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Evaluation of the efficiency of an air purification device in different conditions

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Importance of clean air

- Particles $\leq 20\ \mu m$ can float in the air for $\sim 1\ h$. [1]
- Droplets $\geq 100\ \mu m$ either sediment or evaporate in $\sim 20\ s$. [1]
  - Air purifiers recommended for reducing airborne infectious aerosol exposure by organizations such as WHO and ASHRAE [2,3].

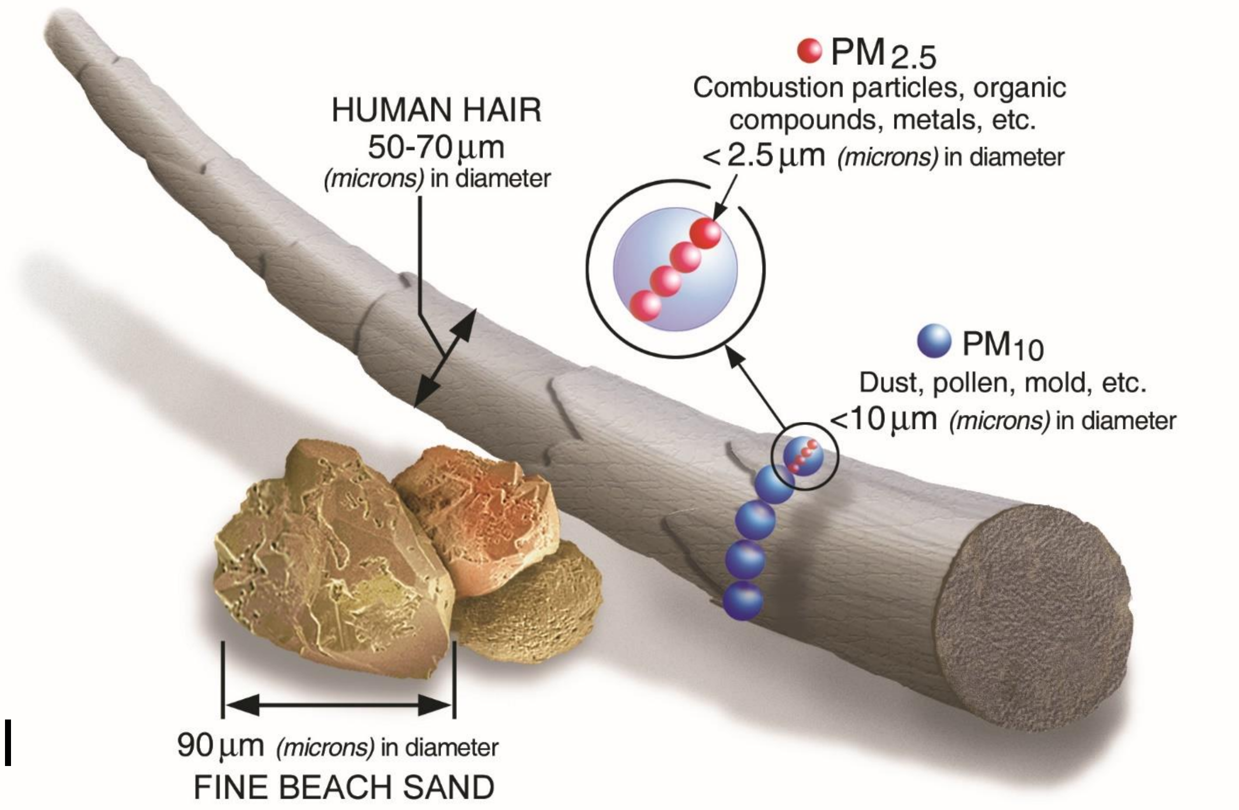
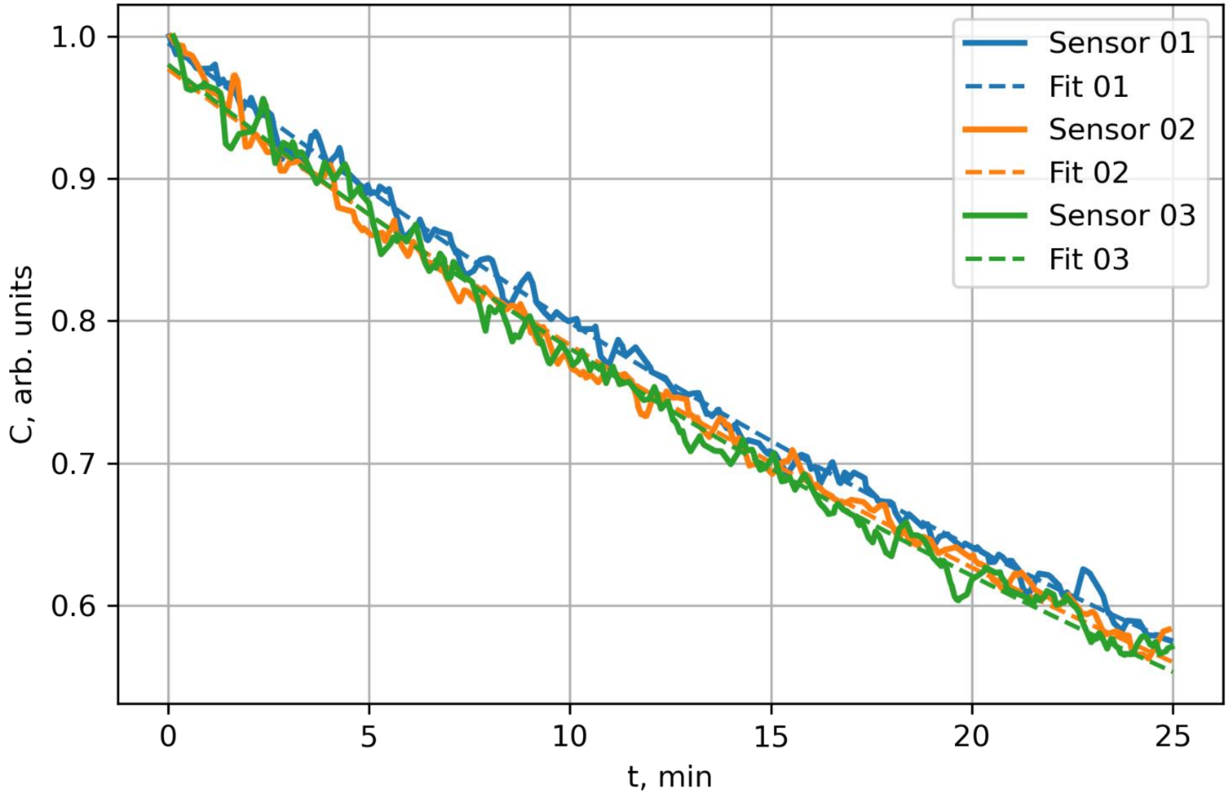


Image courtesy of U.S. EPA

Clean Air Delivery Rate

$$C(t) = C_0 \exp(-k\,t)$$

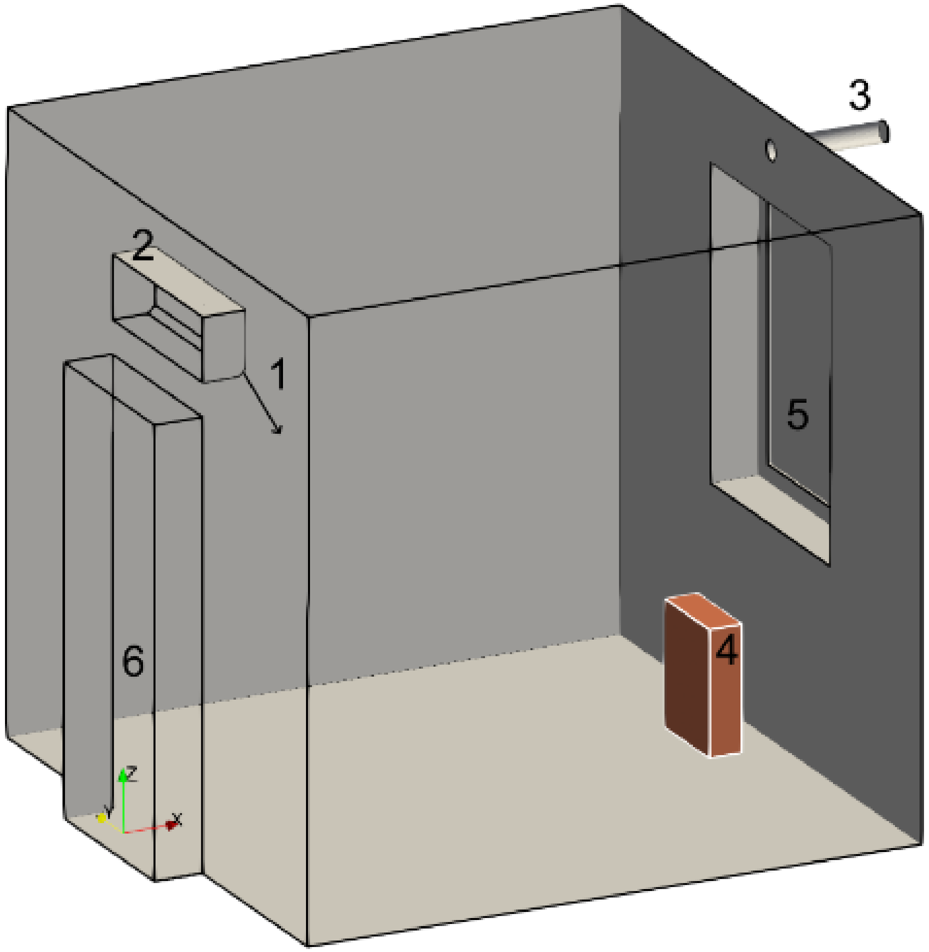
- A commonly used metric is the CADR $= k\,V\ (m^3/h)$, where V is the total room (air) volume.
- 20 minute measurement of relative reduction in contaminant concentration.
  - standard measurement chamber is 28.5 m^3.
- CADR $= (k - k_{natural})V$



Room model and CFD

- Steady state indoor airflow
- Turbulence model k-ω SST
- Bouyancy (ideal gas law density)
- Radiative heat transfer

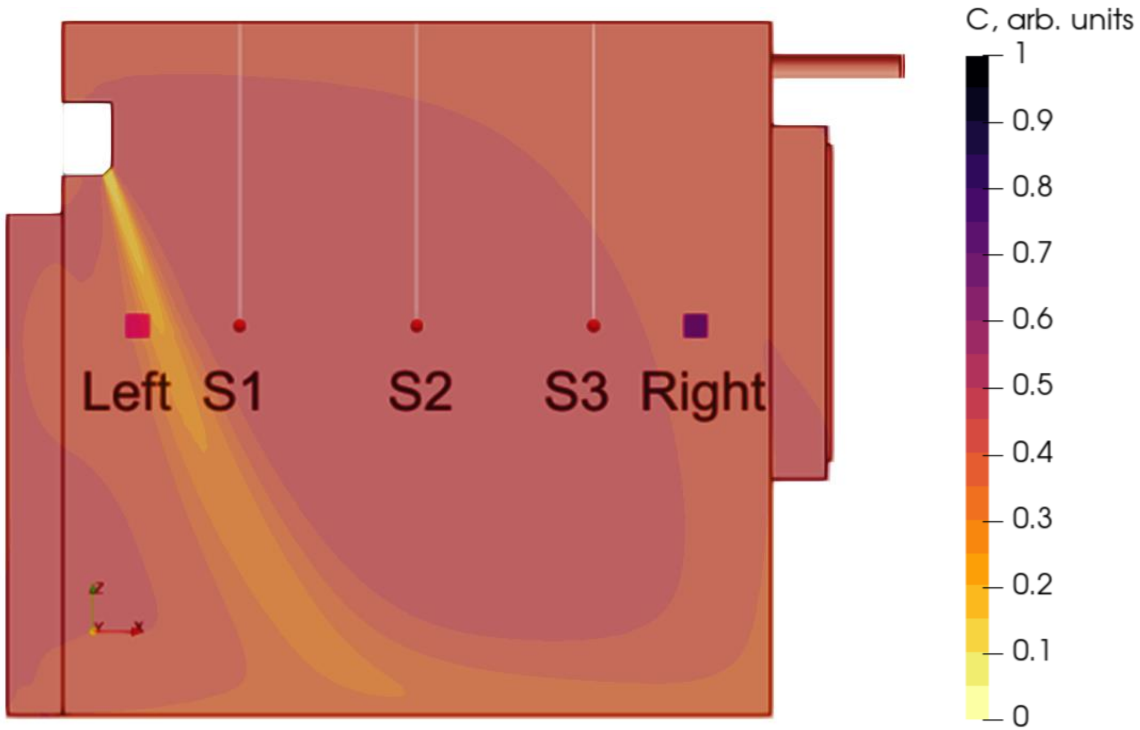
- Room volume 27 m^3
- Outside temperature –6 °C
- Inside temperature 20 °C



Numbering: conditioner inlet (1) and air feedback (2), ventilation outlet (3), radiator (4), window (5) and door (6)

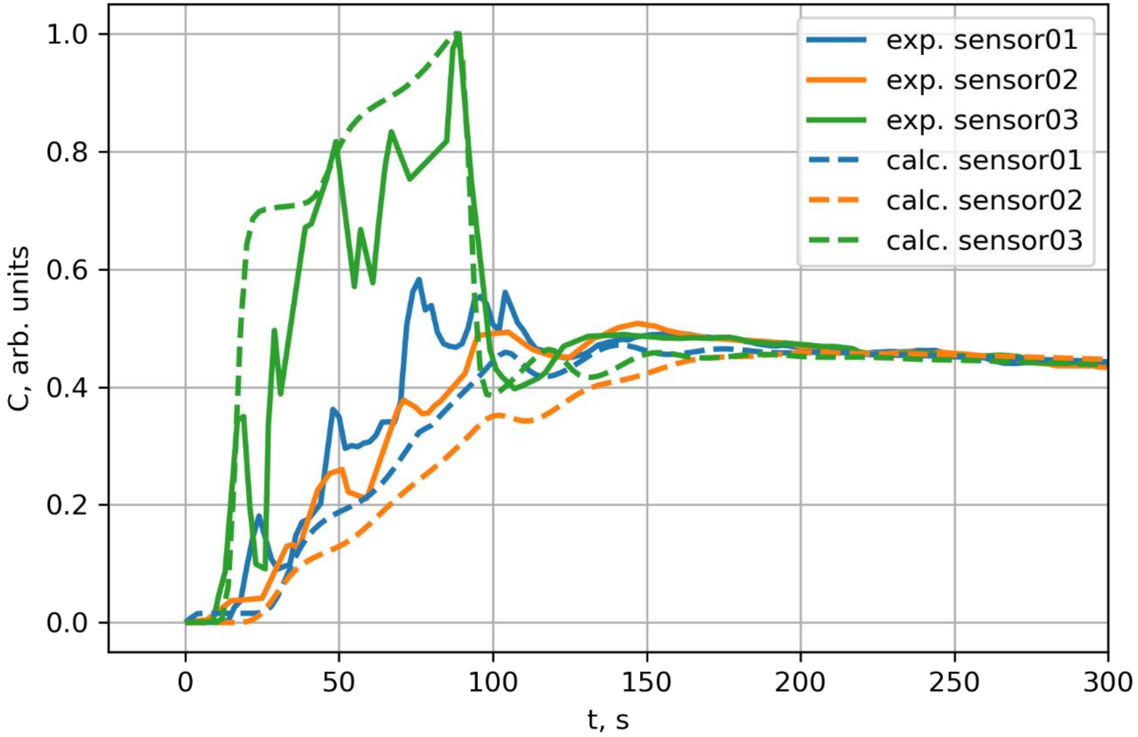
Experimental setup

- Three low-cost PM 2.5 sensors S1, S2, S3
- Humidifier 5% NaCl solution at Left/Right
- Conditioner 0.45 ACH + filter

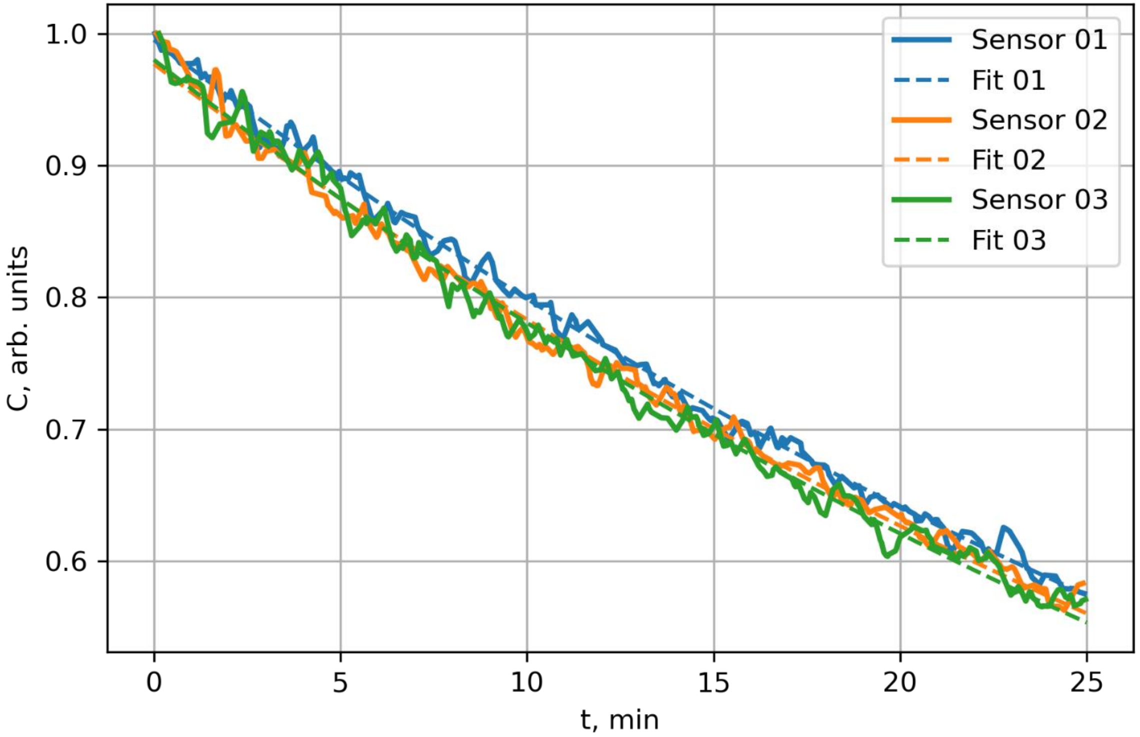


Experiment data and calculation

Source Left



CADR $= 36\, m^3/h$



Conditioner 0.45 ACH + filter ⇒

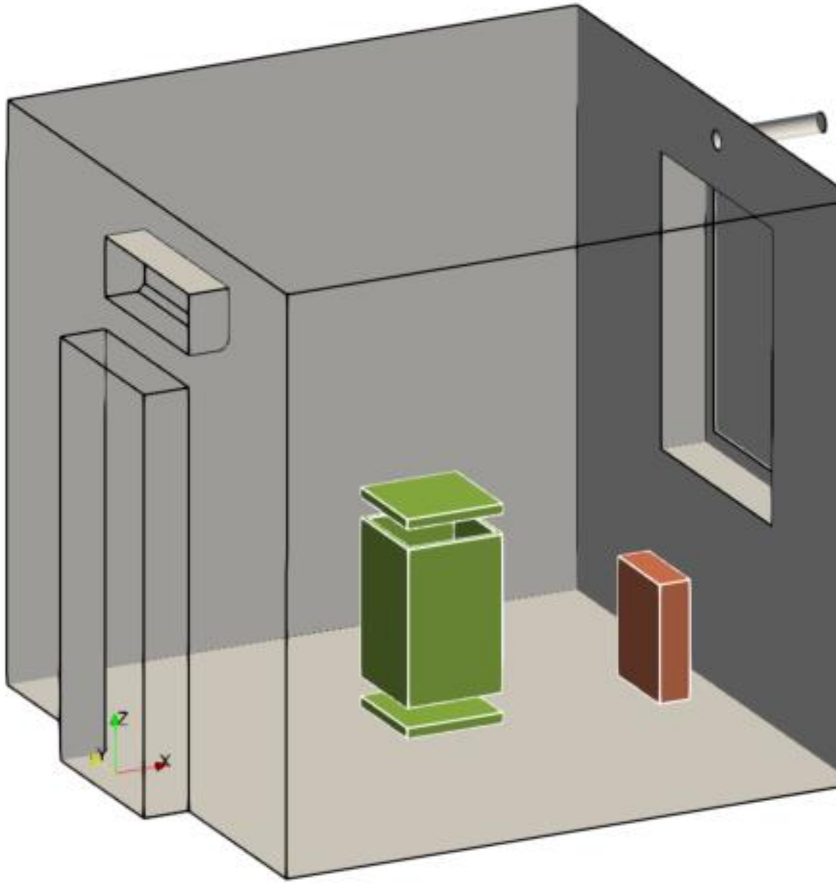
CADR $PM_{2.5} = 12.5 + 23.5 = 36\, m^3/h$

Air purification device model

Passive scalar transport (Euler)

$$\frac{\partial C}{\partial t} + \vec{U}\nabla C = \nabla(D_{\text{eff}}\nabla C) + \frac{S\,C}{V}$$

- Sink term S inside of purifier
  $\eta = 99.26\%$
- $0.5\ m$ wide and $1\ m$ tall
- Flow rate $\mathrm{Q} = 729\ m^3$
- CADR ? – simulation results

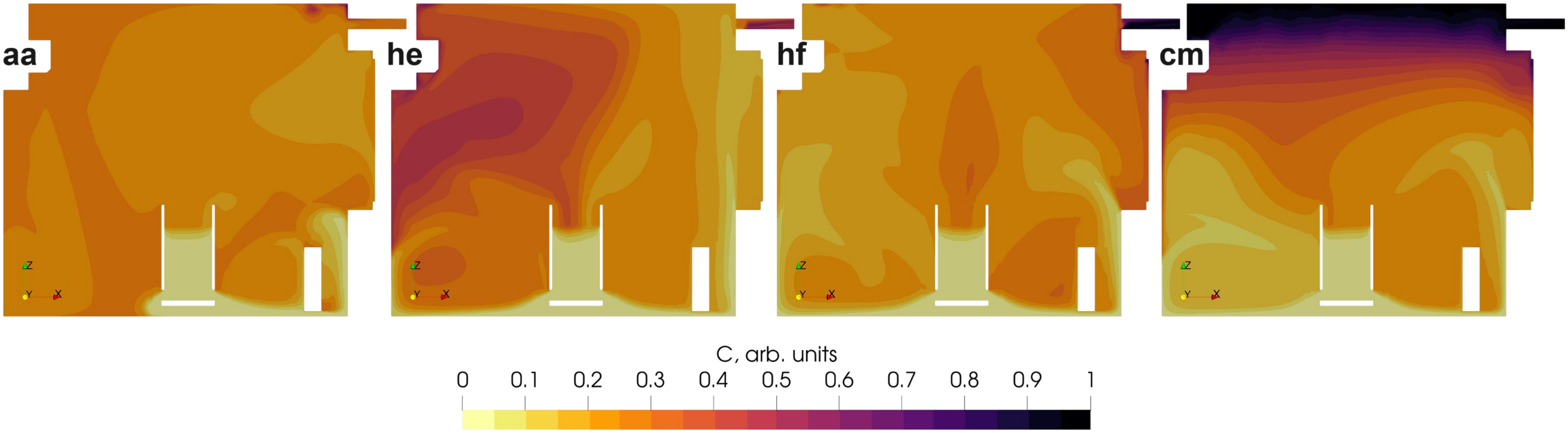


Concentration distributions

Heating regimes

IC: Uniform

$C_0 = 1$



air-air heat pump

heater (radiator)

heated floor

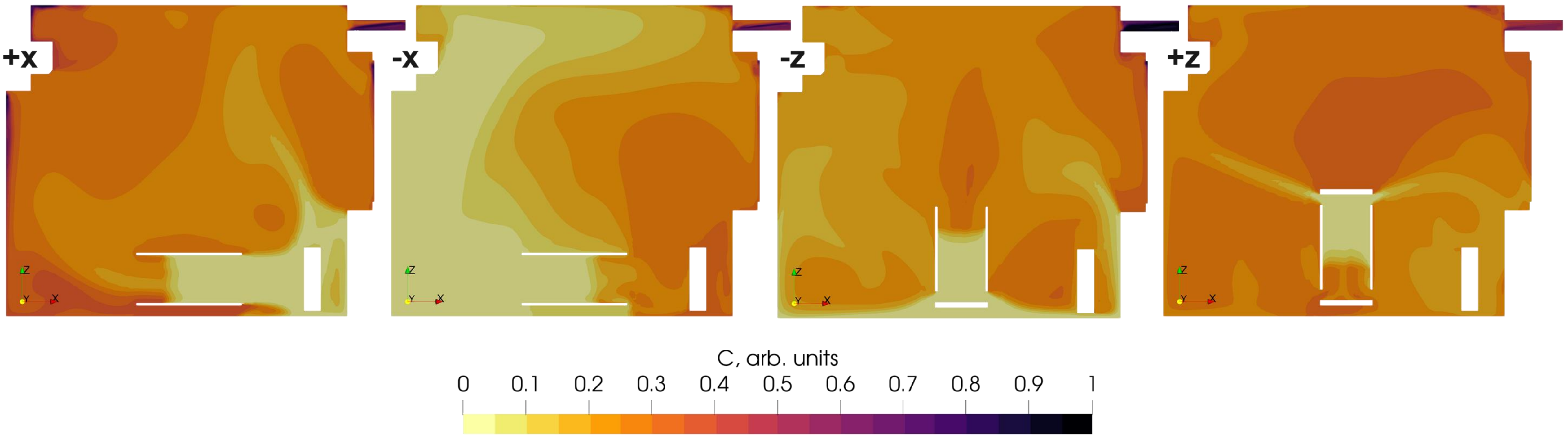
capillary mat (heated ceiling)

Concentration distributions

Device orientation

IC: Uniform

$C_0 = 1$



horizontal towards window	horizontal towards door	vertical downwards	vertical upwards /w top

Results

- Worst CADR – **218** m^3/h (horizontal he -x)
- Best CADR – **581** m^3/h (vertical cm +z)
- Average CADR – **390** m^3/h

1. Heated ceiling 457 m^3/h
2. Heated floor 389 m^3/h
3. Air-air heat pump 362 m^3/h
4. Heater 353 m^3/h

Conclusions

- CADR values can vary highly depending on heating conditions
- Horizontal flow air purifiers show inconsistent results, rank worse
- Heated ceiling shows remarkable improvement in CADR
- Good air mixing does not always equal good air quality

Thanks for the attention!

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Sources

[1] Vuorinen, V., et. al. «Modelling aerosol transport and virus exposure with numerical simulations in relation to SARS-CoV-2 transmission by inhalation indoors» (2020).

[2] World Health Organization. "Roadmap to improve and ensure good indoor ventilation in the context of COVID-19." (2021).

[3] Bahnfleth, William, & DeGraw, Jason. Reducing Airborne Infectious Aerosol Exposure. United States.