Estimation of Airborne Particle Removal Efficiency in Personal Isolation Room based on Full-scale Experiment

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SUMMARY

This study investigates the performance of Temporary Isolation Rooms (TIRs) in controlling airborne transmission of aerosols. The study utilized a full-scale experimental chamber with various airflow rates of Fan Filter Units (FFUs) and Air Changes per Hour (ACH). Aerosol removal efficiency and penetration coefficients were evaluated using Di-Ethyl-Hexyl-Sebacate (DEHS) particles and optical particle counters. Results showed that TIR performance varies significantly with aerosol diameters and FFU airflow rates. Larger aerosol diameters and higher airflow rates improved removal efficiency, crucial for controlling smaller aerosols relevant to airborne transmission. However, aerosols with diameters from 0.3 µm to 0.46 µm consistently penetrated the TIR from the room, regardless of airflow rate. This study underscores the importance of optimizing airflow dynamics and understanding aerosol behavior for effective infection control in healthcare settings.

KEYWORDS

Healthcare facility, infection control, temporary isolation room, parameter optimization, multi-zone airflow network, removal efficiency

1 INTRODUCTION

Temporary isolation room (TIR) is a small, lightweight structure designed to temporarily cover the patient bed area, preventing the transmission of infection throughout the healthcare facility. The need for effective infection control measures, such as isolation rooms, has significantly increased since the COVID-19 pandemic caused hospital operational paralysis. Temporary

Figure 1: Full-scale chamber experiment for evaluating efficiency of TIR

negative pressure isolation (TNPI) rooms, which share similar infection control principles with airborne infection isolation room (AIIR) using negative pressure, have been the focus of relatively active research on their effectiveness (Lee, 2020; Davis, 2008). In contrast, TIR does not employ negative pressure, leading to lower expectations for their infection control efficacy (Mitchell, 2017). However, due to their lower costs and faster turnover time, TIRs can serve as efficient alternatives to traditional isolation rooms (Mitchell, 2017). This study aims to assess the efficiency of the TIR in a full-scale chamber experiment and quantify the removal efficiency through parameter estimation.

2 METHODS AND MATERIALS

2.1 Full-scale experiment

As illustrated in Figure 1, a PIR is positioned at the third patient bed within the full-scale experimental chamber. The chamber measures 11m × 4.8m × 3m and contains four patient beds. The airflow rate of fan filter unit (FFU) within the PIR is adjustable, and the filter is rated as HEPA13. To evaluate the efficiency of the TIR, Di-Ethyhl-Hexyl-Sebacate (DEHS) aerosols were generated inside the TIR using aerosol generator (3073, TSI). Real-time particle counts were monitored by optical particle counters (OPC-N3, Alphasense) deployed both inside and outside of the TIR.

2.2 Parameter optimization

The performance of the TIR can be quantitatively evaluated by estimating the aerosol removal efficiency using the equation below.

$$\frac{dC_{Room}}{dt} = (1-\eta_r)\frac{Q_{TIR}}{V_{Room}}C_{TIR} - \left(\frac{Q_{TIR}}{V_{Room}} + \frac{Q_{Room}}{V_{Room}} + D_{Room}\right)C_{Room} \quad (1)$$

$$\frac{dC_{TIR}}{dt} = P\frac{Q_{TIR}}{V_{TIR}}C_{Room} - \left(\frac{Q_{TIR}}{V_{TIR}} + D_{TIR}\right)C_{TIR} \quad (2)$$

C_{Room}, C_{TIR}	concentration of experimental room and TIR [#/m^3]
Q_{Room}, Q_{TIR}	airflow rate of experimental room and TIR [m^3/h]
V_{Room}, V_{TIR}	Volume of experimental room and TIR [m^3]
D_{Room}, D_{TIR}	Deposition rate in experimental room and TIR [m^3/h]
η_r	removal efficiency of TIR [-]
P	penetration coefficient of TIR [-]

Equation (1) and equation (2) represents the derivative of aerosol concentration with respect to time in the experimental room and the TIR, respectively. These equations include unknown parameters such as the deposition rate, removal efficiency and penetration coefficient, which will be optimized.

3 RESULTS

Table 1 presents the average estimated removal efficiencies and penetration coefficients of TIR in various FFU airflow rates and air change rates (ACH). The penetration coefficient is a parameter related to aerosols that penetrate the TIR from the experimental room. Each experimental case with different airflow rates was repeated three times, except for two datasets of the experimental case with the lowest airflow rate (120 m^3/h), which were excluded from the analysis.

Table 1: Removal efficiency and penetration coefficient of the TIR

Airflow Rate	ACH	Removal efficiency			Penetration coefficient		
		0.3 – 0.46ηm	**0.46 - 1ηm**	**1-5ηm**	**0.3 – 0.46ηm**	**0.46 - 1ηm**	**1-5ηm**
120 m^3/h	13 /h	0.48 (-)	0.71 (-)	0.43 (0.00)	1.00 (-)	1.00 (-)	1.00 (-)
200 m^3/h	22 /h	0.76 (0.19)	0.97 (0.02)	0.98 (0.03)	1.00 (0.00)	0.95 (0.06)	0.85 (0.22)
290 m^3/h	31 /h	0.88 (0.02)	0.96 (0.01)	0.98 (0.03)	1.00 (0.00)	0.67 (0.47)	0.33 (0.47)
500 m^3/h	54 /h	0.96 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	0.50 (0.50)	1.00 (0.00)

The parentheses refer to sd (standard deviation)

The result implies that the performance of the TIR varies depending on the aerosol diameters and the airflow rates of the FFU. Larger aerosol diameters and higher airflow rates lead to higher removal efficiency; thus, a larger airflow rate is necessary for effectively removing smaller aerosols when controlling airborne transmission is the primary objective. The penetration coefficient also shows better performance with larger aerosol diameters and airflow rates. However, it was observed that aerosols with diameters ranging from 0.3 ηm – 0.46 ηm penetrate the TIR completely from the room, regardless of the airflow rate. Similarly, aerosols smaller than 5 ηm penetrate 100% into the TIR when the airflow rate is 120 m^3/h.

4 ACKNOWLEDGEMENTS

This research was supported by a grant of the project for Infectious Disease Medical Safety, funded by the Ministry of Health & Welfare, Republic of Korea (grant number: HG22C0020).

5 REFERENCES

Mitchell, B. G., Williams, A., & Wong, Z. (2017). Assessing the functionality of temporary isolation rooms. *American Journal of Infection Control*, *45*(11), 1231-1237.

Lee, S. Y., Choi, S. H., Park, J. E., Hwang, S., & Kwon, K. T. (2020). Crucial role of temporary airborne infection isolation rooms in an intensive care unit: containing the COVID-19 outbreak in South Korea. *Critical Care*, *24*, 1-3.

Mitchell, B. G., Williams, A., Wong, Z., & O'Connor, J. (2017). Assessing a temporary isolation room from an infection control perspective: A discussion paper. *Infection, Disease & Health*, *22*(3), 129-135.

Davis, M. A., Landesman, R., Tadmor, B., Hopmeier, M., Shenhar, G., Barker, T., ... & Walls, R. M. (2008). Initial test of emergency procedure performance in temporary negative pressure isolation by using simulation technologies. *Annals of emergency medicine*, *51*(4), 420-425.