AGRICULTURE CONSTRUCTION SHIPPING ENGINEERING AVIATION TRANSPORT PACKAGING OIL AND GAS
ELECTRONICS PHARMACEUTICALS COMPUTING CLEANING COMMERCE CHEMICALS FOODSTUFFS SERVICES

Southern African Institute for Occupational Hygiene

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Ventilation and COVID-19

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Content

To achieve the following understanding:

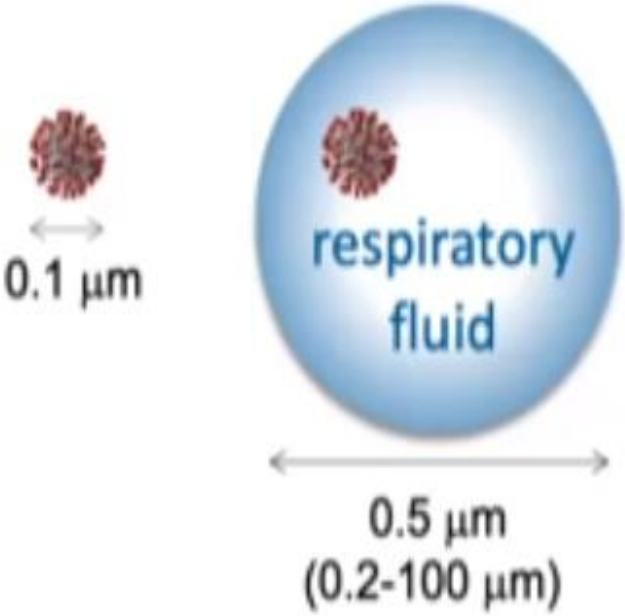
- Transmission mechanisms
- Types of ventilation systems
- Controls / recommendations specific to COVID-19

Notes:

This presentation pulls the outstanding work of multiple people / organisations together particularly Dr Greg Kew, REHVA, AIHA & ASHRAE

Size of Droplet / Aerosol Critical

1. Airborne virus is not naked
2. Size of carrier droplet/aerosol defines transport



- How long it stays aloft
- How far it can travel
- How quickly it falls to surfaces
- Where it deposits in the respiratory system
- How efficiently it is removed by masks and filters
- Physics is the same for all viruses

Not only N95 & HEPA

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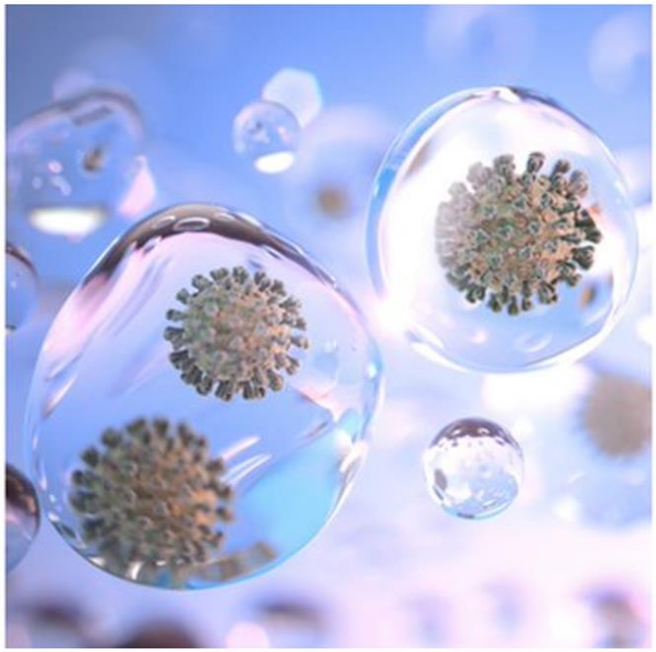
Many visualizations are incorrect

Incorrect

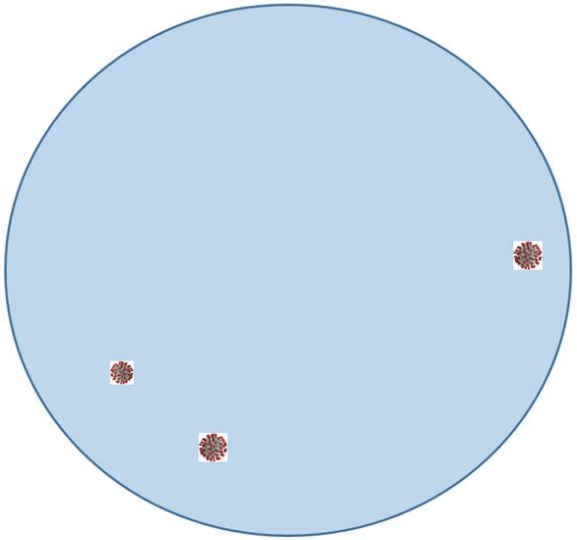
- Aerosols too small relative to the virus (look like 0.2-0.3 um)
- Looks like water + virus only
- Mass fraction of virus very high



From Klompas et al., JAMA (2020)
https://jamanetwork.com/journals/jama/fullarticle/2768396

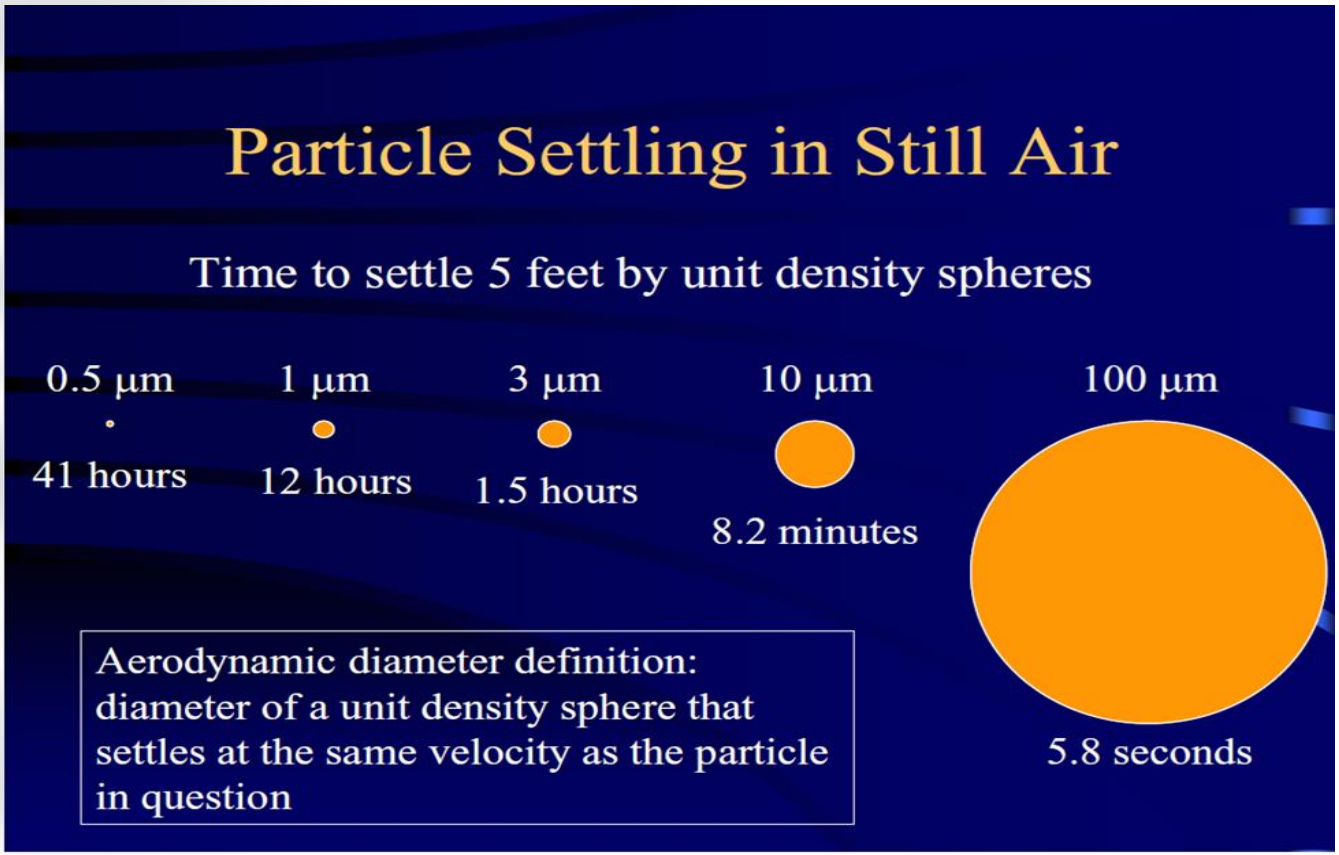
More correct

- More typical: few micron aerosol
- Mucin, NaCl, water + sprinkle of virus
- Mass fraction of virus very low



Droplets vs Aerosols

- "Droplets traditionally have been defined as being >5 µm in size https://www.cdc.gov/infectioncontrol/guidelines/isolation/scientific-review.html
- CDC also say: web page, "Aerosols 101" presentation: https://t.co/HXnHGnf2up?amp=1



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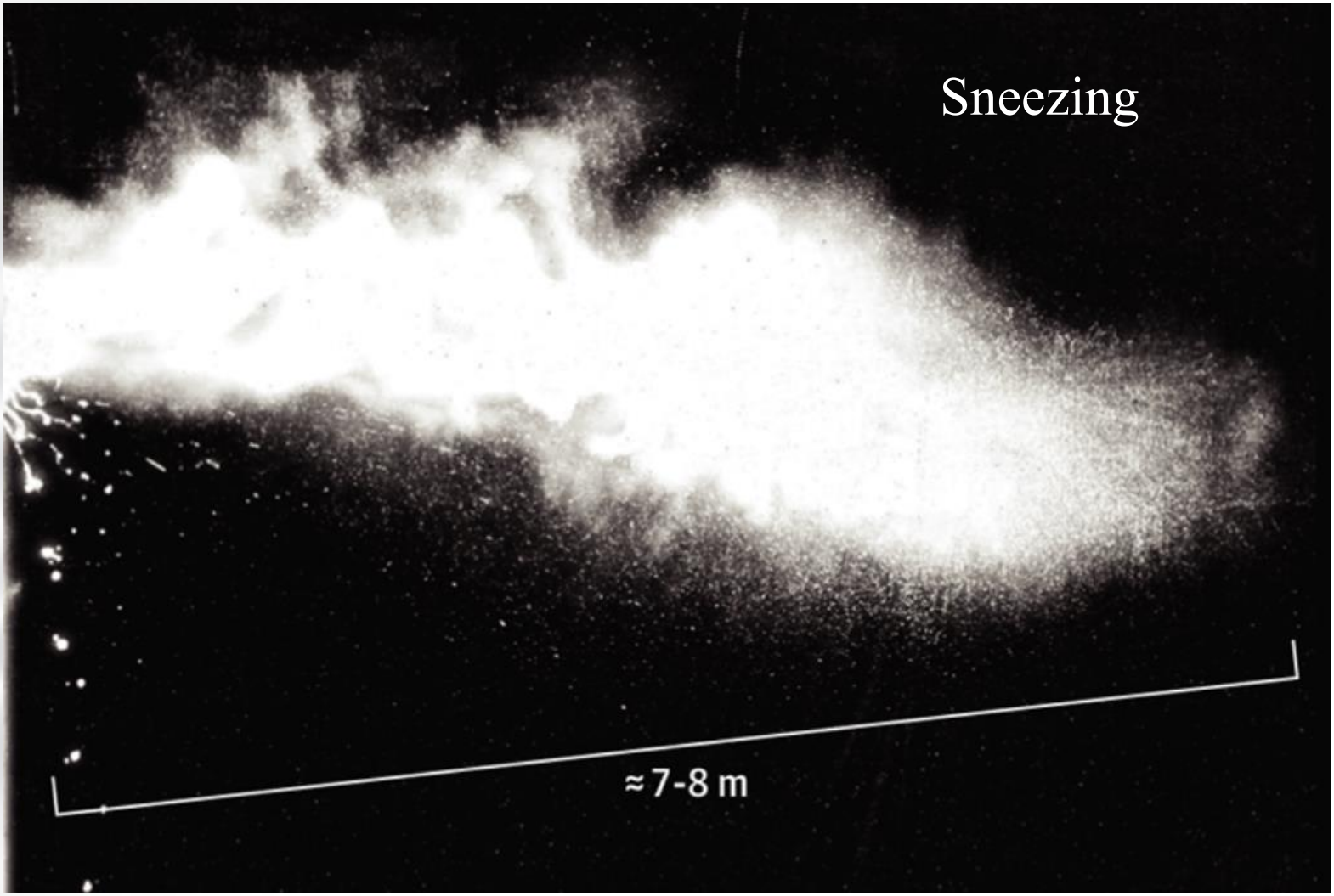

Speaking produces 100x more aerosol than droplets

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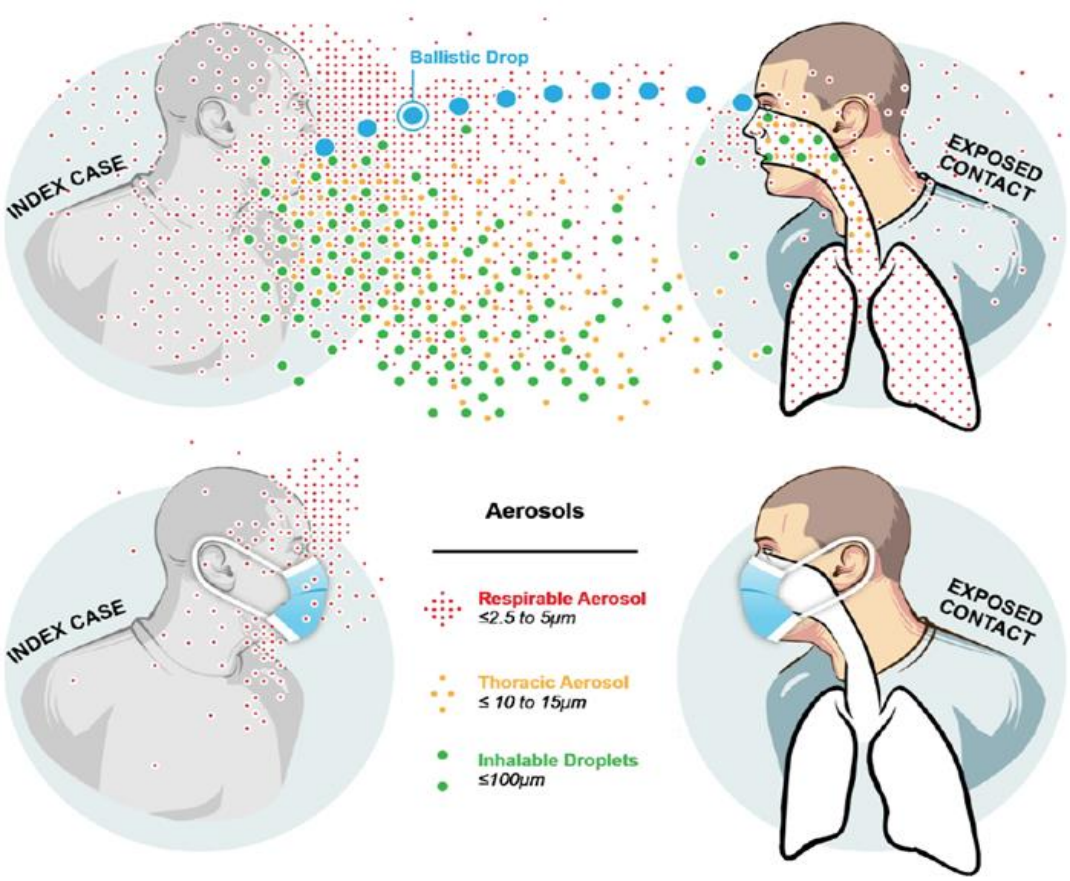
COVID-19 Airborne disease

It is Time to Address Airborne Transmission of COVID-19

Lidia Morawska1,*,
Donald K. Milton2

239 scientists signed commentary



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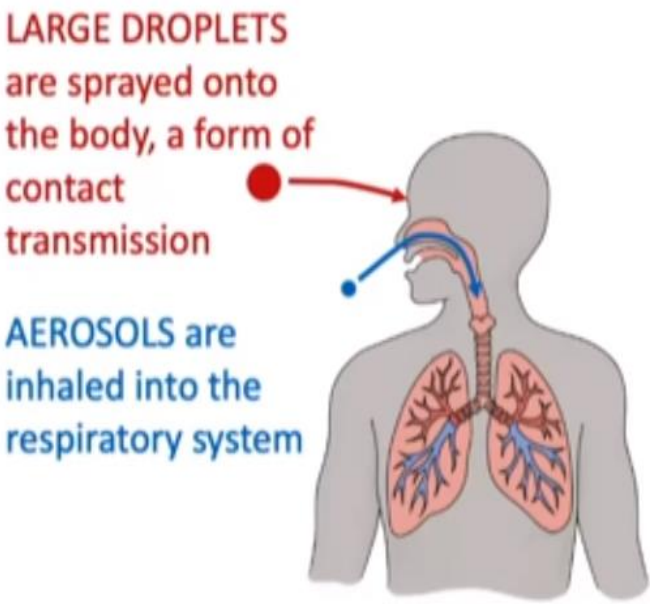
Defining transmission by Exposure path

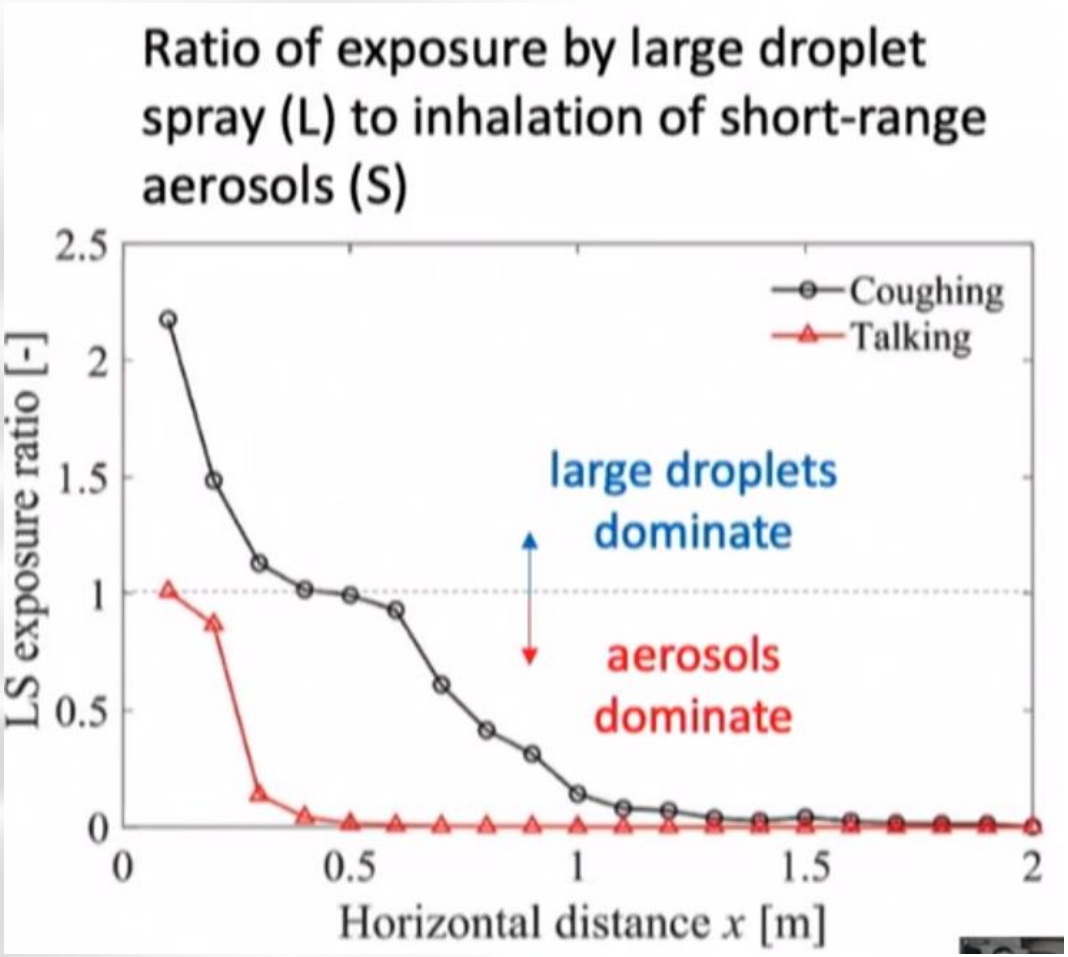
Droplets / Aerosol ***inside*** the body & ***outside*** the body are different sizes – important for ventilation

Inside the body:
RESPIRATORY VS NON-RESPIRATORY
> 5µm URT < 5µm LRT



Outside the body:
DROPLETS, physics based cut-off ***60-100µm***
Sprayed: Ballistic drops > 100µm, direct hit on eye nostril or mouth

Transmission: Droplets vs Aerosols



Primary transmission mechanism of COVID-19 is through aerosol not large droplets

Measles has R0 of 15
COVID-19 has R0 of 5.7, flu has R0 of 1.3

COVID-19 does not spread between floors on multi-story buildings

Measles is a high-contagiousness aerosol-driven disease. COVID-19 is likely a lower-contagiousness aerosol driven disease. It infects best at close proximity, also at the room scale if we "help it along" (indoors, low ventilation, long time, no masks). And it has trouble infecting at long range [1]

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Evidence vs. Modes of Transmission

	Droplets	Fomites	Aerosols
Outdoors << Indoors	X	✓	✓✓
Similar viruses demonstrated	X	✓	✓
Animal models	?	✓	✓
Superspreading events	X	X	✓✓
Supersp. Patterns similar to known aerosol diseases	n/a	n/a	✓
Importance of close proximity	✓	X	✓✓
Consistency of close prox. & room-level	X	X	✓
Physical plausibility (talking)	X	✓	✓
Physical plausibility (cough, sneeze)	✓	✓	✓
Impact of reduced ventilation	X	X	✓
SARS-CoV-2 infectivity demonstrated in real world	X	X	✓
SARS-CoV-2 infectivity demonstrated in lab	X	✓	✓
"Droplet" PPE works reasonably well	✓	✓	✓
Transmission by a/pre-symptomatics (no cough)	X	✓	✓
Infection through eyes	✓	✓	✓
Transmission risk models	✓	✓	✓

Key:
✓: evidence
✓✓: very strong ev.
X: no evidence
X: evidence against
n/a: not applicable

More details and references: http://tinyrul.com/aerosol-pros-cons Only including the items that could bear on multiple pathways. See other slides for details and references

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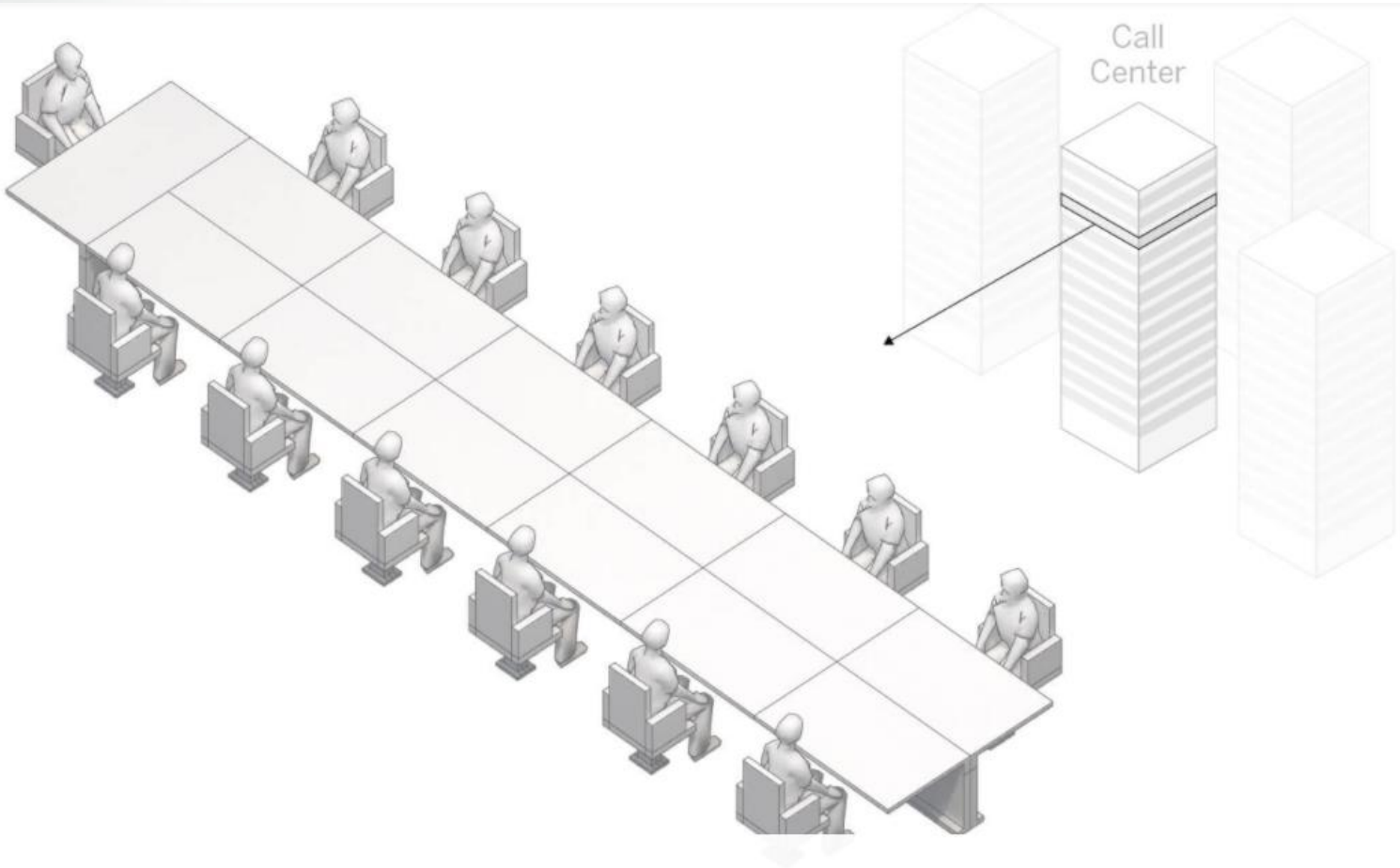
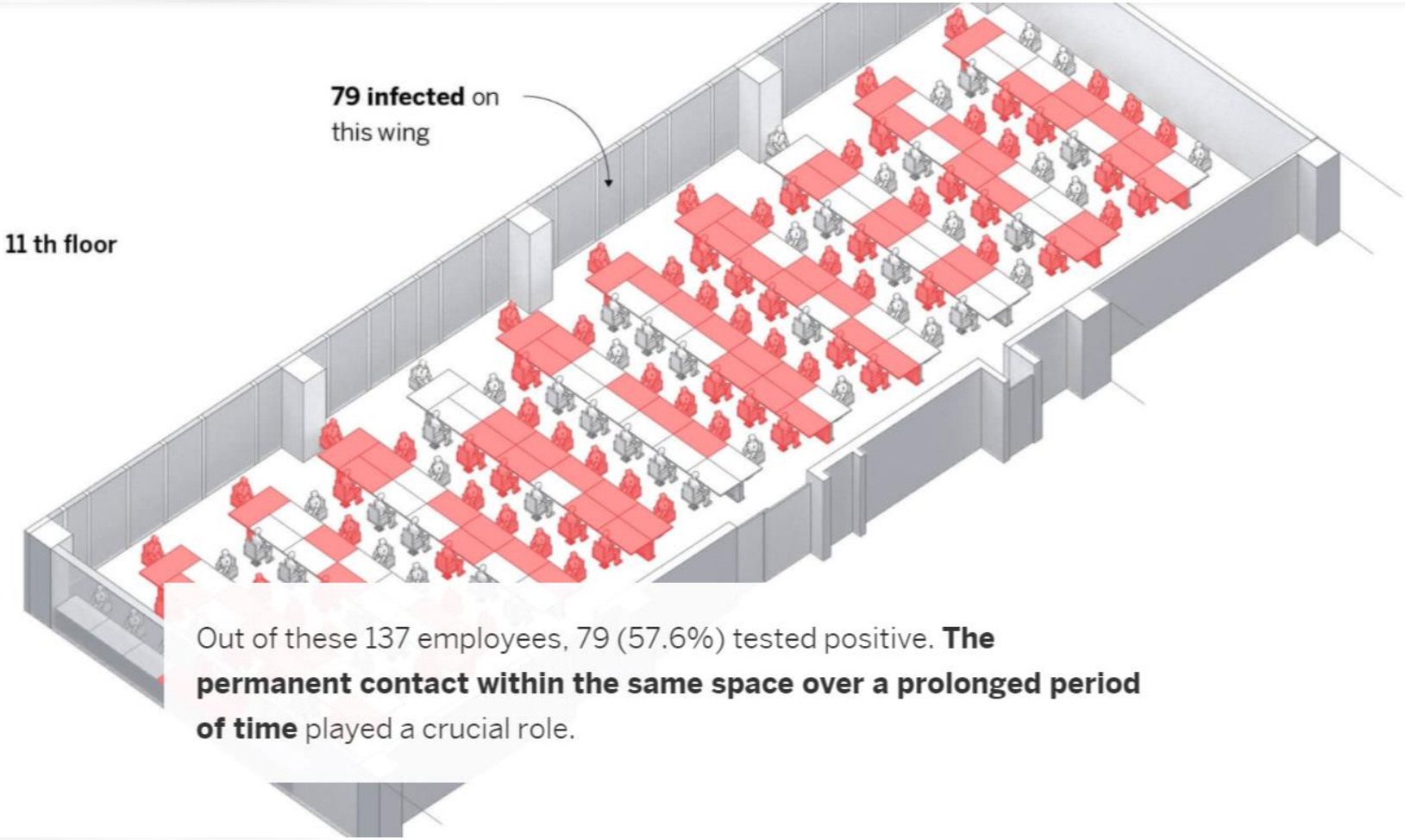
S Korea – call centre

South Korea



The staff at the call center on the 11th floor **work together** at desks containing 13 work stations.

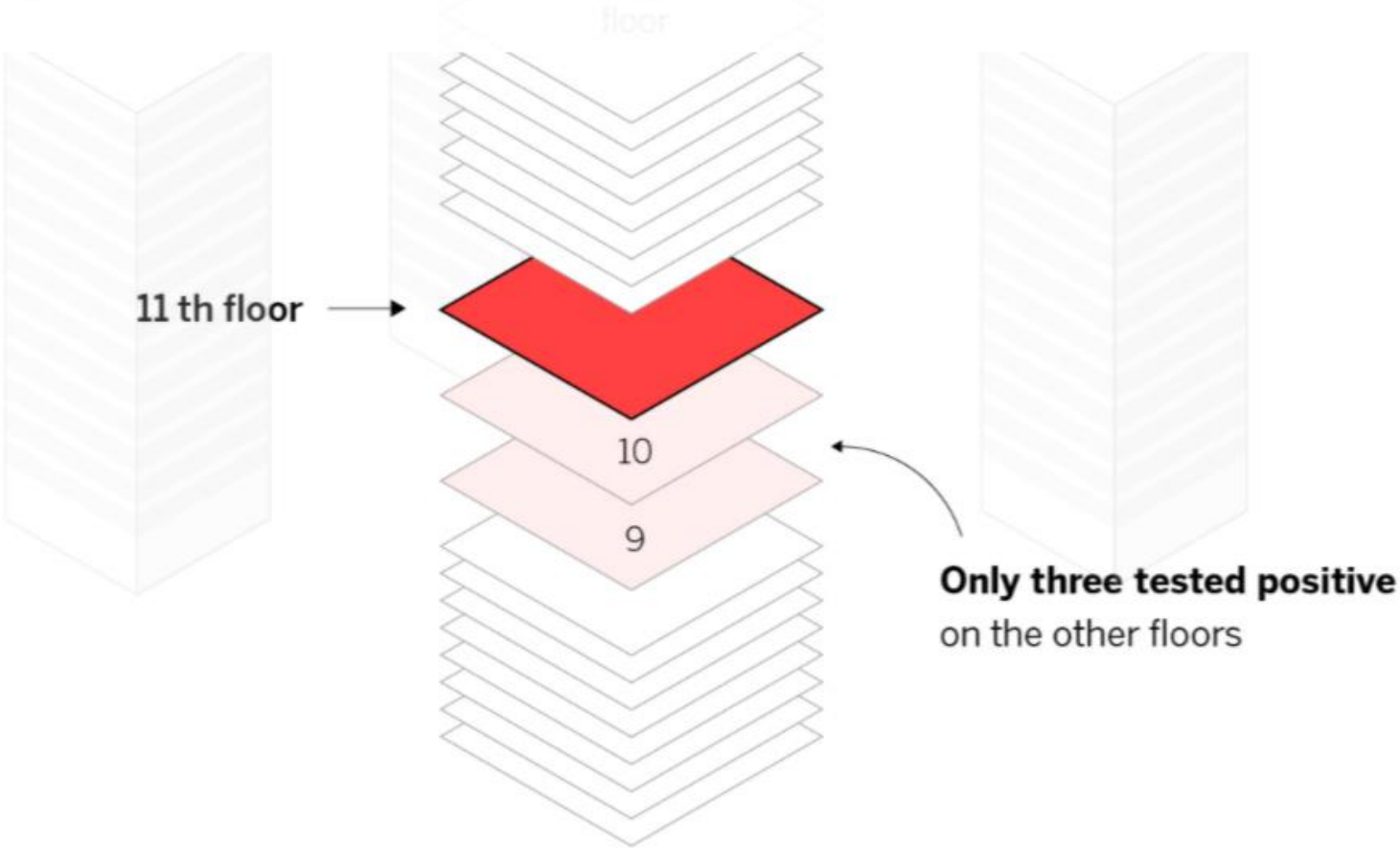
S Korea – call centre



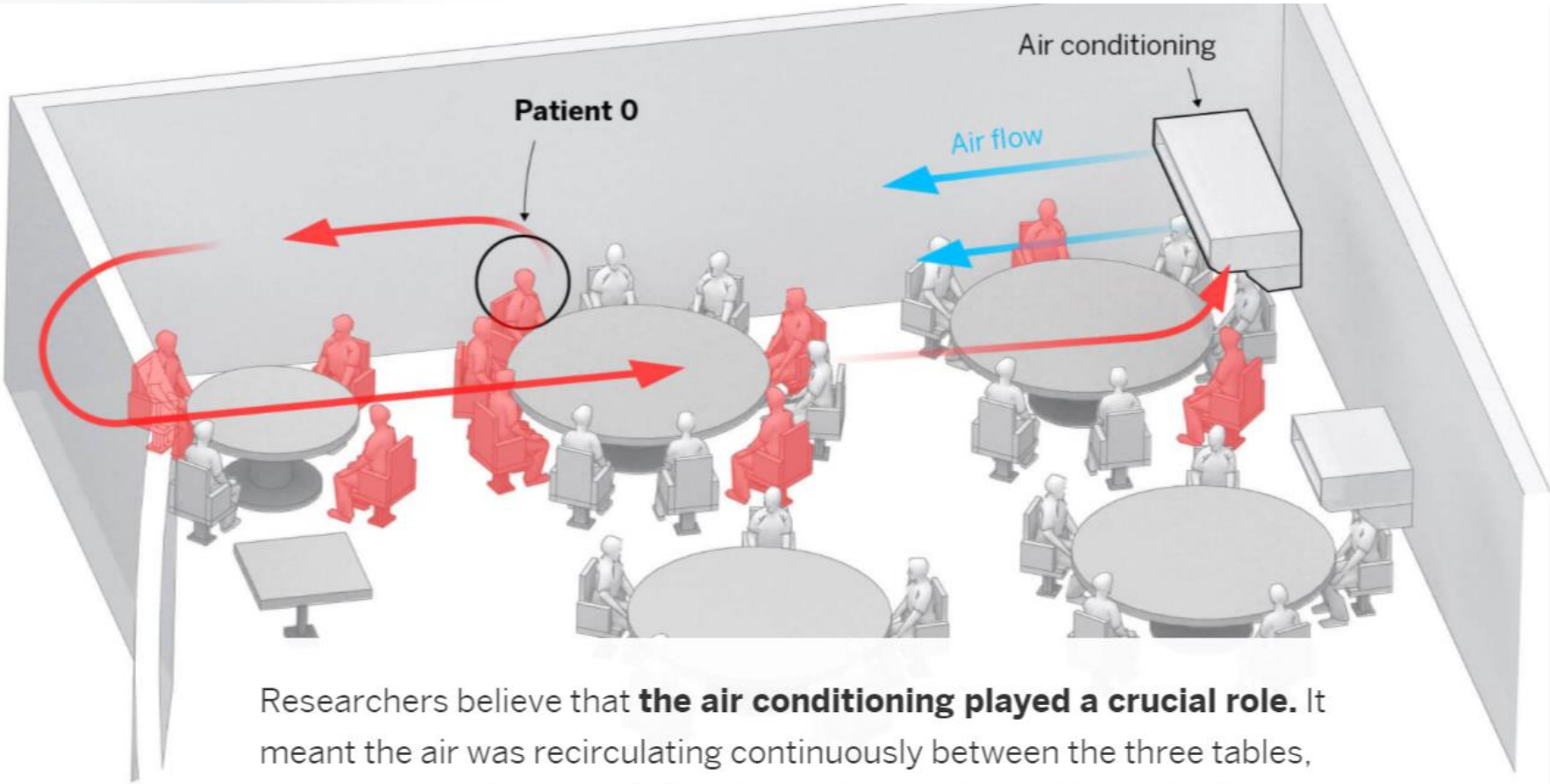
Out of these 137 employees, 79 (57.6%) tested positive. **The permanent contact within the same space over a prolonged period of time** played a crucial role.

S Korea – call centre

In the rest of the building, **only three people tested positive** out of 927 who underwent checks (0.3%) despite the fact they shared lobbies, elevators and other communal areas.



Chinese Restaurant



Researchers believe that **the air conditioning played a crucial role.** It meant the air was recirculating continuously between the three tables, concentrating the tiny, **virally charged micro-droplets** that Patient 0 was expelling into the atmosphere among these customers.

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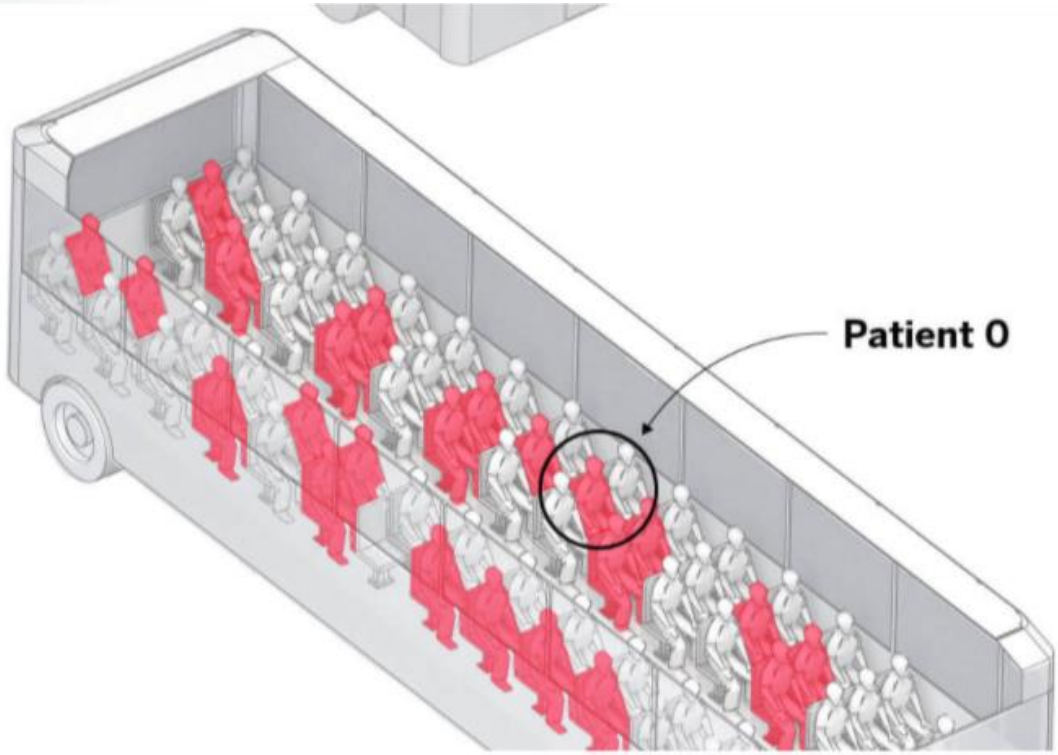
Chinese – Buddhist bus

23 infected from Covid-19 on the bus

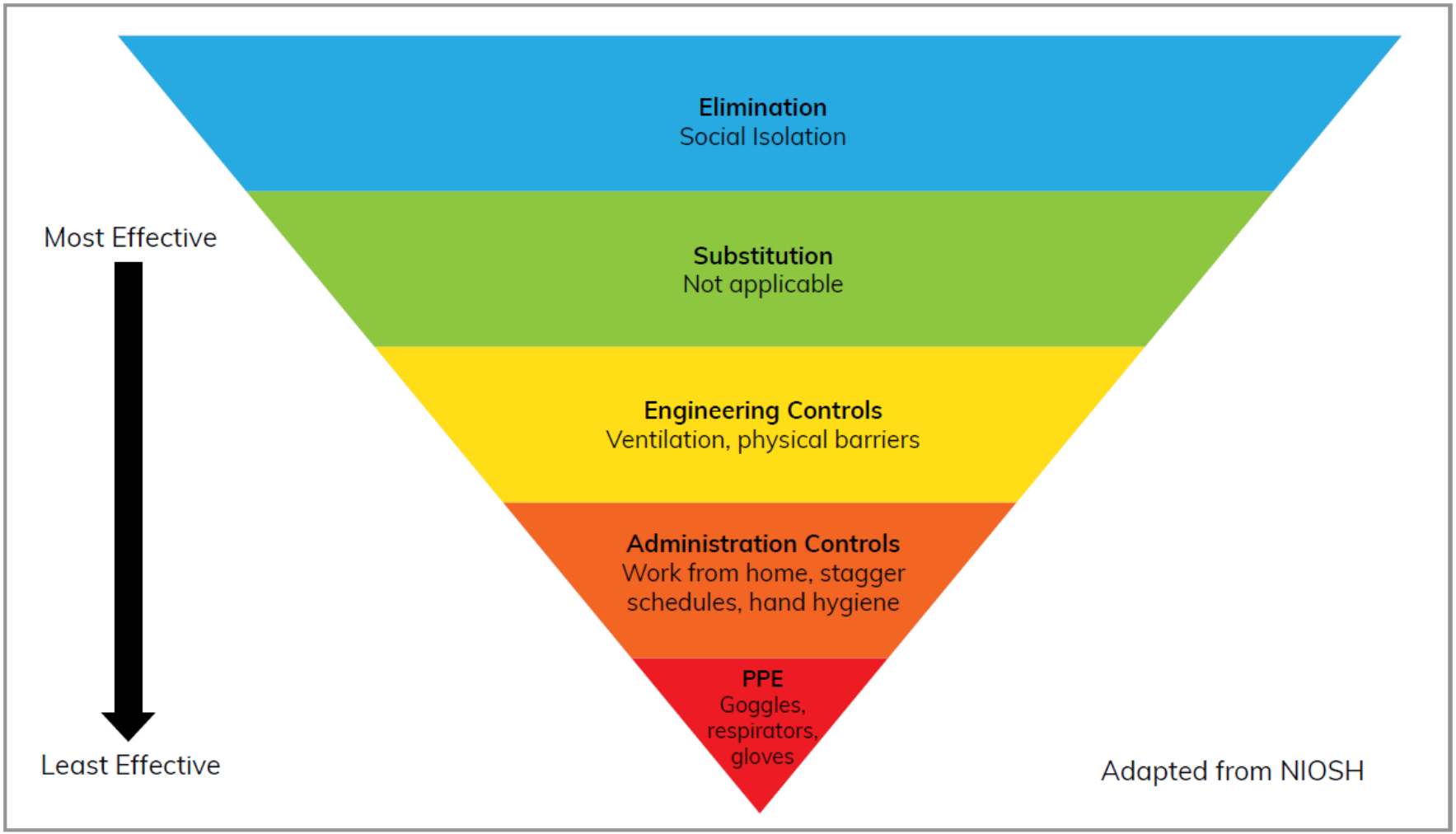


In total, **23 people got infected** on the bus. No one became ill on the other bus, despite the fact they were all mixing at the ceremony.

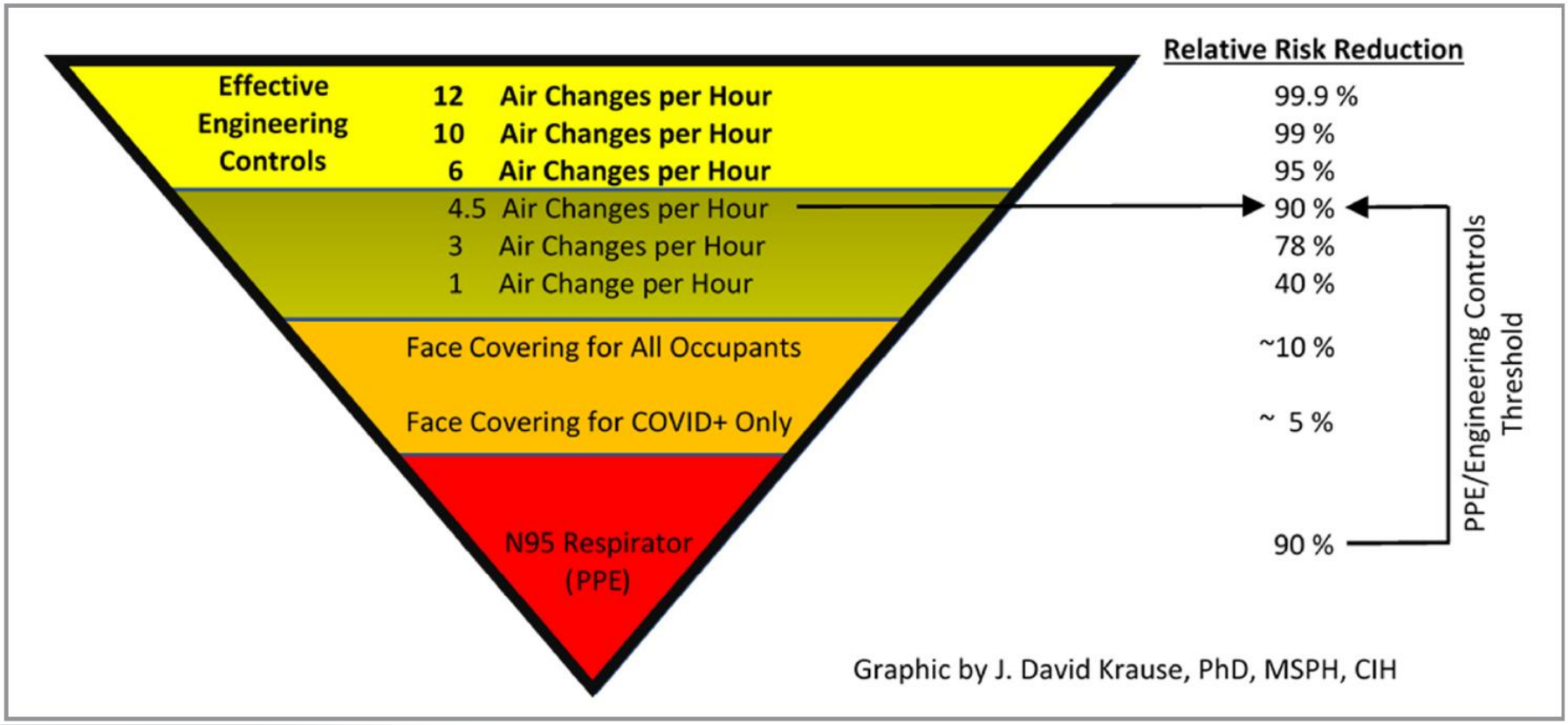
Definition ventilation

Ventilation (alternate definition)
Designed supply and removal of air to and from a treated space. (EN 12792)

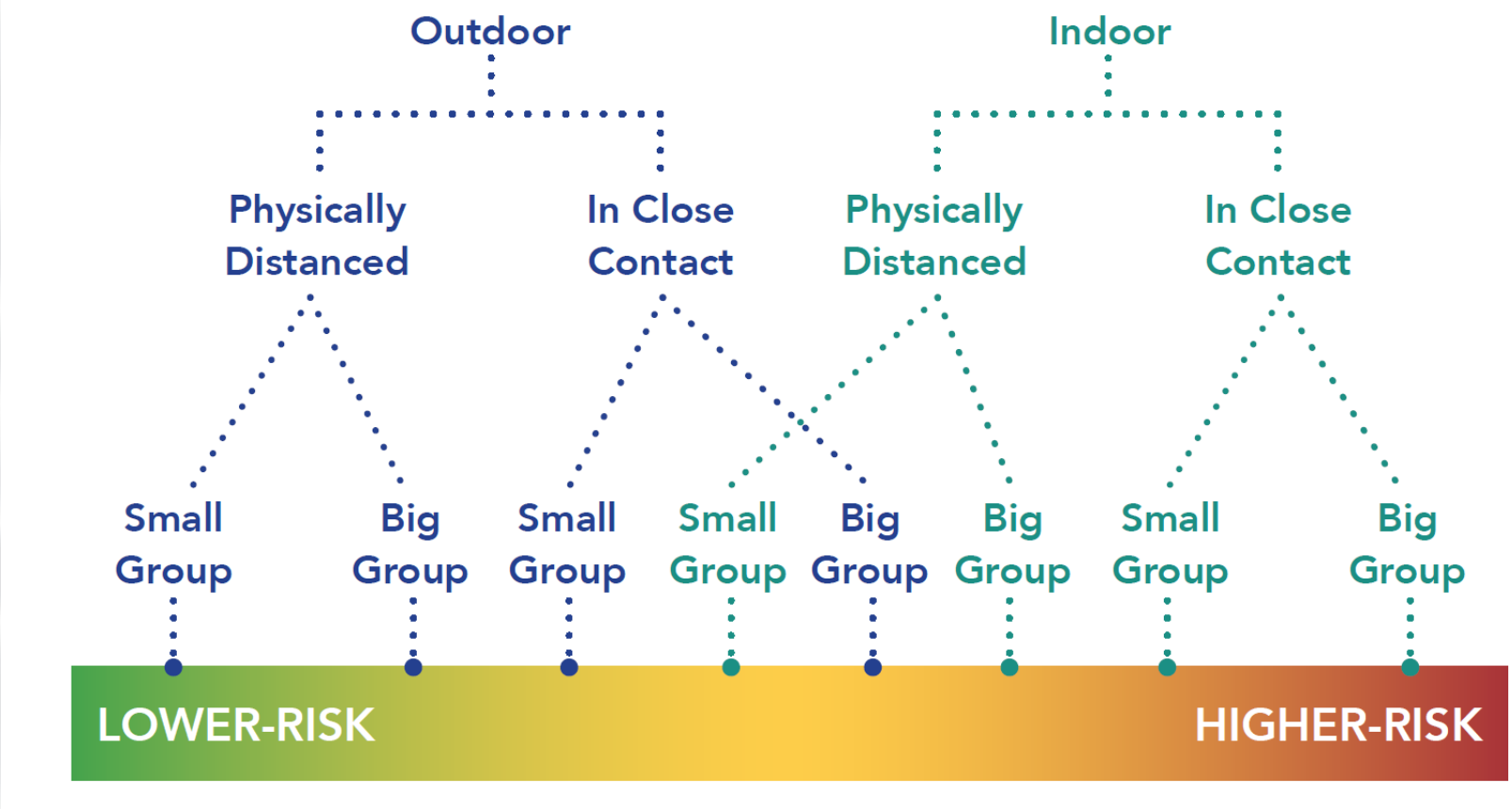
Not all barriers are equal



% Risk reduction

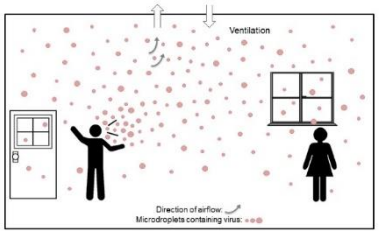


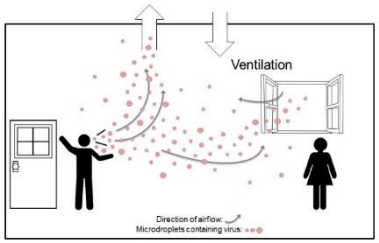
Risk assessing meetings



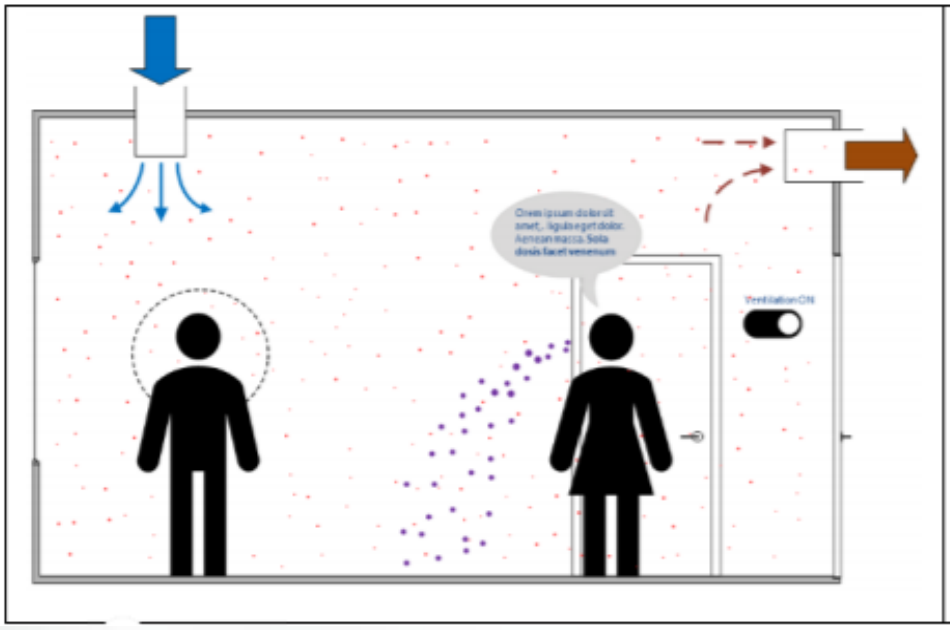
Virus concentration & ventilation

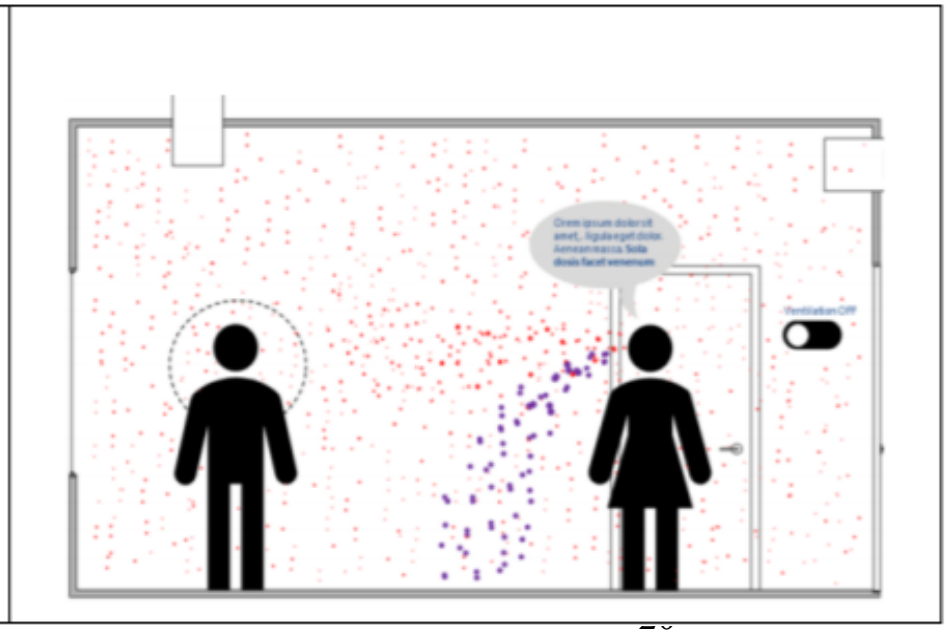
The particles generated by respiratory activities are small enough to stay suspended in the air for a long time…





…unless they are removed from the air by ventilation (and other processes).





Ventilation STD's – South Africa

SANS 10400-O (2011): Buildings either naturally ventilated (4.3.1) or artificially ventilated (4.3.2).

ARTIFICIAL

Type of occupancy	Minimum outdoor air requirements		Requirement
	Air changes per hour	L/s per person	
Educational buildings			
Classrooms	2	7,5	Air supply required per person with required minimum air changes per hour
Laboratories	2	7,5	
Libraries	2	6,5	
Health care facilities			
Surgical and critical care:			
Operating theatres and suites	20	–	Pressure relative to adjacent area shall be positive
Wound intensive care (burns)	6	–	Pressure relative to adjacent area shall be positive
Critical and intensive care, treatment and delivery rooms	6	–	Pressure relative to adjacent area shall be positive
Trauma, ER waiting rooms, radiology waiting rooms and triage	12	–	Pressure relative to adjacent area shall be negative

2 ACPH – allows comfort & prevents body odour – doesn't smell stuffy
12 ACPH – prevents transmission of HBA – Influenza / COVID-19

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Current ASHRAE CO2 guidance

- Research shows ASHRAE guidance of 700 ppm above ambient does not prevent measles, influenza, or rhinovirus in a school or office
- SANS 10400 Part O, EN 16798 and research all align

Cat	Indoor Air Quality	CO_2 above outdoor air (ppm)	Fresh Air Face (L/s/person)
IDA1	High	<400	>15
IDA2	Medium	400-600	10-15
IDA3	Moderate	600-1000	6-10
IDA4	Low	>1000	<6

Indoor Air Quality and CO_2 levels and Fresh Air Face delivery (EN 16798)

Require 15L/s per person - approximately 12 ACPH

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CO2 – proxy for SARS CoV2 concentrations

- Recommended COVID-19 guidance for CO2 = <400 above ambient / 800ppm
- Practically continuous CO2 dataloggers should be set to alarm at 800ppm

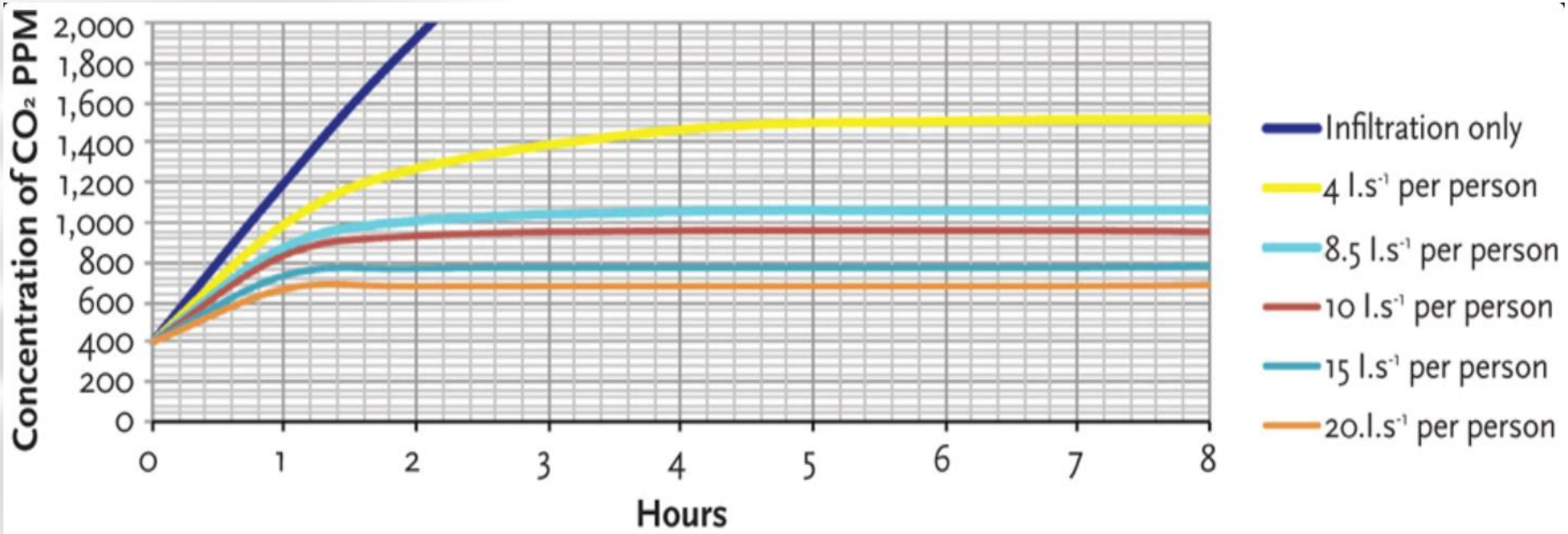
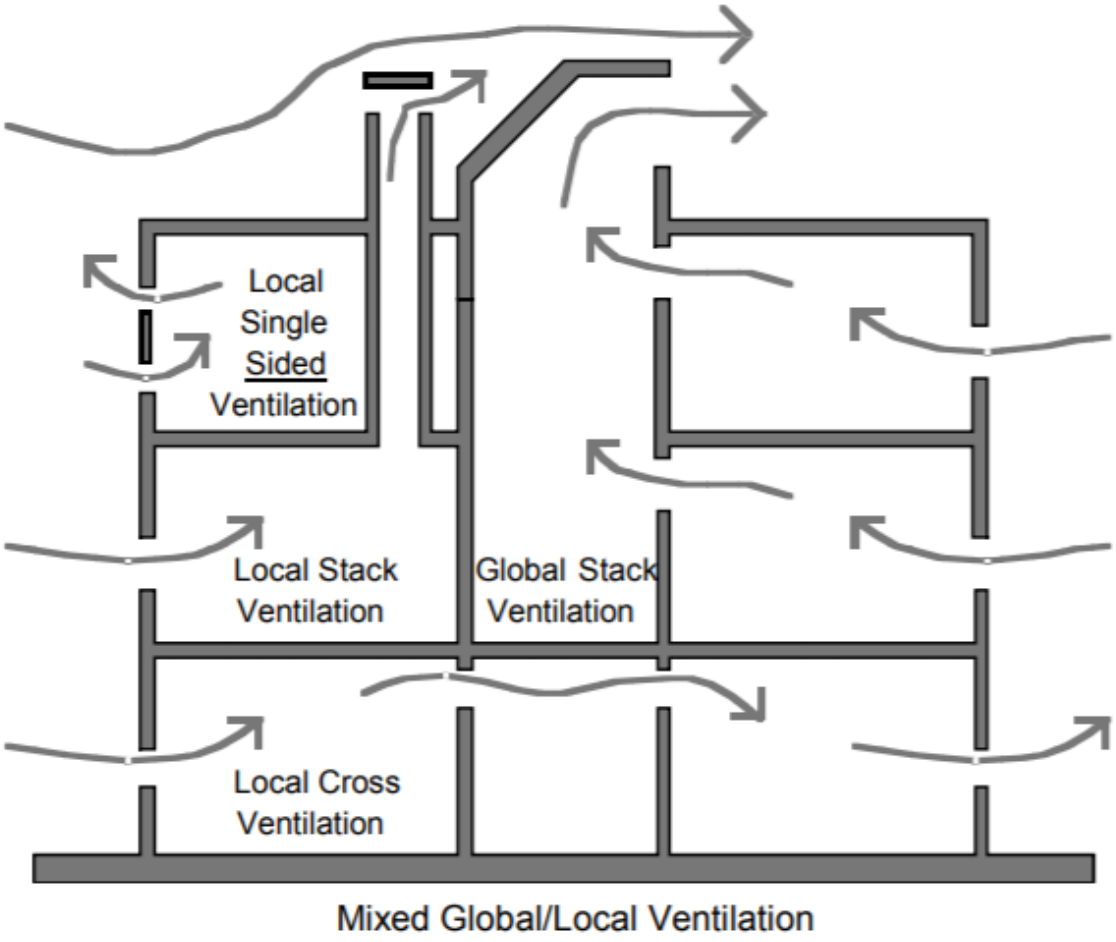


Figure 2: Average room CO_2 levels at various fresh air supply rates for example office with 20 people

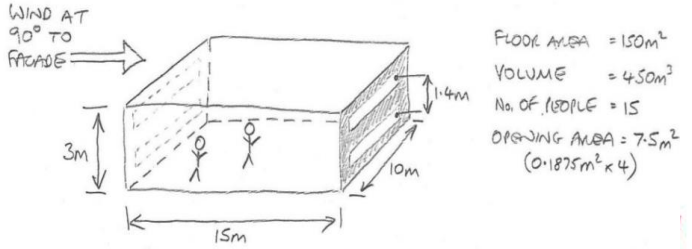
Natural ventilation



Mixed Global/Local Ventilation

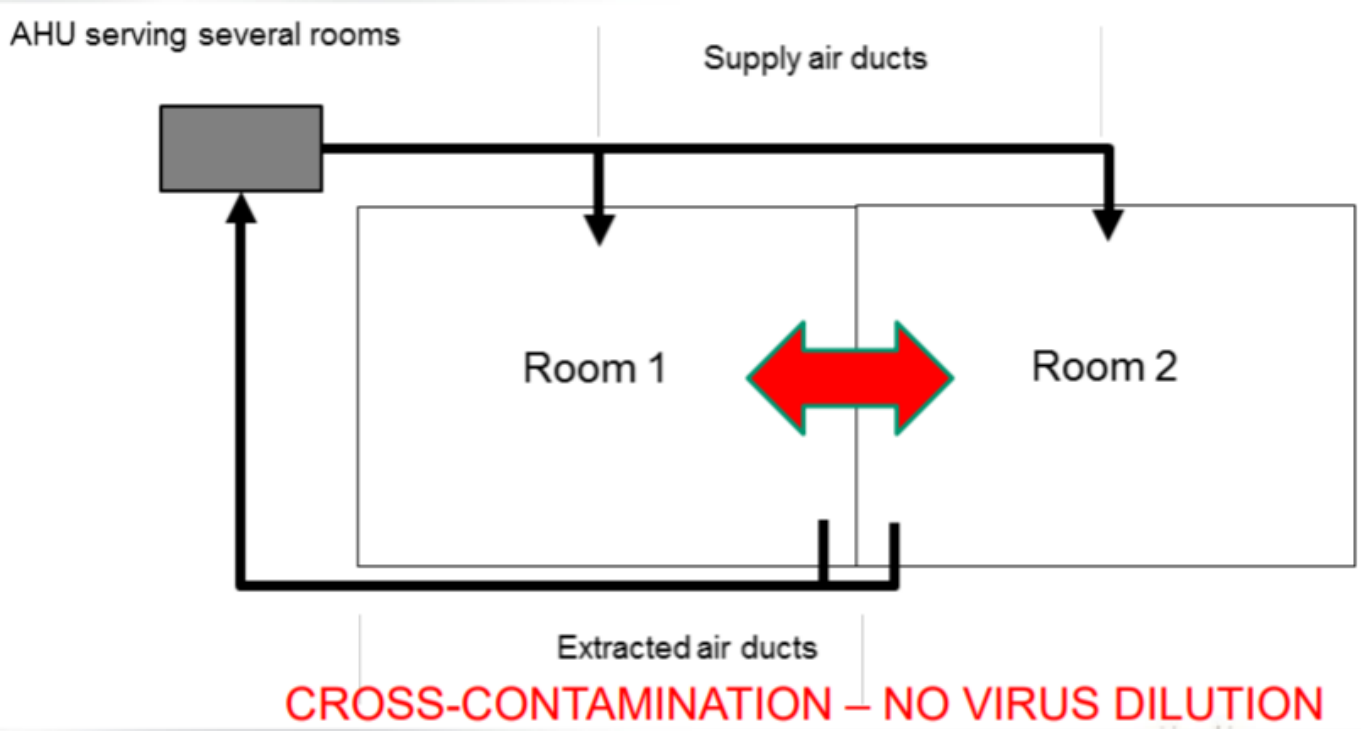
Three fundamental approaches to natural ventilation:

- Wind-driven cross ventilation - preferred
- Buoyancy-driven stack ventilation, and
- Single-sided ventilation

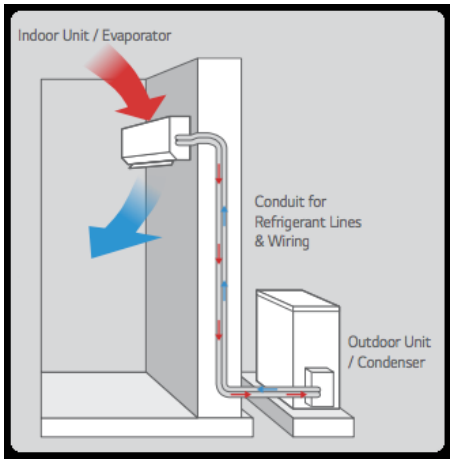


Example building zone with cross ventilation and 5% ventilation openings

Air conditioning system – no ventilation

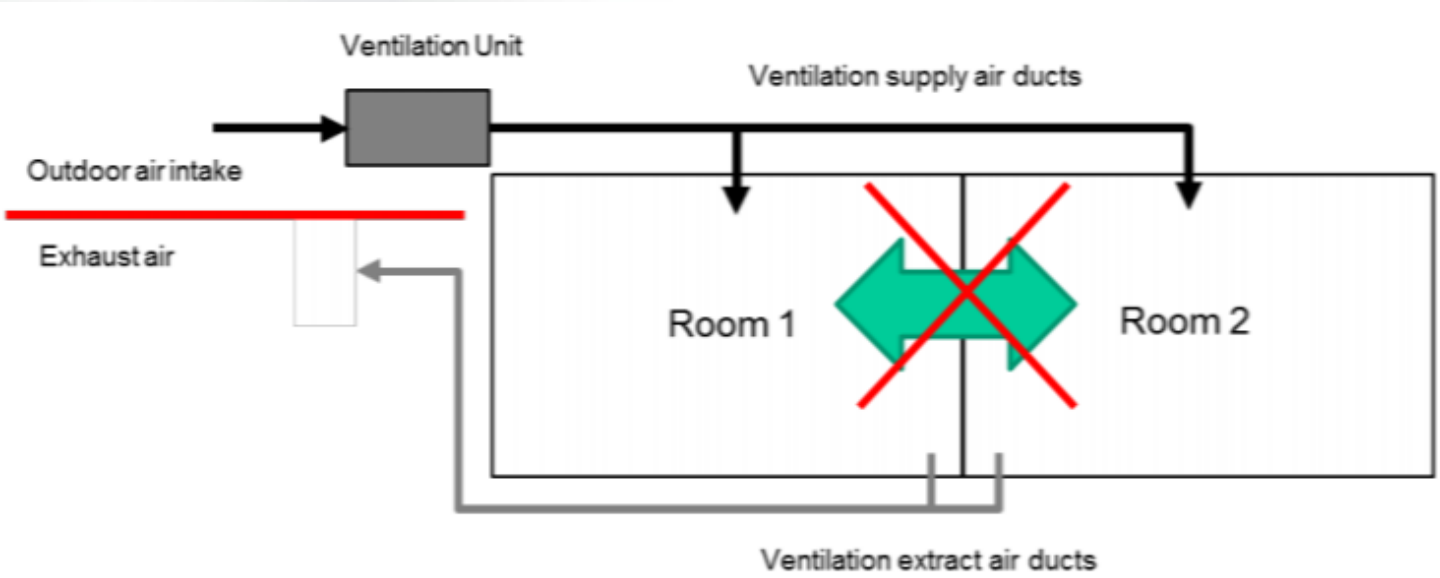


Mid-wall split unit – with no fresh make up air capability does not provide ventilation

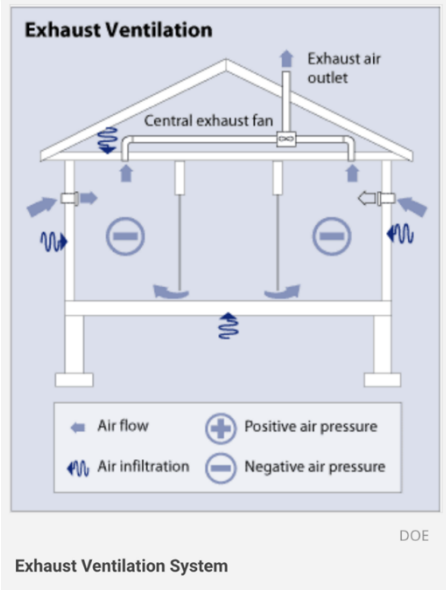


- No artificial ventilation system – only ventilation possible is through opening windows / doors

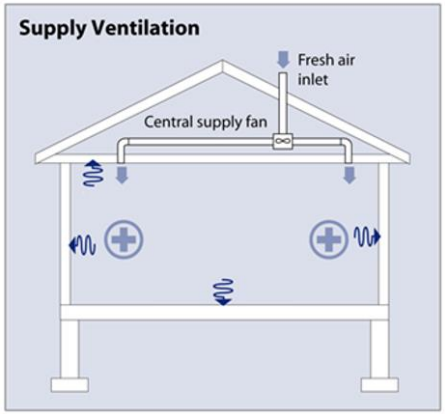
Split unit air conditioner + Mechanical ventilation



NO CROSS-CONTAMINATION AND VIRUS DILUTION



Exhaust Ventilation System



- Supply outdoor air is provided to each room, is extracted and expelled outdoor,
- Virus concentration reduced through dilution with provided outdoor air.

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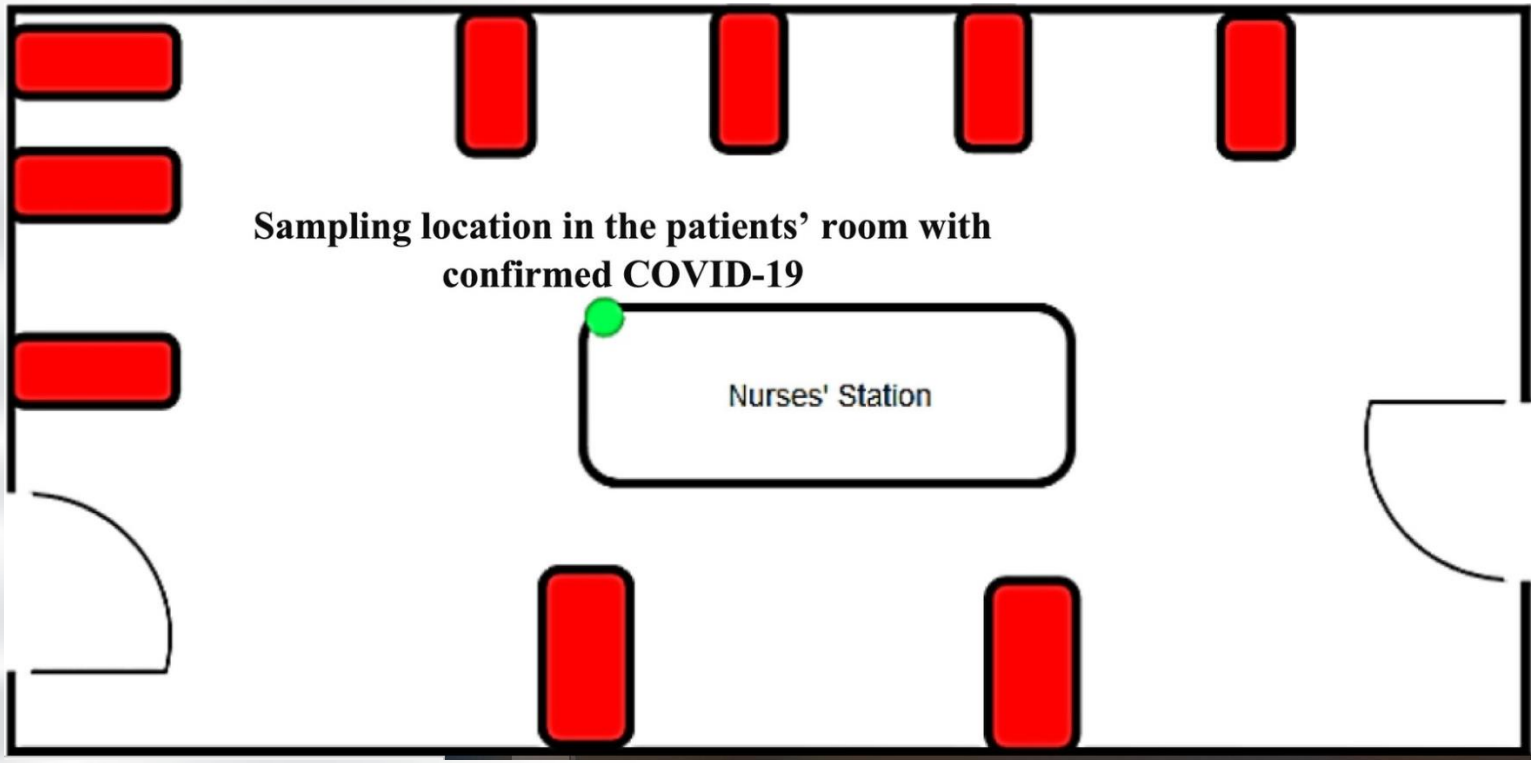
Hospital Positive COVID-19 patients



Hospital evidence: no infection risk at 2 m distance, with ventilation rates at 36 L/s per person

https://doi.org/10.1016/j.scitotenv.2020.138401 –

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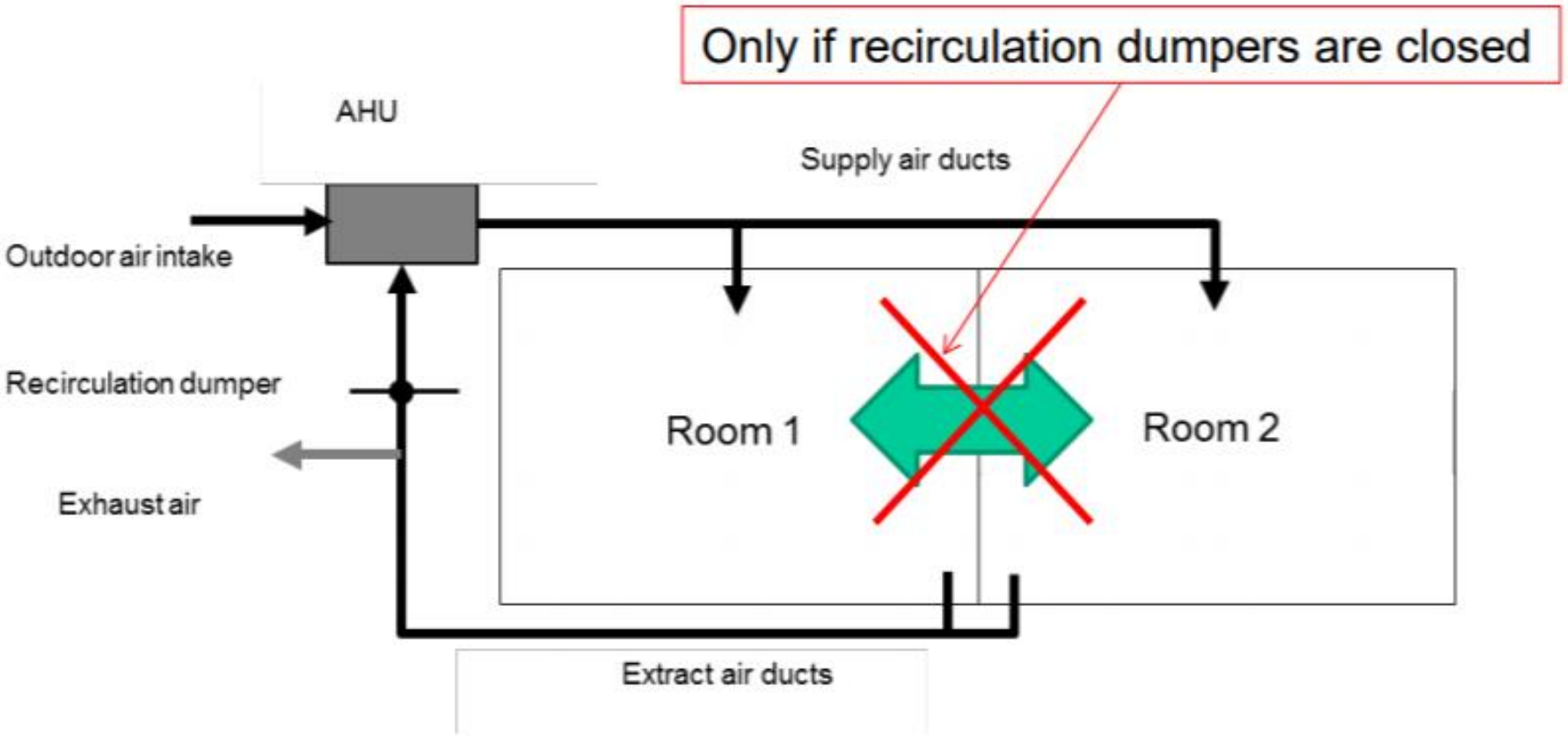
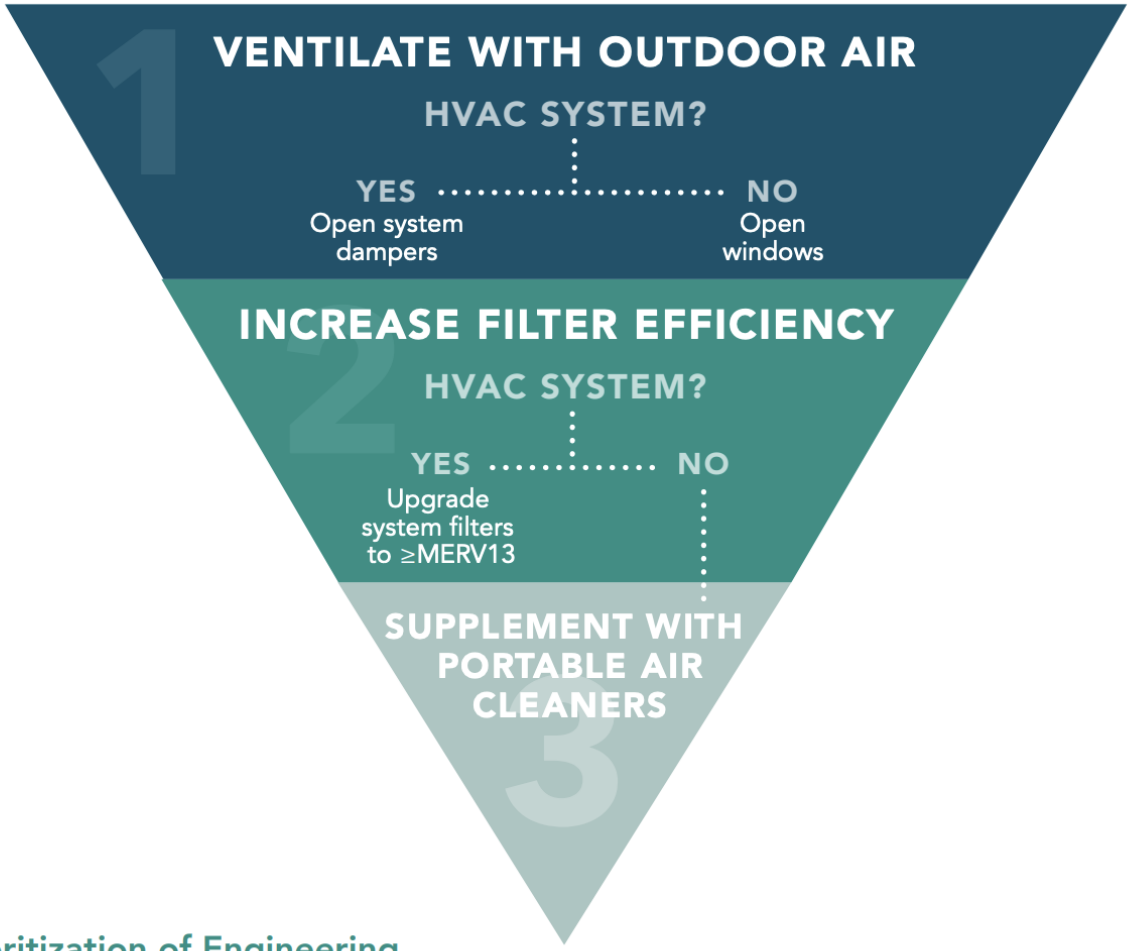
All-Air HVAC System



POSSIBLE CROSS-CONTAMINATION IF RECIRCULATION IS ALLOWED BUT VIRUS DILUTION

Selection of engineering controls



Prioritization of Engineering Controls to Reduce Long-Range Airborne Transmission

Assessment of all buildings

Developing "Limitations of use"

Meeting Rooms

Meeting Rooms	Natural	Windows	Doors	Cooling system	Mechanical Ventilation	Dampers open	SANS 10400 Part O (Compliant Y/N)	Outdoor air	Floor area M2	No of People (for Social Distance)	Limitations for use
Central training rooms											
1	Yes	3	2	HVAC	Yes	Yes	Yes	Yes	100	23	23 people + Monitor CO2
2	Yes	1	1	HVAC	Yes	Yes	Yes	Yes	20	7	7 people + Monitor CO2
3	No	0	1	HVAC	Yes	Yes	Yes	Yes	10	3	3 people + Monitor CO2
4	Yes	4	1	HVAC	Yes	Yes	Yes	Yes	40	14	14 people + Monitor CO2
5	Yes	4	1	HVAC	Yes	Yes	Yes	Yes	40	14	14 people + Monitor CO2
6	No	0	2	HVAC	Yes	Yes	Yes	Yes	350	67	67 people + Monitor CO2
Ops training rooms											
7	No	0	1	Split	No	N/A	No	No	18	6	6 people + door open for duration + CO2
8	Yes	1	2	Split	No	N/A	No	Yes	18	6	6 people + windows/door open for duration + CO2
9	Yes	2	1	Split	No	N/A	Yes	Yes	20	7	7 people + windows/door open for duration + CO2
10	Yes	2	1	Split	No	N/A	Yes	Yes	20	7	7 people + windows/door open for duration + CO2
11	Yes	2	1	Split	No	N/A	Yes	Yes	36	12	12 people + windows/door open for duration + CO2
12	Yes	2	1	Split	No	N/A	Yes	Yes	26	9	9 people + windows/door open for duration + CO2
13	Yes	3	1	Split	No	N/A	Yes	Yes	18	6	6 people + windows/door open for duration + CO2
14	Yes	6	1	Split	No	N/A	Yes	Yes	28	9	9 people + windows/door open for duration + CO2
15	Yes	2	1	Split	No	N/A	Yes	Yes	38	12	12 people + windows/door open for duration + CO2
16	Yes	2	1	Split	No	N/A	Yes	Yes	21	7	7 people + windows/door open for duration + CO2

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ISO 16890 Filter Group Efficiencies

Coarse	< 50% of PM10
ePM10	≥ 50% of PM10
ePM2.5	≥ 50% of PM2.5
ePM1	≥ 50% of PM1

ISO 16890 exposes a filter to particles from 0.3 µm all the way up to 10 µm. This comes closer to real life conditions.

EN 1822 High efficiency air filters (EPA, HEPA and ULPA)

FILTER CLASS	INTEGRAL VALUE		LOCAL VALUE	
	EFFICIENCY %	PENETRATION %	EFFICIENCY %	PENETRATION %
E10	≥ 85	≤ 15	–	–
E11	≥ 95	≤ 5	–	–
E12	≥ 99,5	≤ 0,5	–	–
H13	≥ 99,95	≤ 0,05	≥ 99,75	≤ 0,25
H14	≥ 99,995	≤ 0,005	≥ 99,975	≤ 0,025
U15	≥ 99,9995	≤ 0,0005	≥ 99,9975	≤ 0,0025
U16	≥ 99,99995	≤ 0,00005	≥ 99,99975	≤ 0,00025
U17	≥ 99,999995	≤ 0,000005	≥ 99,9999	≤ 0,0001

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Changing filters

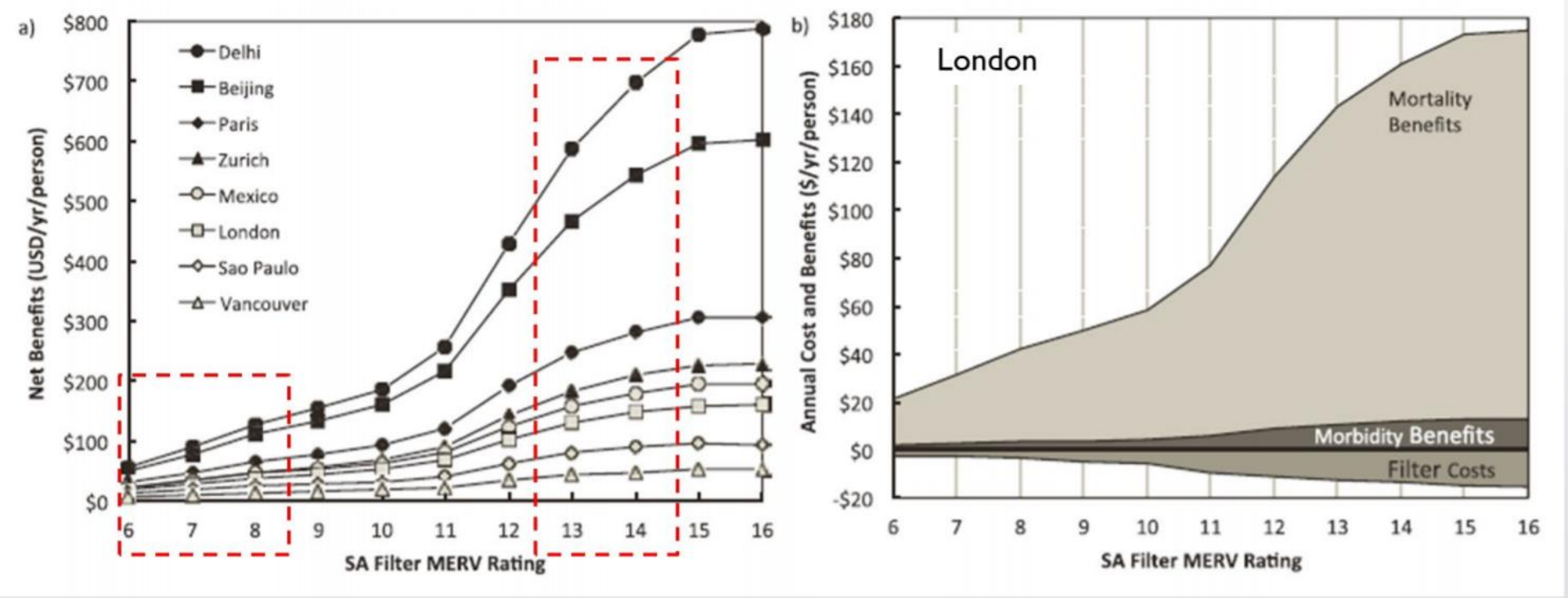
Changing filters not simple:

- Increased pressure load
- > Air bypassing filters
- > maintenance
- > filter changes

Conclusion ventilation beyond COVID

- Understanding of the role of ventilation in reducing influenza infections not new – 2011 research
- Increasing the ventilation rate from 8L/s per person to 15L/s per person, US economy would save US$37.5bn dollars per year through reduced absenteeism and employee performance
- World pre and post COVID-19 different, including a permanent priority change in the control of HBA – including influenza
- Recommendation to achieve ventilation rates of 15L/s per person of outdoors air will stand even once the COVID-19 pandemic has passed

Conclusion: consider pollution & HBA



No one size fits all:

- Higher atmospheric pollution > reliance on filters (CO_2 becomes < useful)
- Lower atmospheric pollution > reliance on outdoor air

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End

Thank you

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