. 3-2 shows the droplet-blocking effect of the air curtain during 110 min. Compared to the droplet diffusion mode when there are no air curtains in the room, the simulations proposed that the setting mode of the fans are 2 meters apart, the length of fans is 1.6 meters, and 0.9 ~1.4 meters away from where teacher stands, which would have a relatively good blocking effect, only a very small part of droplets spreading across the air barrier into the lecture room.

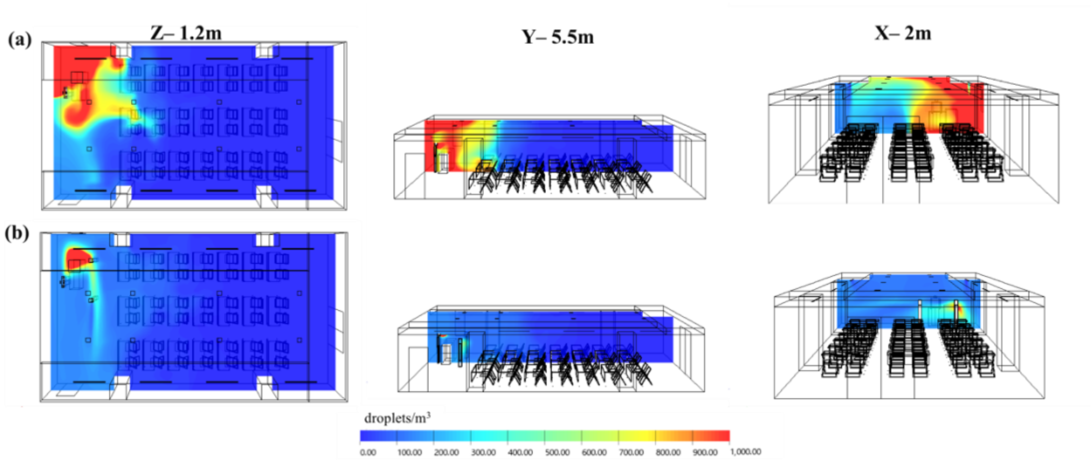

Fig. 3-1 Droplets diffusion modes at 110 min: (a) without air curtains in the lecture room; (b) the blocking effect of optimized air curtain settings.

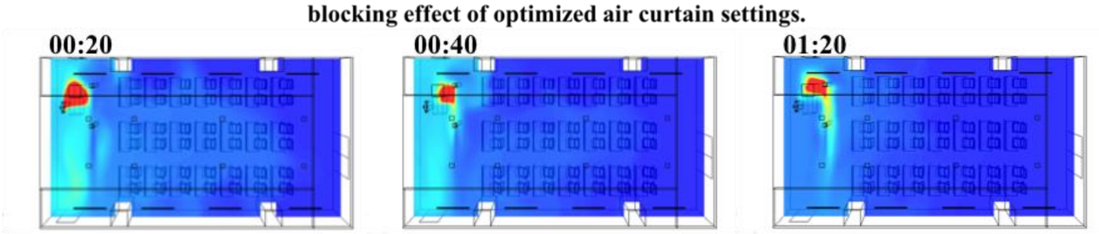

Fig. 3-2 Droplets diffusion changes during 20-80 min in 110 min.

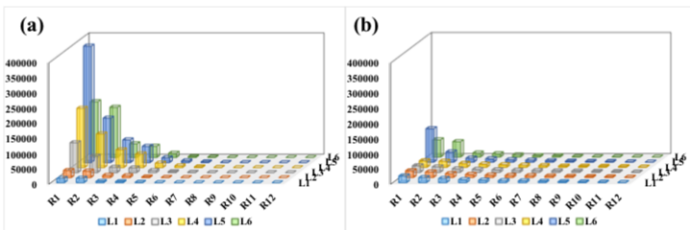

Fig. 4 Droplet numbers of each domain: (a) without air curtains; (b) with optimized air curtains.

In addition, divided the lecture room into 6 x 12 small domains with the geometric dimension of 1 m x 1 m x 1 m, the height of these small domains is set to 0.7-1.7 m and 1-2 m, depending on the height of human mouth, 1.2 m and 1.6 m relatively, and calculated the total number of droplets in each small domain. Fig. 4 suggests that the optimized air curtains proposed in this study can significantly reduce the amount of droplets in the lecture room.

(3) Conditional dependency of the air curtain

The blowing capacities of the air curtains are divided into low (5 m/s), middle (7 m/s) and high (10 m/s) levels. The effect of wind speed on the droplets-blocking was verified by PIV experiment. The wind speed of first air curtain which is responsible for the blowing function were adjusted according to the 3 levels, the wind speed of other air curtain which is responsible for the suction function kept in high-level to have the maximum suction capacity for 2.4 m/s. Used the smoke generated by the smoke generator to replace the droplets expelled by humans.

As shown in Fig. 5, 3-level wind speeds confirmed that an air barrier was formed between the two fans, although the influence range and the velocity of the air barrier were different. At low and middle-level wind speeds, a part of the smoke crossed the air barrier, but it is still able to confirm the blocking effect of the air curtains on the smoke diffusion. On the contrary, due to the insufficient suction capacity of the second air curtains, excessive wind speed accelerated the smoke diffusion.

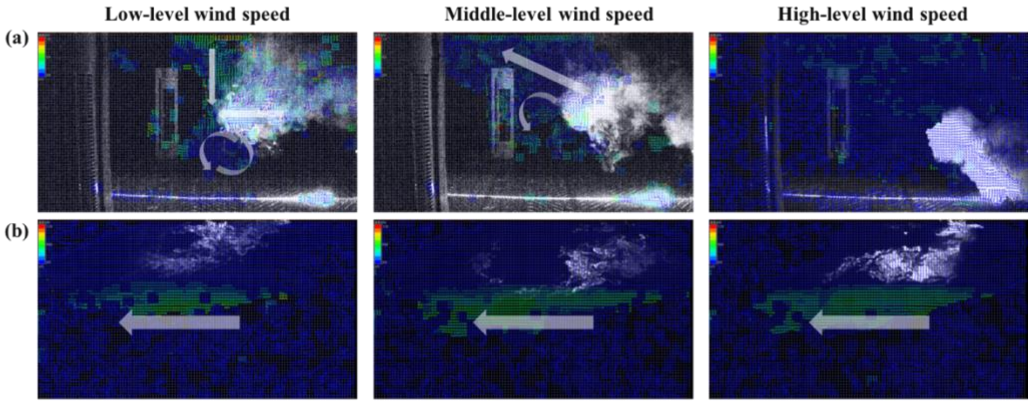

Fig. 5 The movements of smoke observed by PIV: (a) vertical direction; (b) horizontal direction.

4. Conclusion

In this study, the airflow environment in laboratories and lecture rooms were investigated, which are shared by multiple people in universities, through calculations and experiments. In lecture rooms where countermeasures against Covid-19 are required, this study clarified the necessity of quantitative understanding the distribution of air contamination, and the effectiveness of installing local air barriers as a measure to prevent the virus spread. Thus, the study of ventilation was shown to be an important and effective methodology that contributes to environmental safety in university research environments, in that it can quantitatively visualize invisible risks such as air quality and help to understand the current situation and take countermeasures. From these results, the study on ventilation was shown to be an important and effective methodology to contribute to environmental safety in university research environments which can quantitatively visualize invisible risks such as air quality and help to understand the current situation and take countermeasures.

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