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Analysis of indoor air parameters in the occupied zone

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Analysis of indoor air parameters in the occupied zone

S Szekeres[1*]
[1]Department of Building Services and Building Engineering, Faculty of Engineering, University of Debrecen, Ótemető str. 2-4, 4028 Debrecen, Hungary
*Corresponding author: szekeres@eng.unideb.hu

Abstract: Since the COVID-19 pandemic, the number of occupants in many office buildings has decreased around the world, but the comfort parameters in the buildings had to be maintained. Various measures have been taken by the facilities to ensure that the people in the buildings are as protected and safe as possible. Put plexiglass sheets on the desks between the people as a physical barrier and arranged the desks to manage to keep a distance from each other. As a result of these measures, the existing air ventilation system may not be able to provide the designed condition. Analysis of the fresh air ratio was carried out with two different desk arrangements and examined the effect of barriers. As the HVAC systems contribute significantly towards the final energy consumption by buildings it is important to minimalize the level of ventilation. This study focused on the air volume flow, and the mean air velocity. Furthermore investigated the turbulence intensity in percentage as well as the drought rate and comfort levels according to standards. After analyzing the measurement results, various proposals for action have been established.

1. Introduction

Indoor air quality is an often researched area. Since the COVID-19 pandemic. The air quality of the indoor environment became even more important as it can highly affect human well-being. The recommendation of the World Health Organization (WHO), the European Heating, Ventilation and Air Conditioning Associations (REHVA), and the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) to enhance indoor air quality is to boost the grade of ventilation both in quantity and quality [1]. The lower the proportion of fresh air in the room, the worse the perceived air quality. To avoid cross-contamination the air handling units should supply 100% fresh air (outdoor air). This causes greater energy consumption as more air volume requires conditioning to maintain the desired temperature in the occupied zone [2] and could also have a negative impact on thermal comfort, because if the volume flow rate increases with the existing outlets the air velocity increases as well [3]. If the higher mean air velocity gets above 0.22ms^{-1} it becomes unideal, according to the air movement vote of occupants. [4] During and after the COVID-19 pandemic many public offices, office buildings, and banks placed plexiglass sheets between clients and their employees to create a physical barrier [5]. The barriers are used in combination with physical distancing (minimum 1.5m), face coverings, and routine disinfection of high-contact surfaces. As SARS-CoV-2, and other viruses are transmitted by inhalation the barriers can add protection against small respiratory droplets, but could negatively affect airflow and air patterns within a space. In this paper, the measurements concentrated on the effect of the plexiglass sheets on the airflow pattern, mean air velocity in the occupied zone, and draught rate as these are influenced by mechanical ventilation and could affect the conditions for work [6-8]. This study was carried out in a laboratory environment to investigate the change in the air parameters in the occupied zone of a seated person caused by the desk rearrangements and the barriers placed on the desks.

2. Materials and method

The measurements were performed in the Air-ventilation and air-conditioning laboratory at the University of Debrecen, Faculty of Engineering, Department of Building Services and Building Engineering.
The air-conditioning systems are designed to provide fresh air in the building, to remove pollutants/pollutants generated in the room, and not only to supply sufficient fresh air but also to cool, heat, dry, or humidify the air in the room to the desired levels. These desired parameters must be ensured in such a way that the occupied zone is draught-free and noise-free.
Air ventilation can be grouped into two separate categories:

- mixed ventilation, and
- displacement ventilation

In offices, the most common ventilation type is mixed ventilation. The air diffusers for mixed ventilation supply the air above the occupied zone at the ceiling and it can be extracted at the same height or extracted at floor level. The measurements were carried out with a Schako-DQJA-SR air swirl diffuser which is 600×600 mm^2 and can be fitted in a suspended ceiling. As can be seen in figure 1a the diffuser has a winter and a summer setting. In the winter setting the slats are set horizontally allowing the worm air to travel downward to reach the occupied zone. In the summer setting where the slats are set at an angle the colder air travels away from the diffuser near the ceiling level, therefore once its velocity decreases the air lowers due to its higher density. The slats can also be set as universal when halves of the slats are set horizontally while the other halves are set at an angle. During the investigation, the slats were set to winter setting. During the measurements, the air volume flow rate was set to 500 m^{3}h^{-1}. The measurements were carried out with calibrated instruments, see figures 1b and c. The turbulence intensity calculated by the instrument is according to EN ISO 7730 [10].
Turbulence intensity is given in percentage (%) and it is calculated as

$$Tu = \frac{SD}{\bar{v}} \cdot 100 \ [\%] \quad (1)$$

where:
Tu – turbulence intensity
SD – Standard Deviation, of the turbulent velocity fluctuations at a particular location over a specified period of time
$\bar{v}$ – the average of the velocity at the same location over the same time period.
Once the turbulence intensity is obtained the draught rate can be calculated as

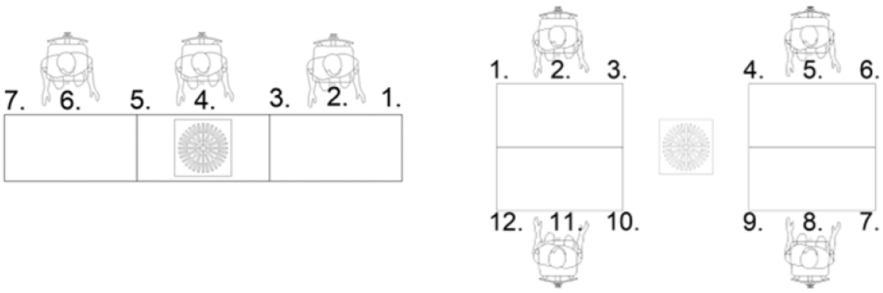
$$DR = (34 - t_a)(v - 0.05)^{0.62}(0.37 \cdot v \cdot Tu + 3.14) \ [\%] \quad (2)$$

where:
t_a – internal air temperature
v – air velocity
Tu – turbulence intensity.

(a) (b) (c)

Figure 1. (a) Schako-DQJA-SR air swirl diffuser [9], (b) Kimo DBM610 airflow meter [11], (c) Testo 400 and turbulence intensity probe [12]

During a pandemic, the main goal of ventilation is to supply as much fresh air to the occupied zone as possible. Swirl diffusers are designed to mix the air on the premises with the supplied air to reduce the velocity of the air as it can influence thermal discomfort. Due to the large induction rate, the fresh air rate is reduced, therefore the exposure to any contaminant could be greater as the air mixed within the occupied zone. Another issue is if a plexiglass sheet is placed in front of the seated person for protection, this could act as a barrier and could obstruct air movement. According to the standard office and client reception layouts, two different layouts were chosen. One of them with three desks in a row, suitable for three people, and seven measurement points were investigated as can be seen in figure 2a. In the other setting four desks were used, pushed together two by two leaving a space between them. In this setting, as can be seen in figure 2b. twelve measurement points were examined. All measurement points were examined at 1.1 m, as that is the neck, and head region for a seated person.



(a) (b)

Figure 2. (a) Measure points at the workstation setup with 3 desks, (b) Measure points at the workstation setup with 4 desks

To visualize the airflow patterns, the measurements were taken in front of a black and white gridded wall in the air laboratory and the airflow was colored with a smoke machine as can be seen in figures 3 and 4. The measurements were carried out with empty desktops and with plexiglass sheets on the top of the desktops. The plexiglass on desks is commonly used, therefore it is important to investigate how it changes the air pattern in the occupied zone.

(a) (b)

Figure 3. Airflow pattern at the workstation setup with 3 desks, (a) with empty desktops, (b) with plexiglass sheets on the desktops

(a) (b)

Figure 4. Airflow pattern at the workstation setup with 4 desks, (a) with empty desktops, (b) with plexiglass sheets on the desktops

3. Results and discussion

The building operators have taken various measures to protect the employees in office buildings. Besides reorganizing the workstation the facility operators installed plexiglass sheets on the desktops to give a guard against high-impulse respiratory droplets. The results for the measurements with the 3 desks setup can be seen in table 1. The results for the measurements with the 4 desks setup can be seen in table 2. According to the measurements for both examined workstation setups, the use of plexiglass sheets did not cause any significant change. When placing the workstation under the diffuser as can be seen in figure 3 the seated person is sitting continuously in a fresh air envelope, but in some measure points a higher air velocity can be experienced as can be seen in table 1. This could cause discomfort for the occupants.

Table 1. Airflow status indicators at the setup with 3 desks

	Empty desktop			Desktop with Plexiglass		
Measure points	v [ms^{-1}]	Tu [%]	DR [%]	v [ms^{-1}]	Tu [%]	DR [%]
1	0.06	39	2	0.04	84	0
2	0.03	55	0	0.03	89	0
3	0.09	30	5	0.06	60	3
4	0.04	73	0	0.05	77	1
5	0.20	51	18	0.06	81	3
6	0.43	35	44	0.12	92	15
7	0.25	33	20	0.30	41	33

Table 2. Airflow status indicators at the setup with 4 desks

Measure points	Empty desktop			Desktop with Plexiglass		
	v [ms^{-1}]	Tu [%]	DR [%]	v [ms^{-1}]	Tu [%]	DR [%]
1	0.03	77	0	0.04	89	0
2	0.03	70	0	0.08	60	1
3	0.03	66	0	0.06	53	1
4	0.03	68	0	0.06	65	1
5	0.04	70	0	0.06	81	3
6	0.03	80	0	0.04	84	0
7	0.12	85	11	0.05	51	1
8	0.10	86	7	0.12	92	15
9	0.10	88	7	0.18	51	18
10	0.04	68	0	0.06	58	1
11	0.07	83	4	0.10	89	13
12	0.11	92	8	0.10	100	9

4. Conclusions

The study focused on investigating the effects of mixed ventilation with air diffusers on the airflow patterns in office environments, particularly in relation to the use of plexiglass sheets as protective barriers on desktops. The measurements were conducted using calibrated instruments and visualized using a smoke machine to analyze airflow patterns. Two different workstation setups were examined, one with three desks in a row and the other with four desks pushed together with spaces in between. The measurements were taken at the neck and head region of a seated person at various points. The findings indicated that the use of plexiglass sheets on the desktops did not significantly alter the airflow patterns in the occupied zone. Placing workstations under the diffuser resulted in the occupants being continuously exposed to a fresh air envelope, although higher air velocities were experienced at some measurement points, which could lead to discomfort. To mitigate this, it is recommended to lower the volume flow rate on the supply diffuser when using a similar setup to reduce the velocity of the air in the occupied zone. Overall, the study demonstrated that the placement of plexiglass barriers on desktops did not cause discomfort for the seated individuals. Lower air velocities, increased turbulence intensity, and reduced drought rates were observed in most cases. For optimal prevention of cross-contamination, it is advisable to position desks away from each other and have the supply air diffuser in the space between the desks to maintain a continuous fresh air envelope. These findings contribute to the understanding of airflow patterns in mixed ventilation systems and provide practical recommendations for optimizing ventilation strategies in office environments, especially in the context of pandemic protection measures. Further research could focus on evaluating the long-term effects of such ventilation setups on indoor air quality and occupant comfort.

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