Advanced airflow distribution methods for reducing exposure of indoor pollution

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ABSTRACT

The adverse effect of various indoor pollutants on occupants' health have been recognized. In public spaces flu viruses may spread from person to person by airflow generated by various traditional ventilation methods, like natural ventilation and mixing ventilation (MV Personalized ventilation (PV) supplies clean air close to the occupant and directly into the breathing zone. Studies show that it improves the inhaled air quality and reduces the risk of airborne cross-infection in comparison with total volume (TV) ventilation. However, it is still challenging for PV and other advanced air distribution methods to reduce the exposure to gaseous and particulate pollutants under disturbed conditions and to ensure thermal comfort at the same time. The objective of this study is to analyse the performance of different advanced airflow distribution methods for protection of occupants from exposure to indoor pollutants.

The study shows that due to complex boundary conditions of the indoor environment, the conventional ventilation methods, like mixing ventilation, may not be able to protect occupants from exposure to various indoor airborne pollutants. The latest developed advanced airflow distribution methods, like protected zone ventilation, downward ventilation, bed and chair incorporated personalized ventilation and localized chilled beam may be used to reduce the personal exposure to various indoor airborne pollutants and ensure thermal comfort. Regarding the exposure to exhaled airflow, the exposure risk can be as high as 20 times by using MV than PV method.

KEYWORDS

Advanced airflow distribution, personal exposure, indoor pollution, ventilation, indoor air quality

1 INTRODUCTION

The adverse effect of various indoor pollutants on occupants' health have been recognized. The traditional ventilation (air distribution) methods may increase the risk of airborne transmission of flu viruses between room occupants. Personalized ventilation (PV) supplies clean air directly into the breathing zone and improves the inhaled air quality and to reduces the risk of airborne cross-infection in comparison with total volume (TV) ventilation ((Bolashikov, Melikov and Krenek, 2011)). Regarding the exposure to exhaled airflow, the exposure risk can be as high as 20 times by using mixing ventilation than advanced ventilation, such as personalised ventilation (Nielsen et al. 2007, Cao et al. 2015). However, it is challenging for the advanced air distribution methods with both gaseous and particulate pollutants under disturbed conditions.

The objective of this study is to analyse different advanced room air distribution methods for protection of occupants from exposure to indoor pollutants.

2 PROTECTED ZONE VENTILATION

During the recent years, the protected occupied zone ventilation (POV) and the protected zone ventilation (PZV) were developed by using downward plane jet to separate indoor space into source and protected zones. This has proven to reduce the personal exposure to indoor pollutant. Figure 1 shows that the use of a downward plane jet will interact with the exhaled jet and will reduce the exposure to airborne pollution from another person who stands close.

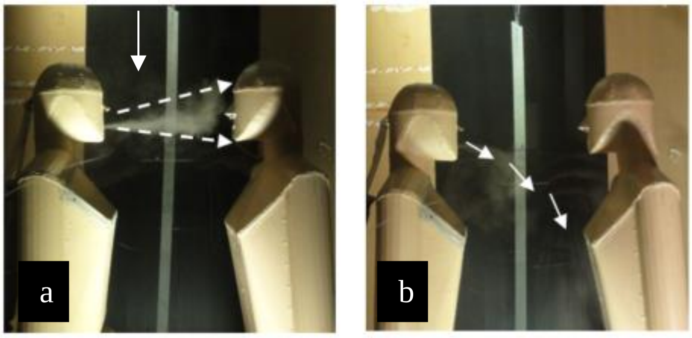
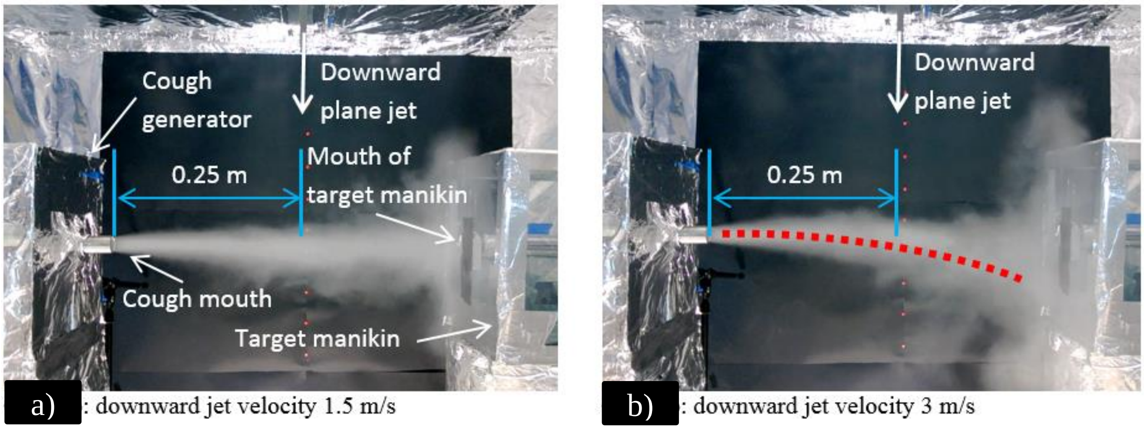


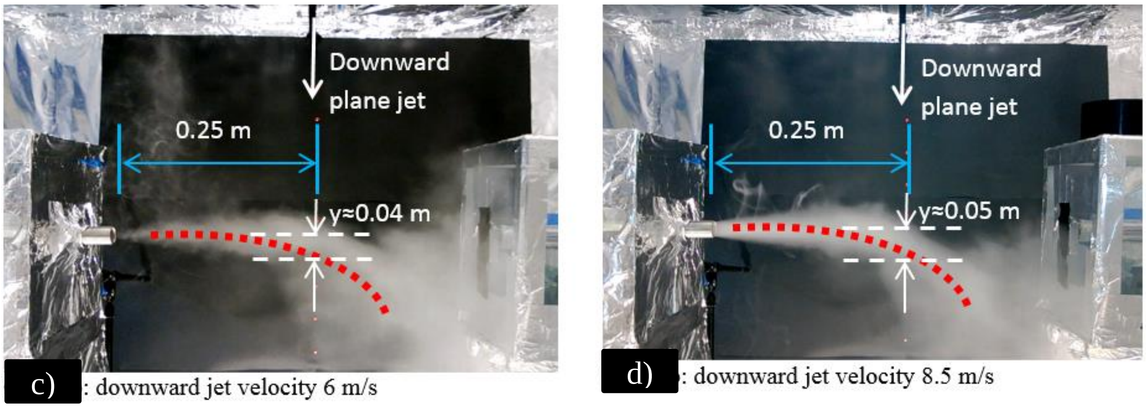
Figure 1: Smoke visualization of the performance of downward plane jet, a) without downward plane jet, b) with downward jet. (Cao et al. 2015)

Figures 2 show that the smoke visualization of the interaction of a cough jet and a downward plane jet. When the velocity of a cough is increased to 16 m/s, a downward jet with a velocity less than 6 m/s only marginally affects the travel of the cough jet. The cough jet may directly impinge the “mouth” area of the target thermal dummy (TTD). A downward jet with a velocity of 8.5 m/s may bend the cough jets downward, thus the cough jet cannot directly impinge the “mouth” area of the TTD. This may indicate the application of a downward plane jet for protected zone ventilation will depend on the moment of the pollutant source, like human respiratory activities.



a) : downward jet velocity 1.5 m/s

b) : downward jet velocity 3 m/s



c) : downward jet velocity 6 m/s

d) : downward jet velocity 8.5 m/s

Figure 2: Smoke visualization of a cough of 16 m/s between two manikins with various downward plane jet velocities a) downward jet velocity 1.5 m/s, b) downward jet velocity 3 m/s, c) downward jet velocity 6 m/s, d): downward jet velocity 8.5 m/s (Cao et al. 2017)

3 DOWNWARD VENTILATION

The risk of airborne infection can be minimised in hospital wards by using a high air change rate and high personal exposure index in a downward ventilation system where a. ceiling-mounted low velocity diffuser are giving a downward supply flow outside the occupied zone. The supplied cool air reaches the floor and generates vertical displacement flow when the return openings are located near/on the ceiling. This type of flow (Fig. 2.) can provide cleaner air to inhalation compared to complete mixing air distribution. The system can handle a high flow rate without causing high velocity, and it is therefore appropriate for the ventilation of a hospital ward (Nielsen et al. 2010). Figure 3 shows the location of different exhaust outlet. A further improvement is to use a bed with personalized ventilation (Nielsen et al. 2007, Melikov et al. 2011).

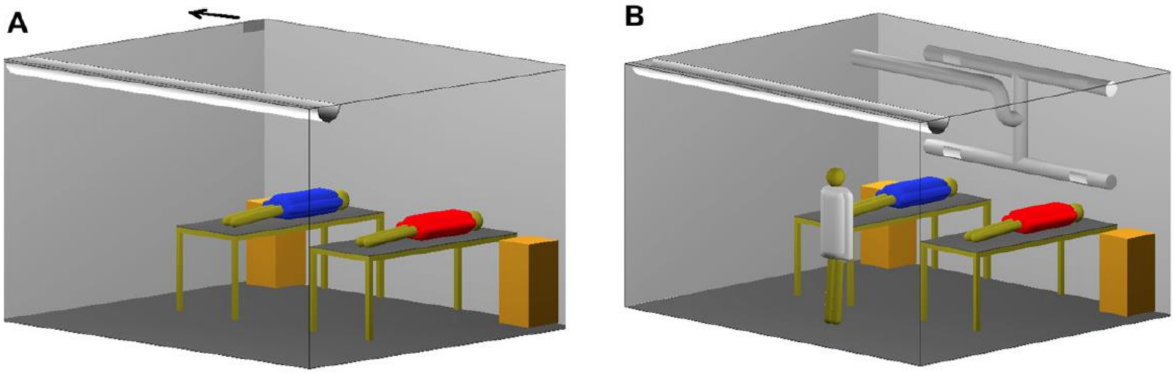


Figure 3: Personal exposure index with a ceiling installed low velocity diffuser

Figure 4 shows the personal exposure index which is concentration in return opening divided with inhaled concentration. Figure 4 a shows the personal exposure index for the target manikin when the source manikin is lying on the back, on the side, and sitting straight in the bed. The target manikin is standing simulating a healthcare person close to the downward flow below the ceiling mounted diffuser. Figure 4 b shows the personal exposure index for the target manikin when the source manikin is lying on the back, on the side, and sitting straight in the bed. The target manikin is standing and simulates a healthcare person close to the downward flow below the ceiling-mounted diffuser.

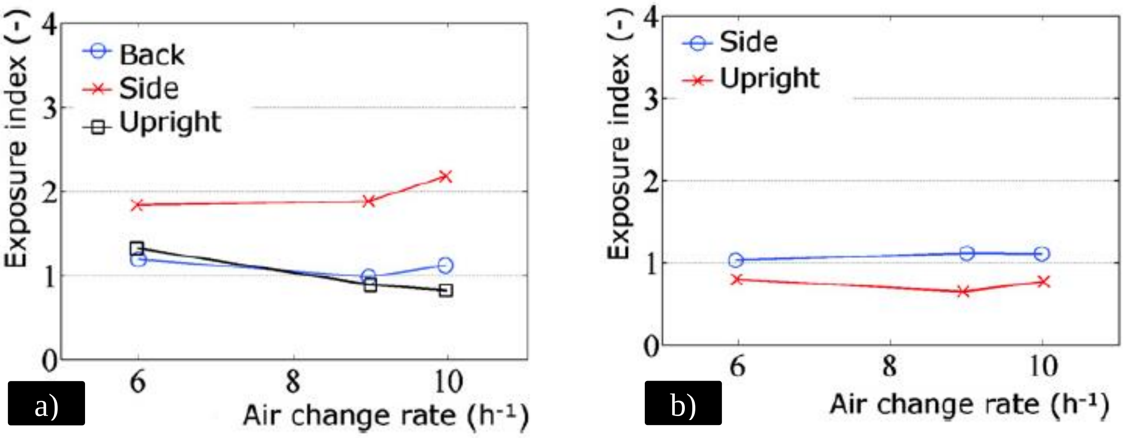


Figure 4: Personal exposure index with different ventilation systems: a) The room has one return opening. b) Four return openings at low level

4 SEAT INCORPORATED PERSONALIZED VENTILATION

The seat-incorporated personalized ventilation (PV) method was developed for control of the free convective flow around the human body, with the aim of improving inhaled air quality. Two nozzles placed on the headrest sideways at the head level of a seated occupant supplied the clean air (Figure 5). The PV- methods have been proved to increase the amount of clean air into inhalation at reduced personalized flow rate and to reduce the risk of draft.

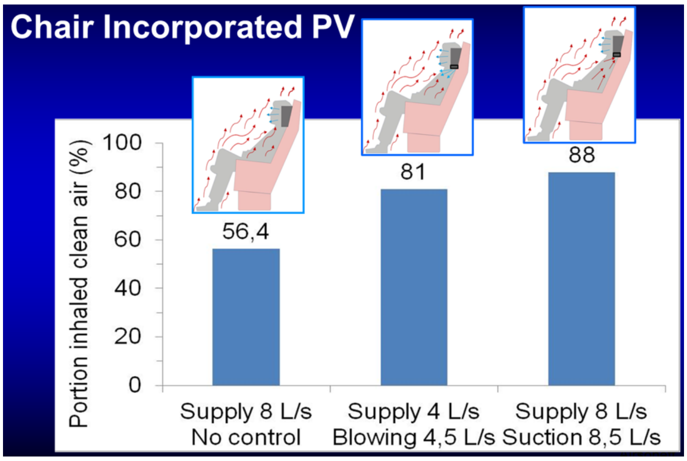


Figure 5: Supply airflow rate and portion of inhaled clean air (Bolashikov, Melikov and Krenek, 2011)

Two of the control strategies studied, namely weakening of the free convective flow by suction of part of its air at the breathing zone and weakening and diluting the free convective air by clean personalized air proved to be efficient. The comparison shown in Figure 6 documents that both strategies improved personal exposure effectiveness (PEE) dramatically: PEE increased from 22.8% without control to 79.5% when suction of 16 L/s was applied and to 92.4% when convective air was diluted by 4.5 L/s clean air. The improvement was higher when the suction and the dilution flows increased.

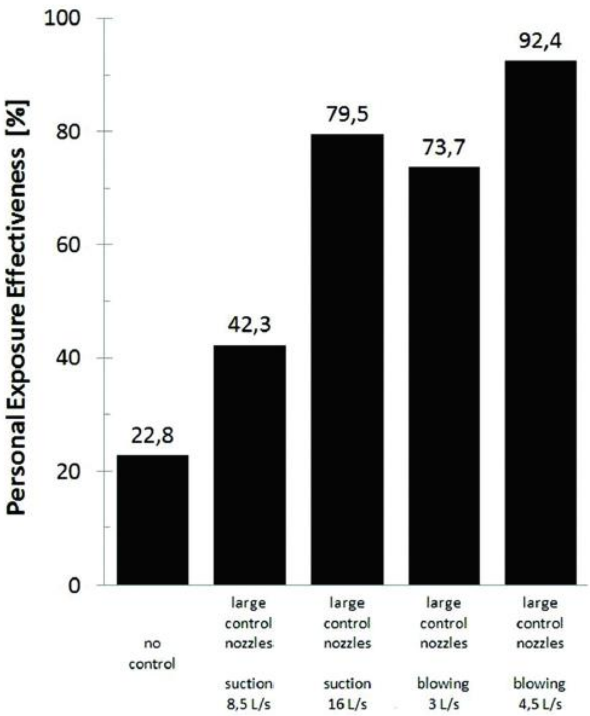


Figure 6: Impact of the control strategies on personal exposure effectiveness (PEE) at 6 L/s from "head rest" type PV nozzle by weakening of the free convective flow (suction) and use of its momentum to transport an additional amount of clean air (blowing), room temperature of 20°C. "Large ATDs"—personalized and control flows with large initial dimensions, i.e., low initial momentum. (Bolashikov, Melikov and Krenek, 2011)

5 LOCALIZED CHILLED BEAM

Microenvironment airflow may be affected by human subjective response. Recently, a new microenvironment control method was developed to create a comfort personal zone by using combined radiant and convective cooling by chilled ceiling combined with localized chilled beam (see Figure 7). This combination generated preferred thermal environment at the workstation and acceptable thermal environment in the rest of the occupied zone.

Figure 7: Microenvironment airflow distribution by a Localized chilled beam

6 CONCLUSIONS

Due to complex boundary conditions of the indoor environment, the conventional ventilation method, like mixing ventilation, may not be able to protect occupants from exposure to various indoor airborne pollutants. The latest developed advanced airflow distribution methods, like protected zone ventilation, downward ventilation, bed and chair incorporated personalized ventilation and localized chilled beam may be used to reduce the personal exposure to various indoor airborne pollutants and ensure thermal comfort.

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