Case study #2 – Preventing outbreaks on ground transportation

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Close and distant range of the expired aerosols

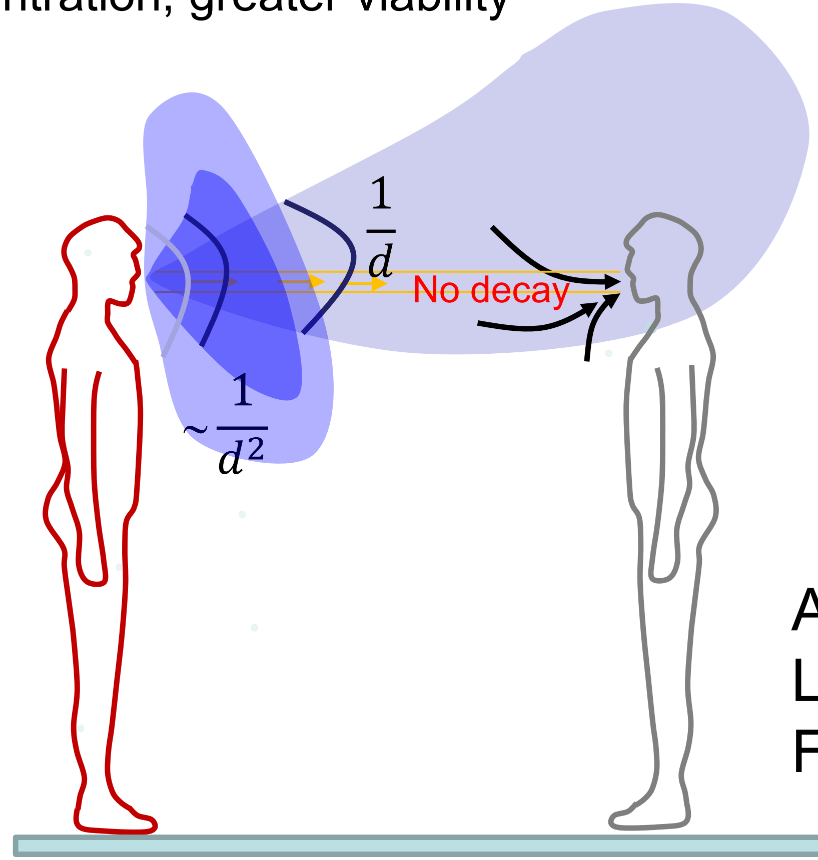
effective dilution air
effective clean air
effective non-infectious air

deactivation filtration

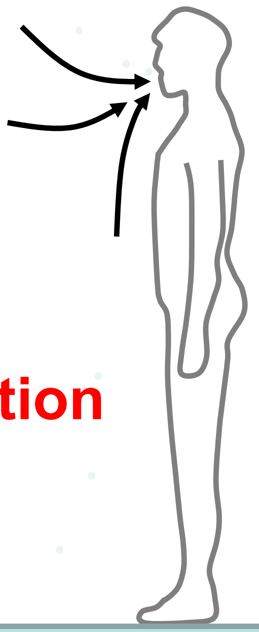
$$q_E = q_v + q_s + q_d + \eta_f q_f$$

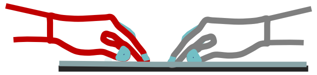
Outdoor air settling

Close range <1.5 m: 0.5-2 m/s; 1 s; <75 μm;
high concentration; greater viability



Distant range : <0.25 m/s; hours, <5-10 μm;
low concentration; low viability





Airborne route → aerosol **inhalation**
Large droplets → drop **spray**
Fomite route → surface **touch**

Li Y, Cheng P and Jia W. 2022. Indoor Air, 32(1), e12946.
Jia W, Wei J, Cheng P, Wang Q and Li Y. 2022. *Building and Environment*, *219*, 109166.

The probable required effective dilution flow rate is 10 L/s per person for ancestral virus and 40 L/s per person for Omicron

$$N_\iota \approx Q \frac{\bar{q}_{in}}{q_e} \overline{\Delta t},$$

$$q_E = q_v + q_s + q_d + \eta_f q_f$$

Effective dilution rate

Ancestral virus

If Q=100 h^{-1}, $\overline{\Delta t}$=1h,

q_e=10 L/s

Omicron

If Q=400 h^{-1}, $\overline{\Delta t}$=1h,

q_e=40 L/s

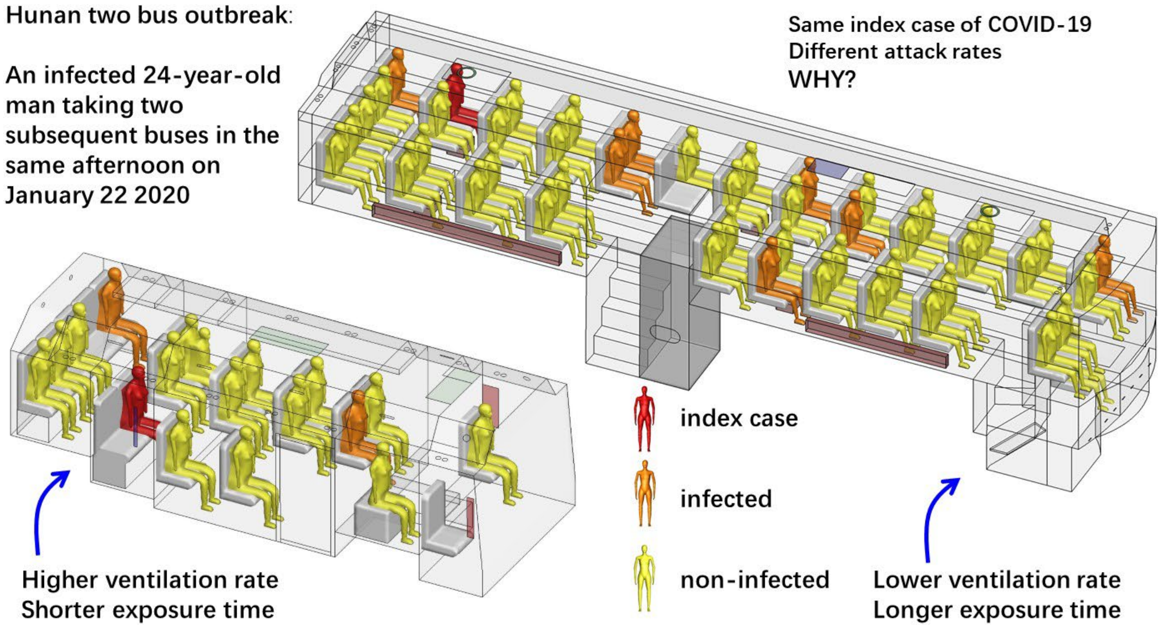
- Mass masking would reduce the ventilation requirement to
- 2.5 L/sp for ancestral virus
- 10 L/sp for Omicron
- Ventilation cannot control close-range within 0.4 m, and social distancing would work

Jia, W., et al., 2022. Building and Environment, p.109674.

Hunan bus outbreak:

The effective dilution rate was only 2.1 L/s per person on B1 and 3.7 L/s per person on B2

$$q_E = q_v + q_s + q_d + \eta_f q_f$$



Due to crowdedness, the contribution from settling and natural decay is small. However, if air conditioning is on, filtration helps.

	B1	B2
persons	46	17
secondary cases	7	2
attack rate (%)	15.2	11.8
q_v outdoor air	1.7	3.22
Exposure time (min)	200	60
q_f filtration	**0**	**0**
q_s settling	0.11	0.11
q_d deactivation	*0.23*	0.22
q_e effective dilution	**2.1**	**3.7**

Ou, et al., 2022. Insufficient ventilation led to a probable long-range airborne transmission of SARS-CoV-2 on two buses. *Building and environment*, *207*, p.108414.

It appears that inflight outbreaks (before Omicron) are not as many considering a crowded space

- Lei et al (submitted) found only 16 inflight outbreaks (Jan 8, 2020 to Jun 9, 2021) with data. Duration 85 min - 18 hrs.

- A total of 41 index cases infected 88 of the 1,326 passengers, with an overall attack rate of 6.6%.

- Historically only 15 influenza outbreaks, and 4 SARS outbreaks reported.

- Effective dilution rate $q_e \approx 10 \frac{L}{s.p}$

$$q_E = q_v + q_s + q_d + \eta_f q_f$$

Air flow per person L/s.p	**Narrow-body**	**Wide-body**
q_v outdoor air	4.2	5.7
q_f filtration	5.2	6.1
q_s settling	0.08	0.13
q_d deactivation	*0.18*	0.28
q_e effective dilution	**9.7**	**12.2**

Walkinshaw, D.S., 2011. Germs and flying: developing ventilation system criteria. *SAE International Journal of Aerospace*, *4*(2).

Existing ventilation standards for ground transportation

- 2.8 L/s.p on bus (CJ/T 134-2001 GB7248-2012)
- 2.8-8.3 L/s.p in subway station: (GBT 51357-2019).
- 2.7-4.2 L/s.p railway (BS EN 14750-1:2006)
- CO_2 2500 ppm (level 1) and 3500 ppm (level 2) on bus, railways and ferries (Hong Kong ProPECC PN 1/03, 2/03, 1/15)

Harvard University shuttle bus in 2008. CO_2 went up to 2862 ppm

S. Zhu et al. / Building and Environment 45 (2010) 2077–2088

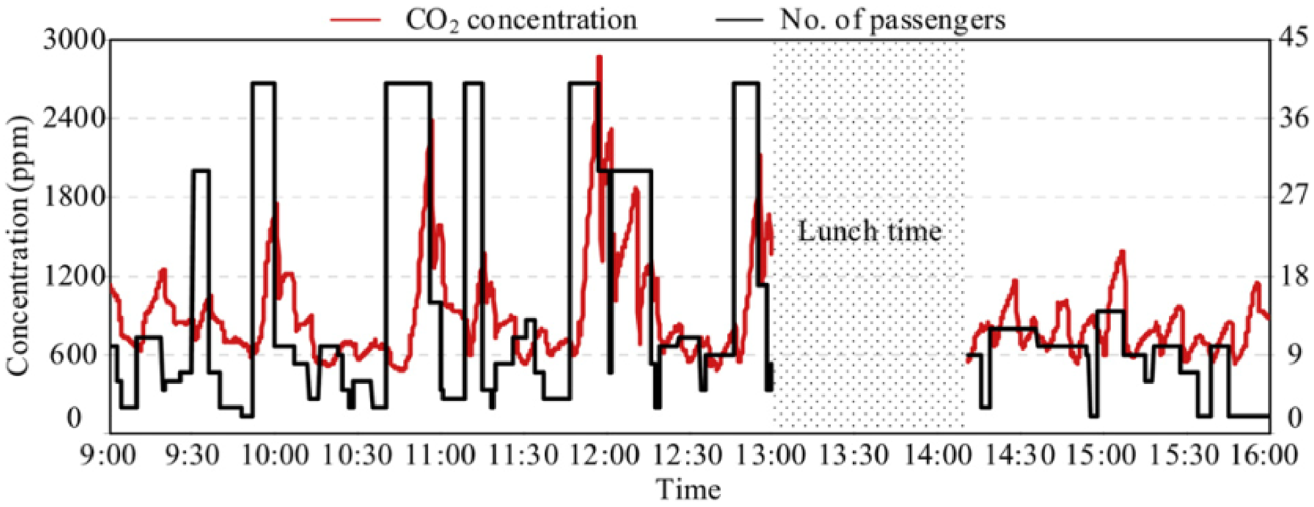


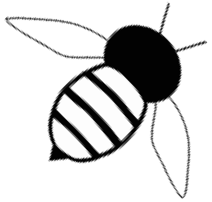
Fig. 11. CO_2 concentration level and occupancy condition in the bus as a function of time (Nov. 19th).

Zhu, S., Demokritou, P. and Spengler, J., 2010. *Building and Environment*, *45*(10), pp.2077-2088.

Recommended measures

- For long-range inhalation, provide 10 L/s per person dilution (outdoor air, filtration and GUV) and wear masks

- Optimize boarding/alighting dynamics to minimize close-range contacts



Thank you