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HUMANIC PROJECT *@ Indoor Air 2026*

Infection Risk between Patients and Healthcare Staff with Mixing and Attachment Ventilation Systems in a Double-bed Patient Room

PROJECT 101119726 — HumanIC — HORIZON-MSCA-2022-DN-01

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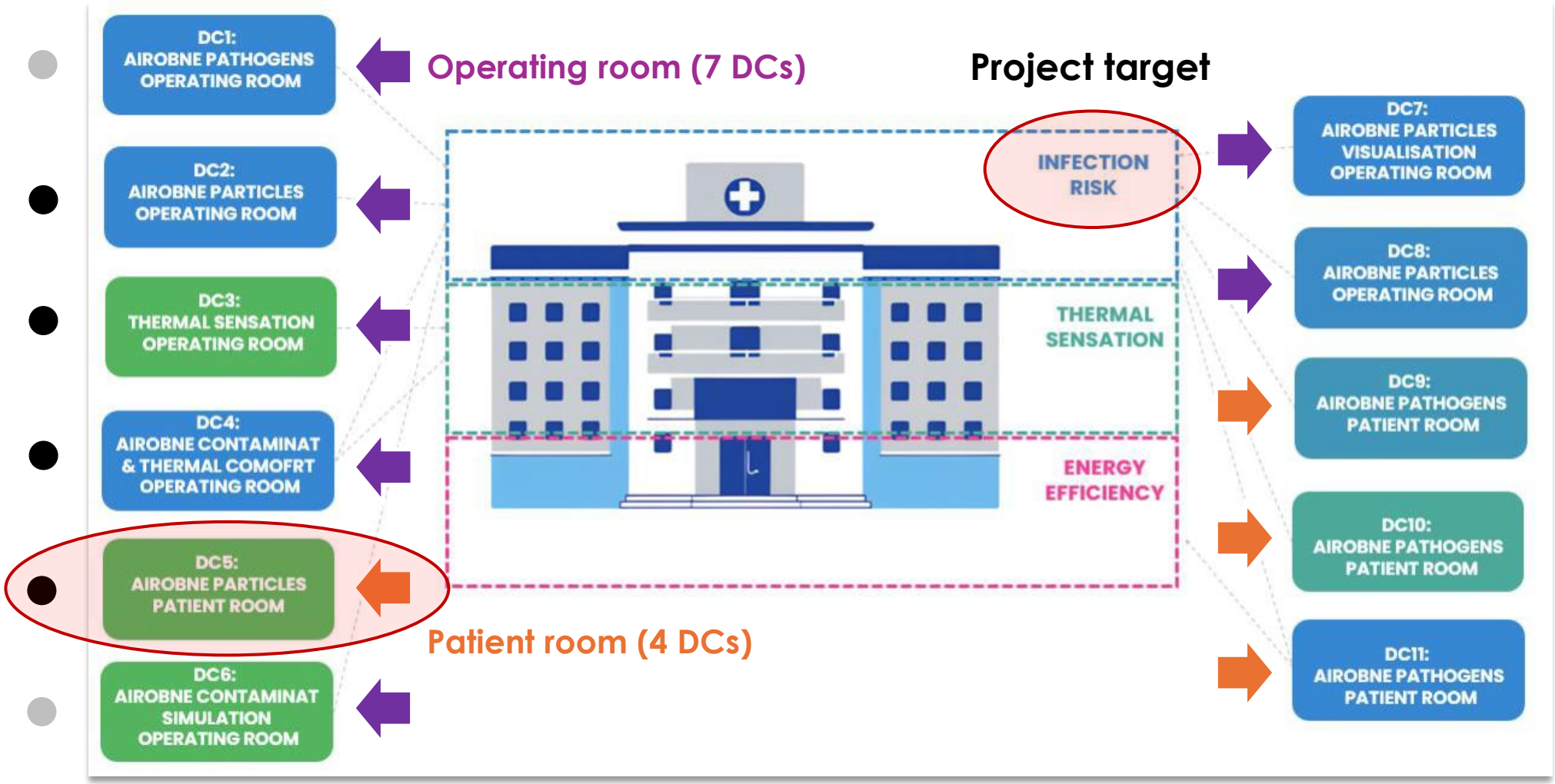
Funded by the European Union

- Experiment (5 DCs)
- Simulation (6 DCs)

Introduction to HumanIC



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My work (DC5)

Infection Risk between Patients and Healthcare Staff with Mixing and Attachment Ventilation Systems in a Double-bed Patient Room

1. Background
2. Methodology
3. Results
   - Dilution ratio
   - Infection probability
4. Conclusions

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1. Background

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HAIs in European hospitals

Healthcare-associated infections (HAIs)

- Infections that patients get while or soon after receiving health care.

European hospitals (annual)

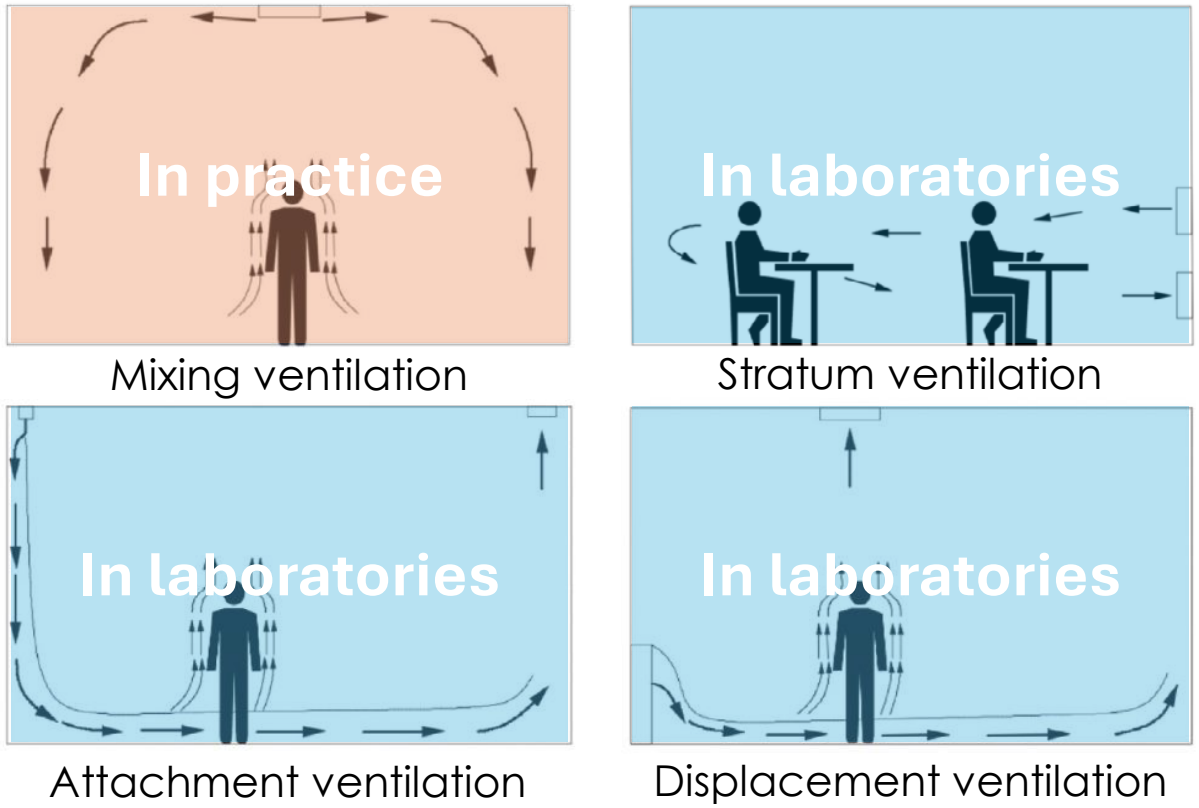
1 / 14

hospital patients have at least one HAI.

93 000

patients have at least one HAI.

Ventilation solutions



Mixing ventilation | Stratum ventilation

Attachment ventilation | Displacement ventilation

Information from: https://www.ecdc.europa.eu/en/news-events/each-year-43-million-patients-hospitals-eueea-are-affected-healthcare-associated
Image from: https://doi.org/10.1016/j.enbuild.2019.109359

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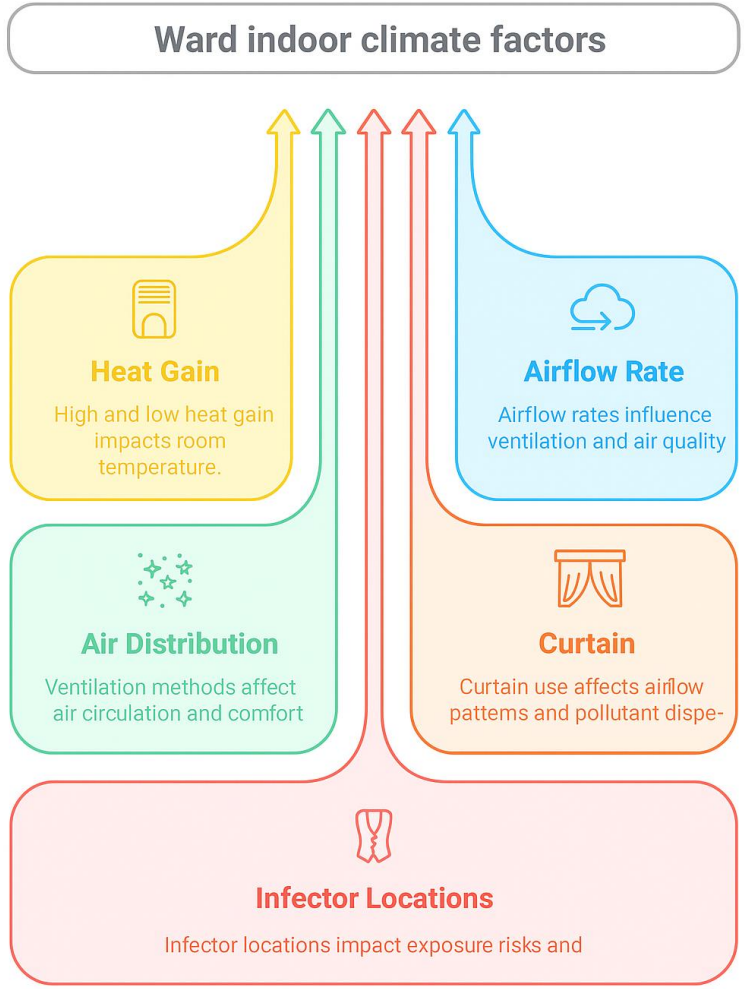
Motivation

Study focus

- Lab experiments in a mock-up **double-bed patient room** (Finnish Hospital)
- **Infection risk assessment** with an infector as a staff member

Key factors

- Airflow rate: 40 L/s (baseline) and 80 L/s
- Air distribution: mixing ventilation and attachment ventilation



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2. Methodology

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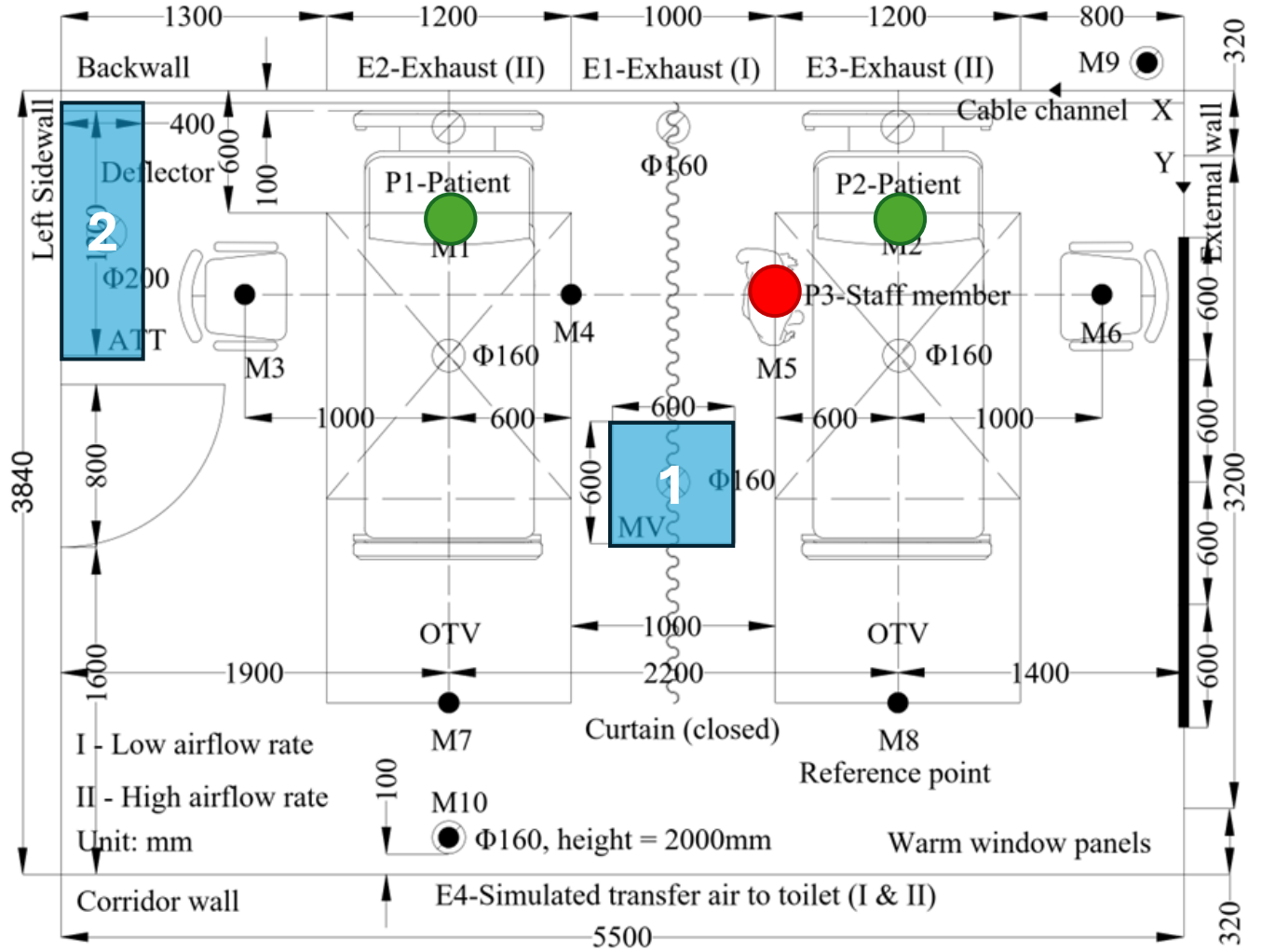
Experimental setup

Room layout

- **Three occupants** (one infector, two susceptible persons)
- **Two diffusers** (**1**-multi-nozzle diffuser; **2**-attachment diffuser with a deflector) applied in occupied zones
- **Closed curtain**



Susceptible patients Infected staff Diffuser

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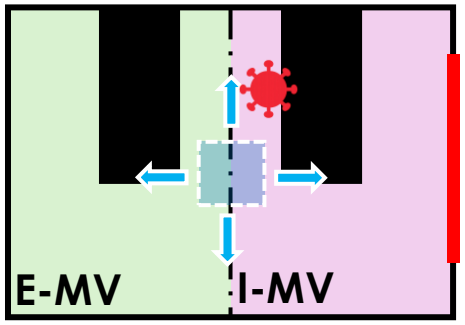
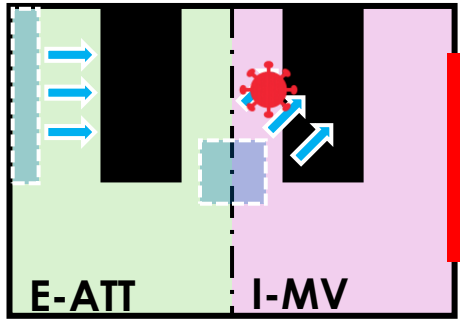
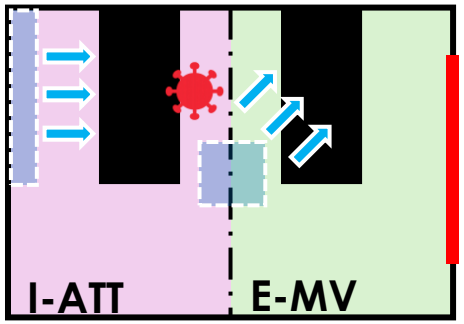
Air distribution methods



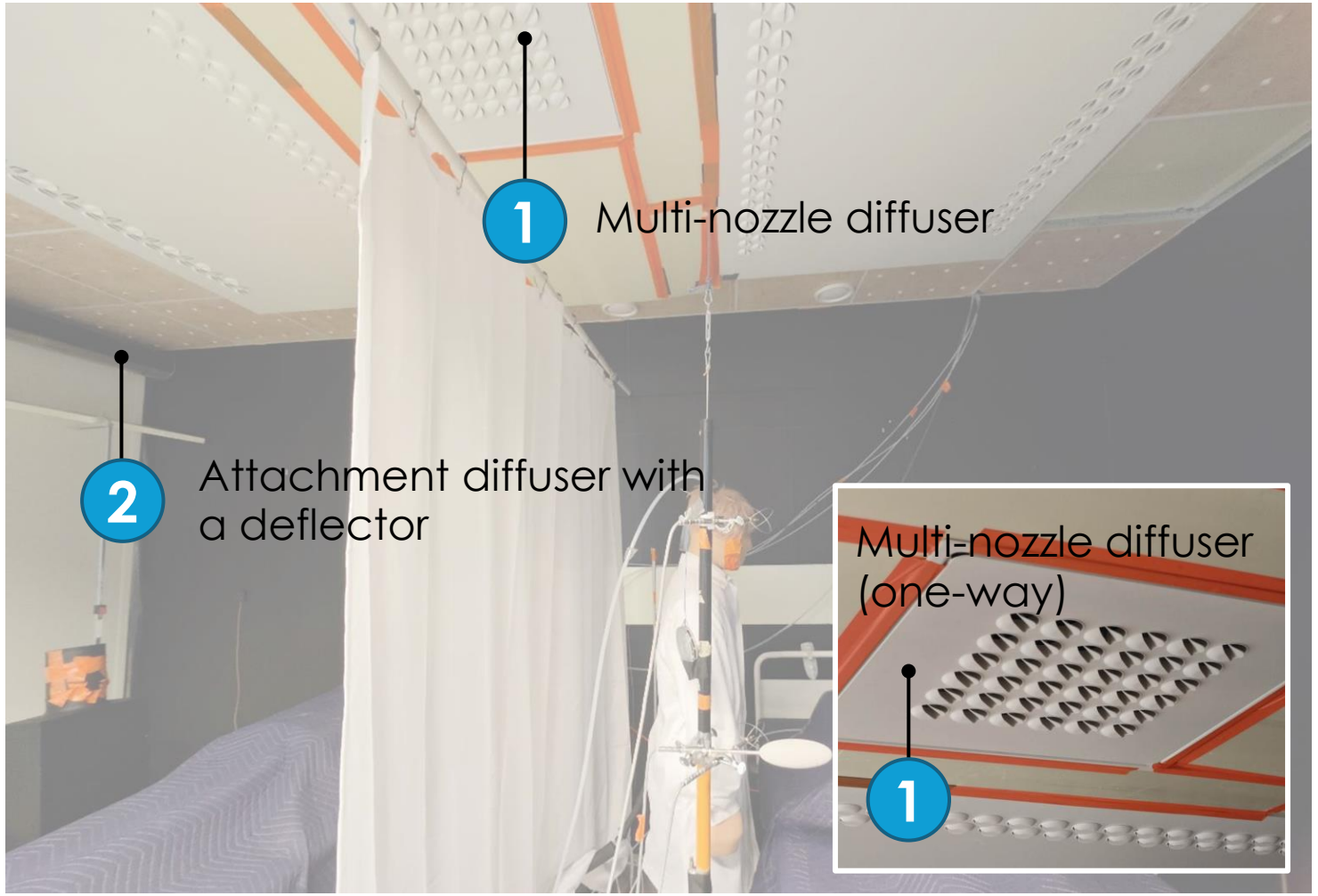
Mixing ventilation (**MV**)



Exposed-side attachment ventilation (**E-ATT**)



Infected-side attachment ventilation (**I-ATT**)



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Tracer gas measurement

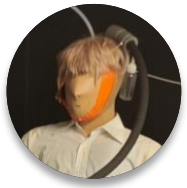
Measurement points

M5: Infected staff

M1, 3, 4, 7: Exposed area

M2, 6, 8: Infected area

M9,10: Exhaust



M1, 5: Heated dummies

M9: Total airflow rate from the exhaust

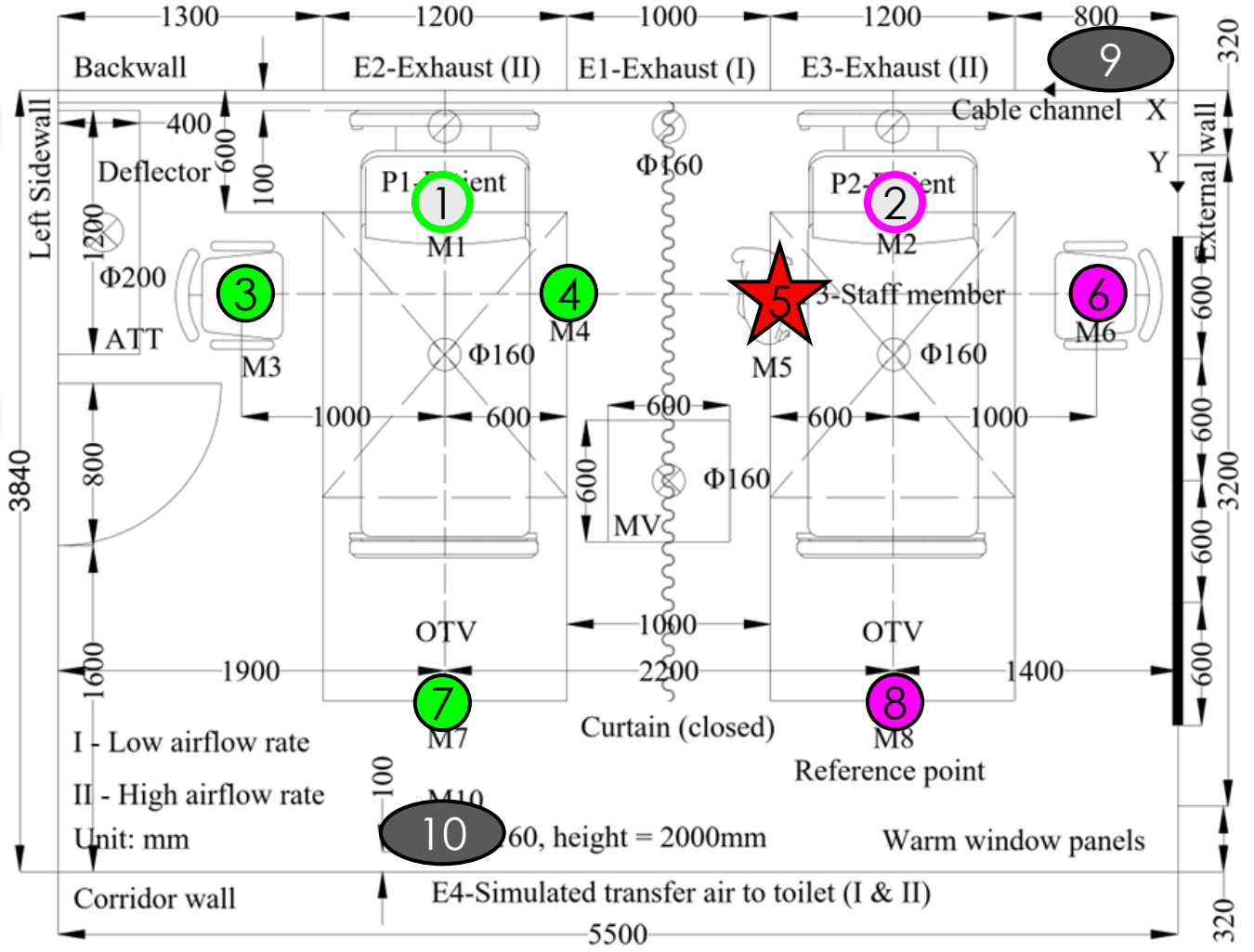
M10: Simulated toilet, 30 L/s (fixed)

Measurement heights

Lying patient: 1.0m

Seated visitor: 1.2m

Standing staff: 1.6m



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Test cases

Environmental factor

- **Heat gains:** Low heat gain (**17 W/m², midseason**)
- **Airflow rates:** Low airflow rate (**40 L/s***) and high airflow rate (**80 L/s**)

Spatial factor

- **Curtain:** Closed

Table. Test cases with different air distribution methods.

Case	Air distribution	Heat flux (W/m²)	Airflow rate (L/s)	Infector
1	MV	17	40	Staff (M5)
2	MV	17	80	Staff (M5)
3	E-ATT	17	40	Staff (M5)
4	E-ATT	17	80	Staff (M5)
5	I-ATT	17	40	Staff (M5)
6	I-ATT	17	80	Staff (M5)

** Data from R3 Nodic Guidelines: https://r3nordic.org/en/guidelines/*

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3. Results

Dilution ratio and infection probability

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Dilution ratio

Formula

$$D = \frac{C_i}{C_s}$$

- D: the dilution ratio at the target position.
- C_i and C_s: airborne contaminant **concentrations at the infectious and susceptible positions.**

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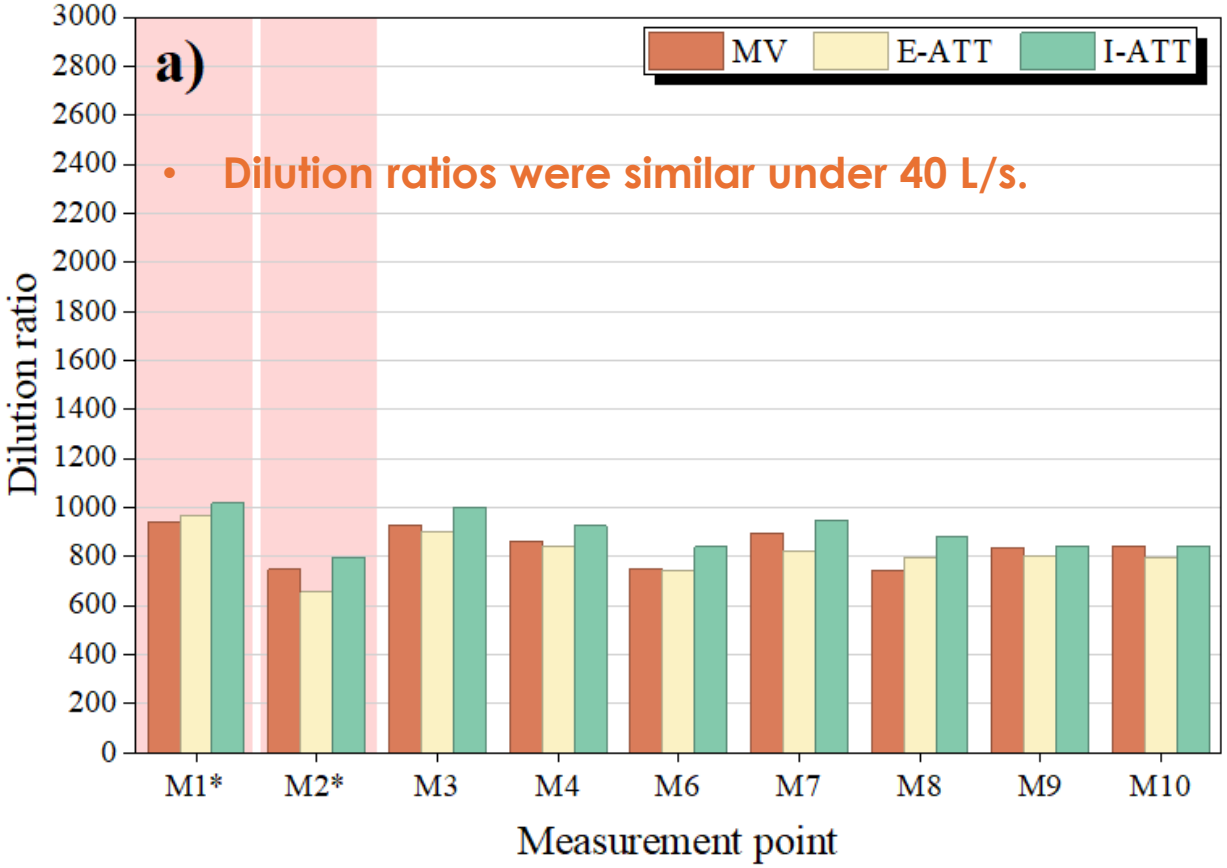
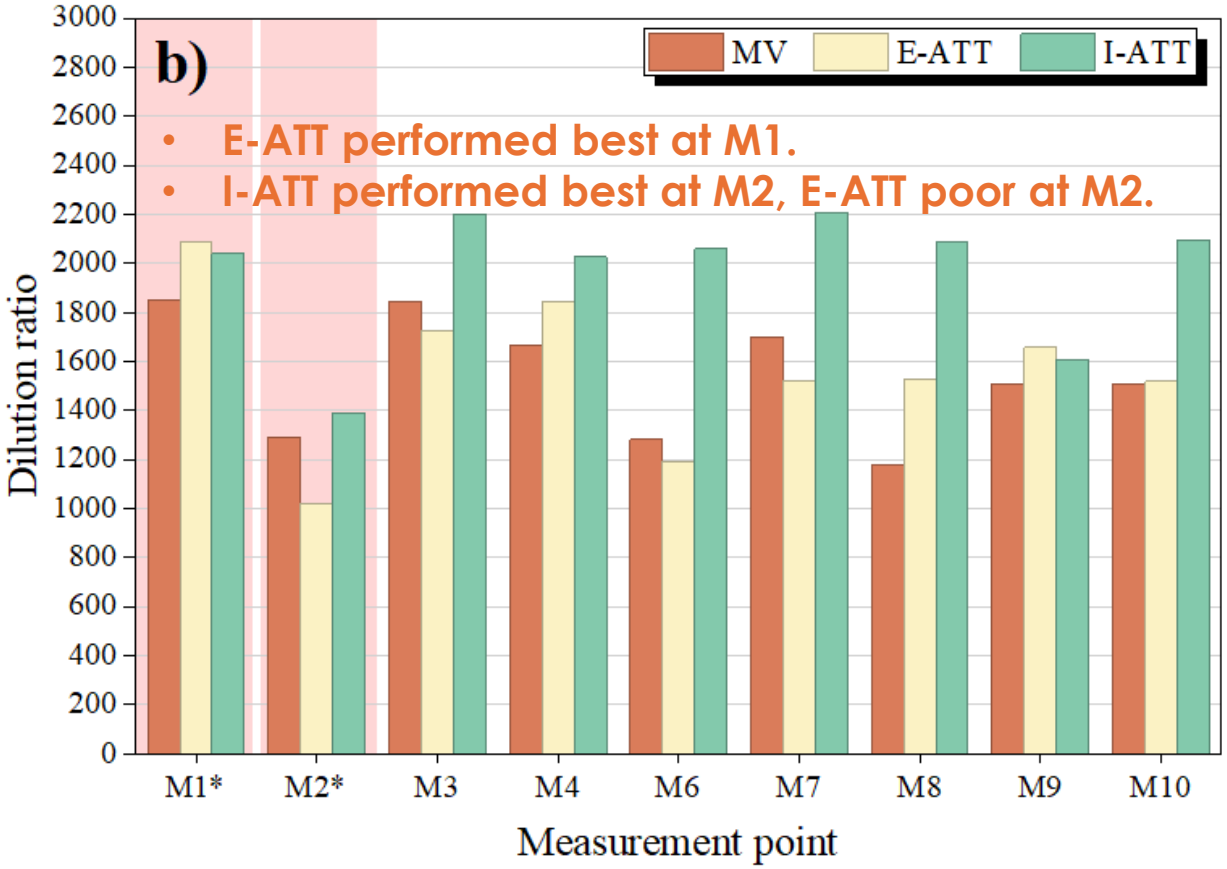
Dilution ratio

Infected staff (M5) 17 W/m² 40 L/s



- Dilution ratios were similar under 40 L/s.

Infected staff (M5) 17 W/m² 80 L/s



- E-ATT performed best at M1.
- I-ATT performed best at M2, E-ATT poor at M2.

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Infection probability

Aspect	Dilution-based Wells–Riley Model
Application	Non-uniform indoor conditions
Formular	$D = \frac{C_{infector}}{C_{exposed}}$ $C_{quantum} = \frac{q}{D^{*}p_{infector}}$ $N_{quantum} = \int_{0}^{T} p_{exposed} C_{quantum}(t)\,dt$ $P_D = 1 - e^{-N_{quantum}}$ $P_D = 1 - e^{-\int_{0}^{T} \frac{q^{*} p_{exposed}}{D(t)^{*}p_{infector}} dt}$
Parameter	**D:** Dilution ratio at the exposed position **q:** Quanta generation rate of the infector (quanta/s) **$p_{infector}$:** Breathing rate of the infector (m^3/s) **$p_{exposed}$:** Breathing rate of the exposed person (m^3/s) **$N_{quantum}$:** Inhaled quanta by the exposed person during the exposure period **P_D:** infection probability

Key values in the model

- Quanta generation rate: staff member (speaking, **16** quanta/h) [1]
- Breathing rate (infected person): **0.36** m^3/h [2]
- Breathing rate (exposed person): patient (**0.24** m^3/h) [3]
- Exposure time: **2** h

[1] Aganovic et al., https://doi.org/10.1016/j.scitotenv.2024.172278
[2] Zhao et al., https://doi.org/10.1016/j.buildenv.2023.110936
[3] ASHRAE. (2023). ASHRAE handbook—Fundamentals (SI Edition), Chapter 9: Thermal comfort. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

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Infection probability

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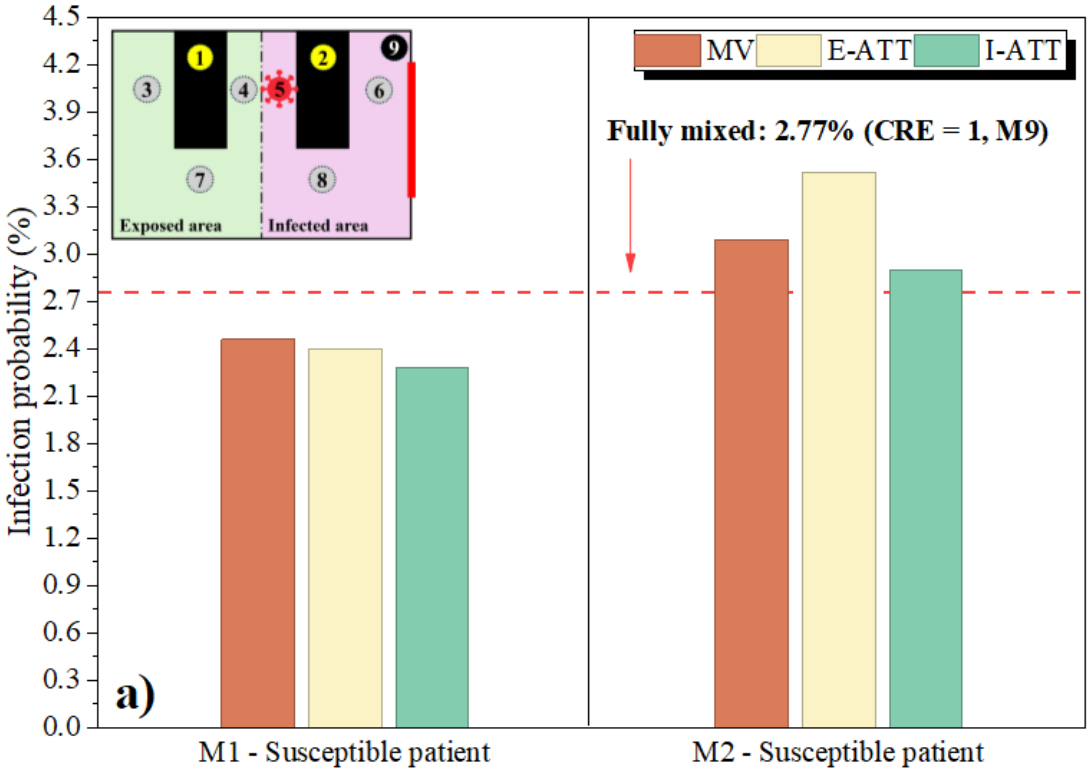
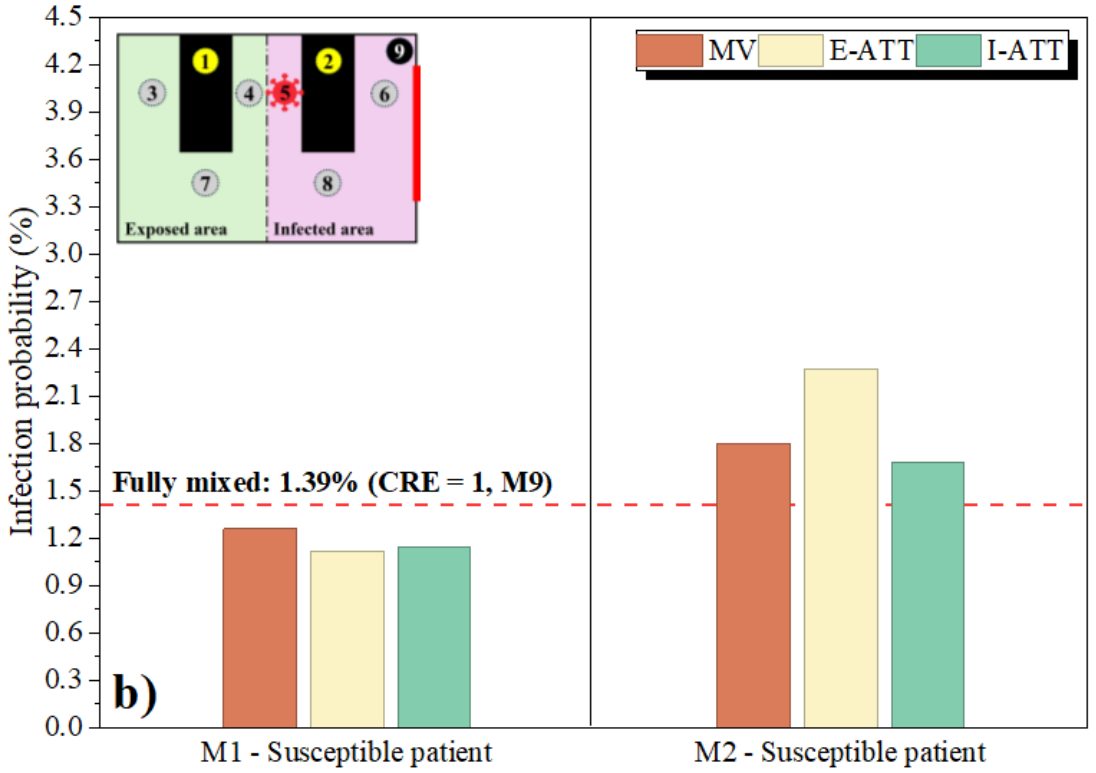


Infected staff (M5) 17 W/m² 80 L/s



M1: Similar across strategies; all lower than fully mixed.
M2: I-ATT lowest, whereas **E-ATT** highest at two airflow rates.

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4. Conclusions

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Summary

Higher airflow substantially improved dilution and reduced infection risk, while infected-side attachment ventilation (I-ATT) provided the most effective protection in the infected area.

Airflow rate

- At **40 L/s**, dilution ratio was relatively uniform, with the exposed area showing **19.1% higher dilution** than the infected area.
- At **80 L/s**, dilution became location-dependent, and **I-ATT** generally achieved the best performance.

Field area

- Doubling airflow increased dilution by **105.4%** in the exposed area and **87.2%** in the infected area, indicating improved local air quality.

Air distribution

- **I-ATT** resulted in the lowest infection risk in the infected area, especially at both airflow rates.

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Thank you! @ Indoor Air 2026

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