Fung Shui of COVID-19

Ventilations and drains

David Lung

Department of Pathology

Queen Elizabeth Hospital / Hong Kong Children's Hospital

SARS-CoV-2 is transmitted by exposure to infectious respiratory fluids

The principal mode by which people are infected with SARS-CoV-2 (the virus that causes COVID-19) is through exposure to respiratory fluids carrying infectious virus. Exposure occurs in three principal ways: (1) inhalation of very fine respiratory droplets and aerosol particles, (2) deposition of respiratory droplets and particles on exposed mucous membranes in the mouth, nose, or eye by direct splashes and sprays, and (3) touching mucous membranes with hands that have been soiled either directly by virus-containing respiratory fluids or indirectly by touching surfaces with virus on them.

People release respiratory fluids during exhalation (e.g., quiet breathing, speaking, singing, exercise, coughing, sneezing) in the form of droplets across a spectrum of sizes.[1-9] These droplets carry virus and transmit infection.

- The largest droplets settle out of the air rapidly, within seconds to minutes.
- The smallest very fine droplets, and aerosol particles formed when these fine droplets rapidly dry, are small enough that they can remain suspended in the air for minutes to hours.

Infectious exposures to respiratory fluids carrying SARS-CoV-2 occur in three principal ways (not mutually exclusive):

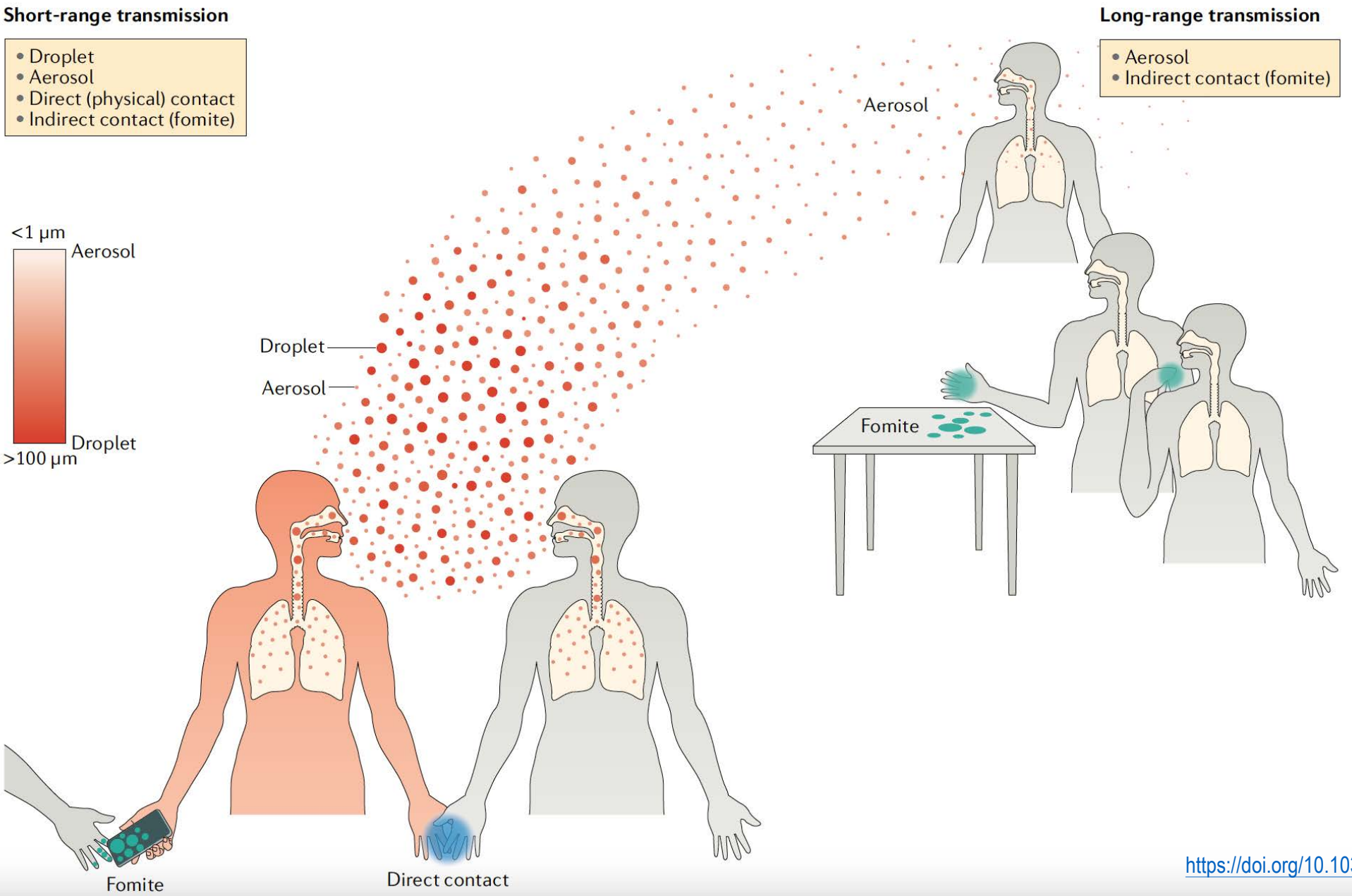
1. **Inhalation** of air carrying very small fine droplets and aerosol particles that contain infectious virus. Risk of transmission is greatest within three to six feet of an infectious source where the concentration of these very fine droplets and particles is greatest.
2. **Deposition** of virus carried in exhaled droplets and particles onto exposed mucous membranes (i.e., "splashes and sprays", such as being coughed on). Risk of transmission is likewise greatest close to an infectious source where the concentration of these exhaled droplets and particles is greatest.
3. **Touching** mucous membranes with hands soiled by exhaled respiratory fluids containing virus or from touching inanimate surfaces contaminated with virus.

Transmission of SARS-CoV-2

1. Inhalation (aerosols)
2. Deposition (droplets)
3. Touching (fomite)

CDC 2021

Under what condition would SARS-CoV-2 be transmitted via air?



https://doi.org/10.1038/s41579-021-00535-6

Transmission of respiratory tract pathogens

	Airborne	Droplet	Opportunistic airborne
Example	TB Measles Chickenpox	Respiratory pathogen	Respiratory pathogen
Description	Dissemination of droplet nuclei Remain suspended in air Long distance (>1m)	Droplet generated during **coughing**, **sneezing** and **talking**	Droplet nuclei generated during **special circumstances**
	>1.5m	<1.5m	Aerosol-generating procedure <3L/s/person → airborne

WHO 2009: Natural Ventilation for Infection Control in Health-care settings

Transmission of COVID-19

Transmission of SARS-CoV-2 from inhalation of virus in the air farther than six feet from an infectious source can occur

With increasing distance from the source, the role of inhalation likewise increases. Although infections through inhalation at distances greater than six feet from an infectious source are less likely than at closer distances, the phenomenon has been repeatedly documented under certain preventable circumstances.[10-21] These transmission events have involved the presence of an infectious person exhaling virus indoors for an extended time (more than 15 minutes and in some cases hours) leading to virus concentrations in the air space sufficient to transmit infections to people more than 6 feet away, and in some cases to people who have passed through that space soon after the infectious person left. Per published reports, factors that increase the risk of SARS-CoV-2 infection under these circumstances include:

- **Enclosed spaces with inadequate ventilation or air handling** within which the concentration of exhaled respiratory fluids, especially very fine droplets and aerosol particles, can build-up in the air space.
- **Increased exhalation** of respiratory fluids if the infectious person is engaged in physical exertion or raises their voice (e.g., exercising, shouting, singing).
- **Prolonged exposure** to these conditions, typically more than 15 minutes.

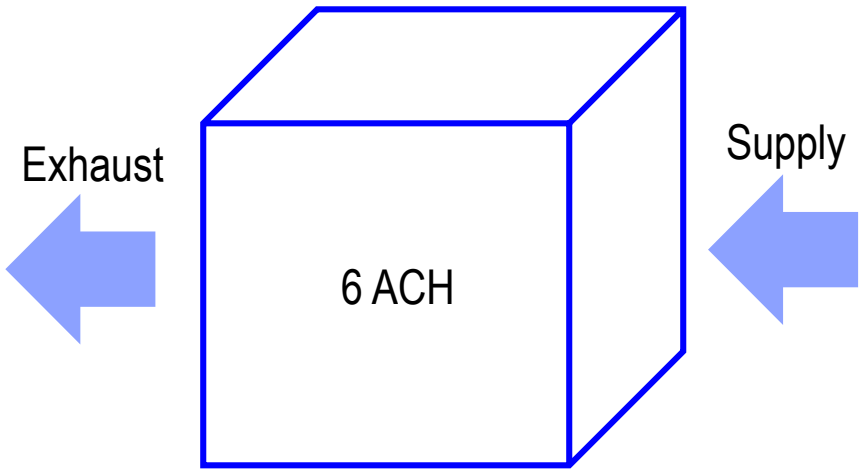
Top of Page

Airborne transmission of SARS-CoV-2

1. Enclosed space / inadequate ventilation
2. Increased exhalation
3. Prolonged exposure

https://www.cdc.gov/coronavirus/2019-ncov/science/science-briefs/sars-cov-2-transmission.html

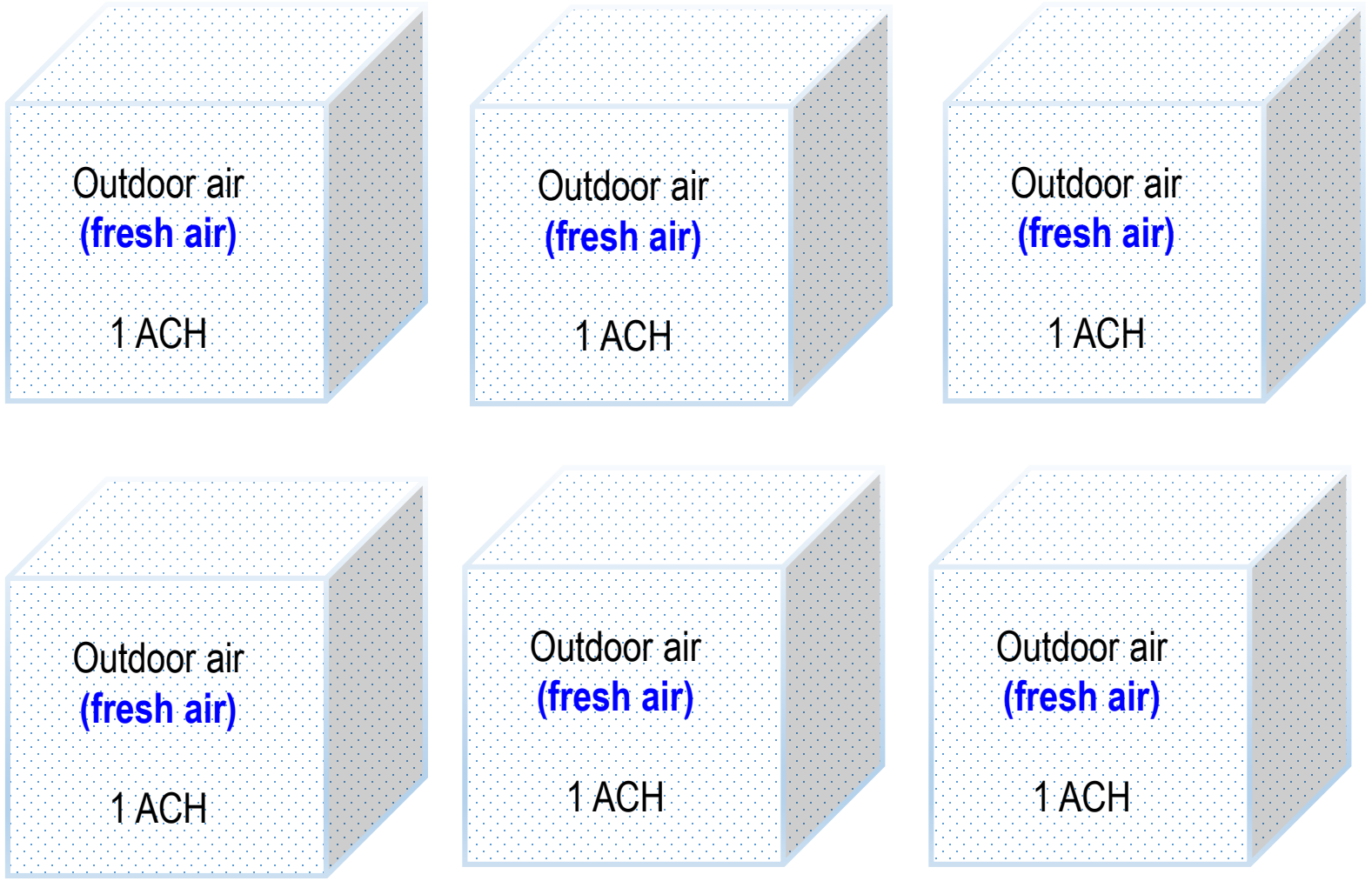
What is ventilation?



100m^2 x 2.9m (ceiling)

Room volume = 290 m^3

290 m^3/hr = 1 ACH
290 x 6 = 1740 m^3/hr = **6 ACH**



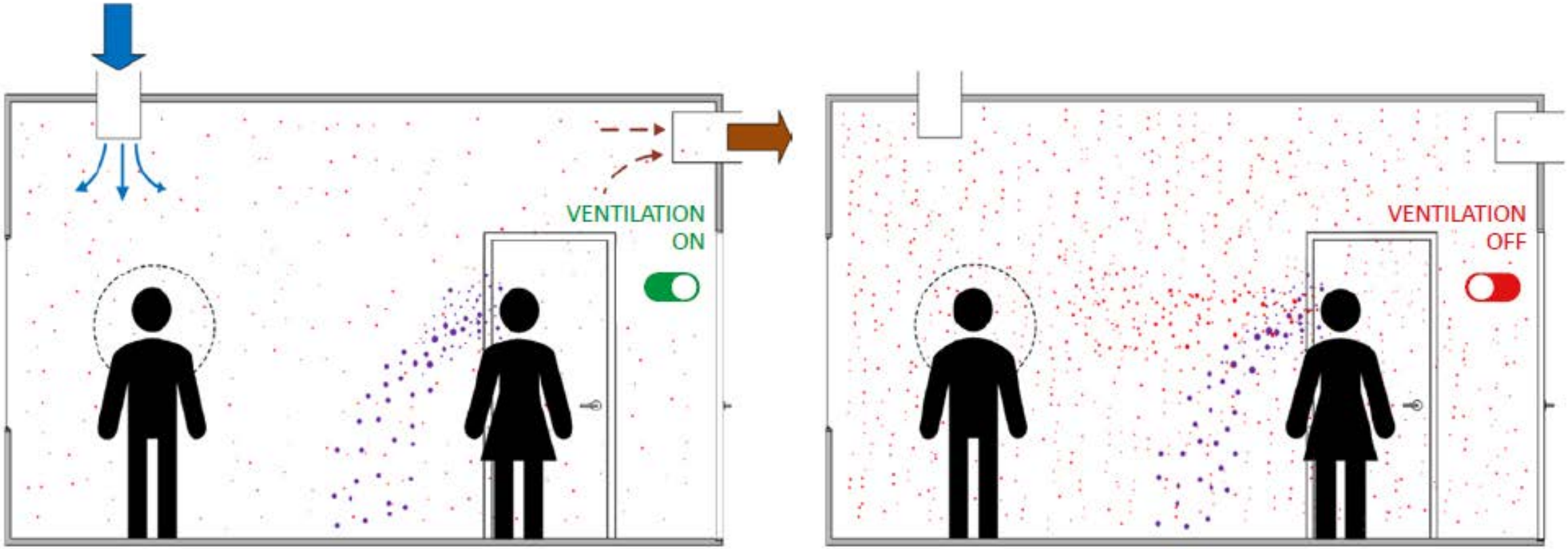
6 times the volume of the room in “clean” air each hour

Different types of room ventilation

	Pressure	Example
Supply = exhaust	Neutral pressure	Office room
Supply > exhaust	Positive pressure	Operation theatre Protective isolation Clean room
Exhaust > supply	Negative pressure	Isolation room Toilet Kitchen

Ventilation

Dilution of contaminant / pollutants in air



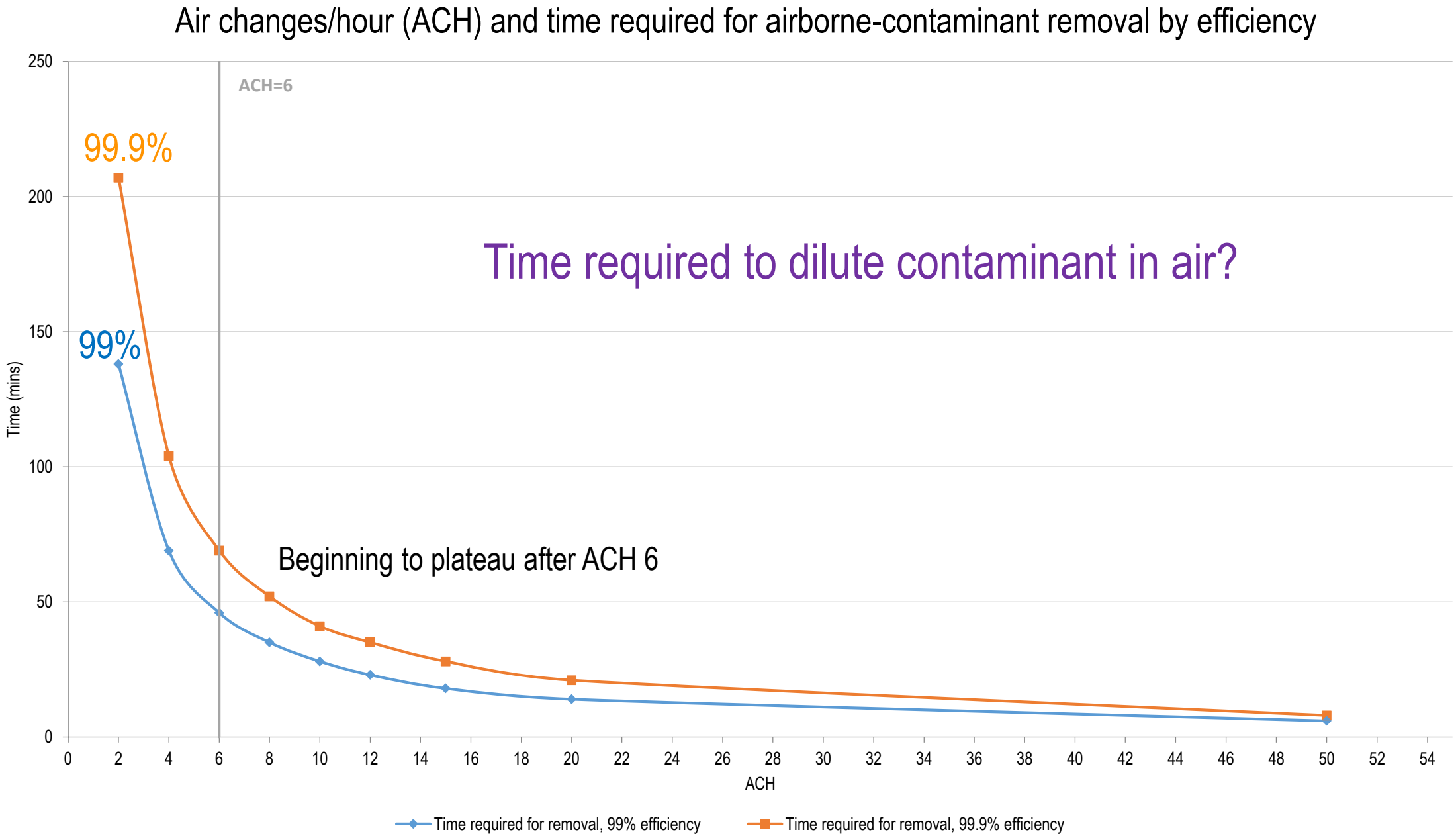
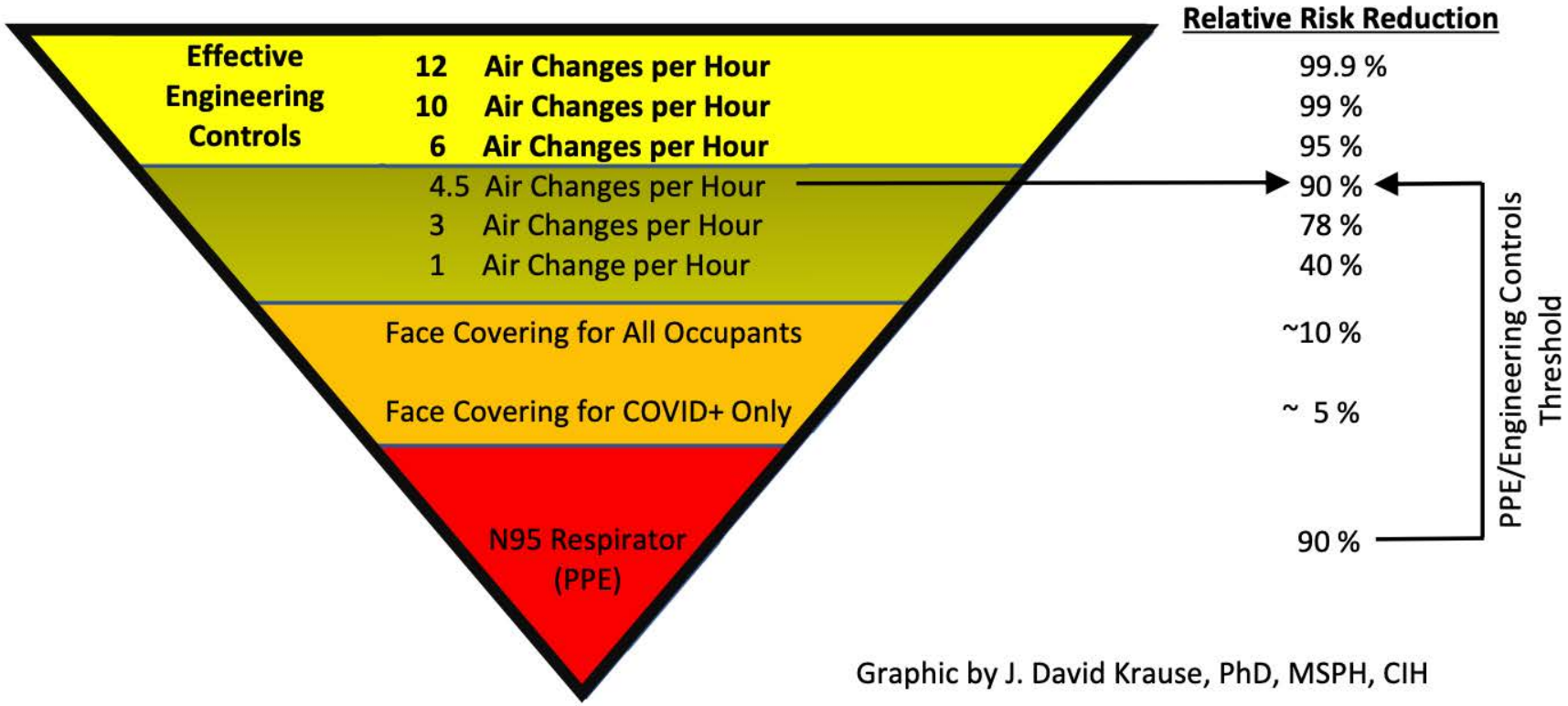


Table B1: **Air changes/hour (ACH) and time required for airborne-contaminant removal by efficiency**
https://www.cdc.gov/infectioncontrol/guidelines/environmental/appendix/air.html#

Guidance Document

SUPPLEMENT to Reducing the Risk of COVID-19 Using Engineering Controls



Graphic by J. David Krause, PhD, MSPH, CIH

Risk reduction by ventilation

Restaurants

Restaurant outbreak in Feb 2021

[redacted]食館爆疫　工程師指鮮風少、空氣停滯　食客座位近易傳播

撰文：李恩慈

出版：2021-03-02 10:33　更新：2021-03-02 19:05

Divided into 2 floors

Kitchen located at upper floor (ACH >6)

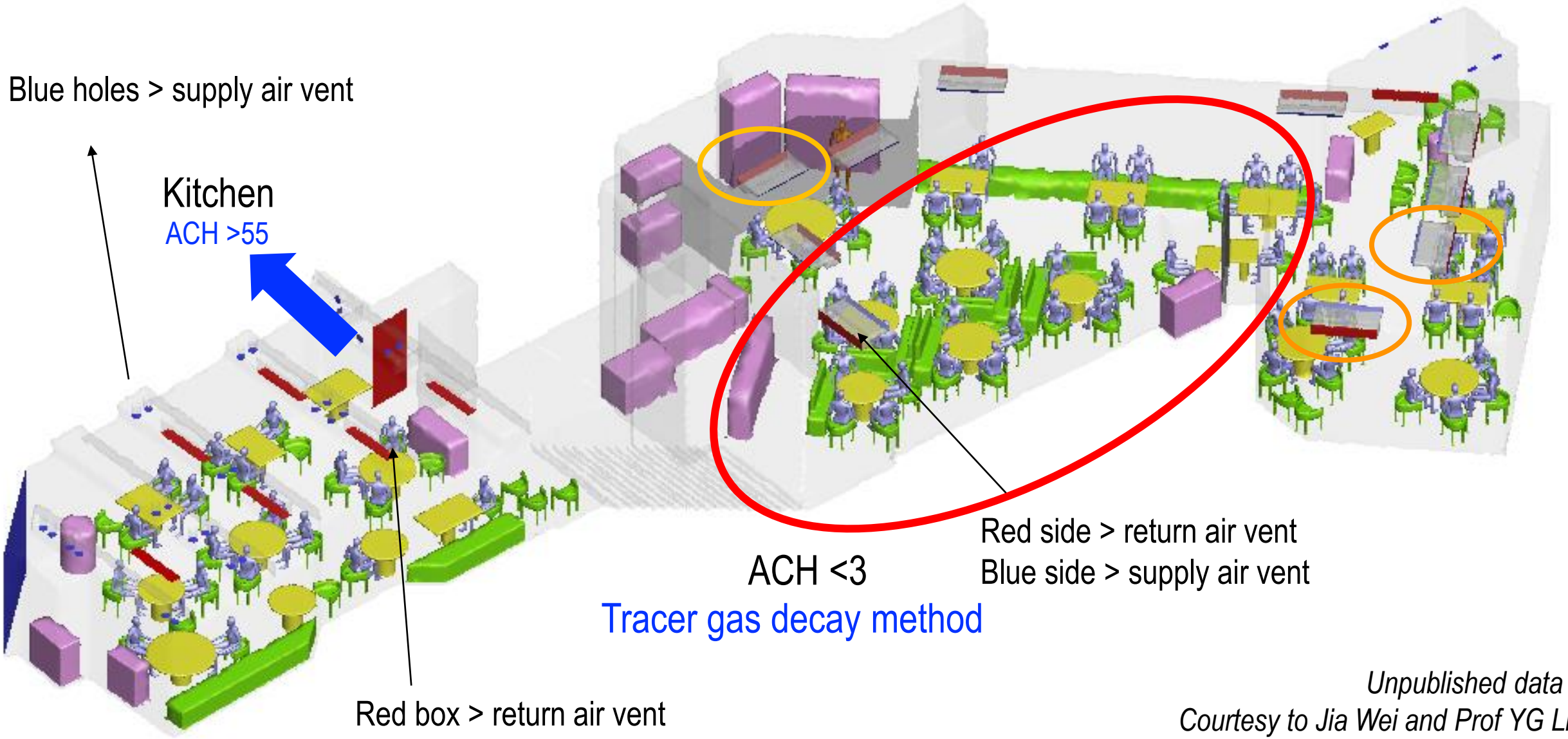
Outbreak located at lower floor

Lunch on 19/2

- **80 customers** during lunch hour
- 22 patrons, 10 staff and 22 close contact confirmed positive

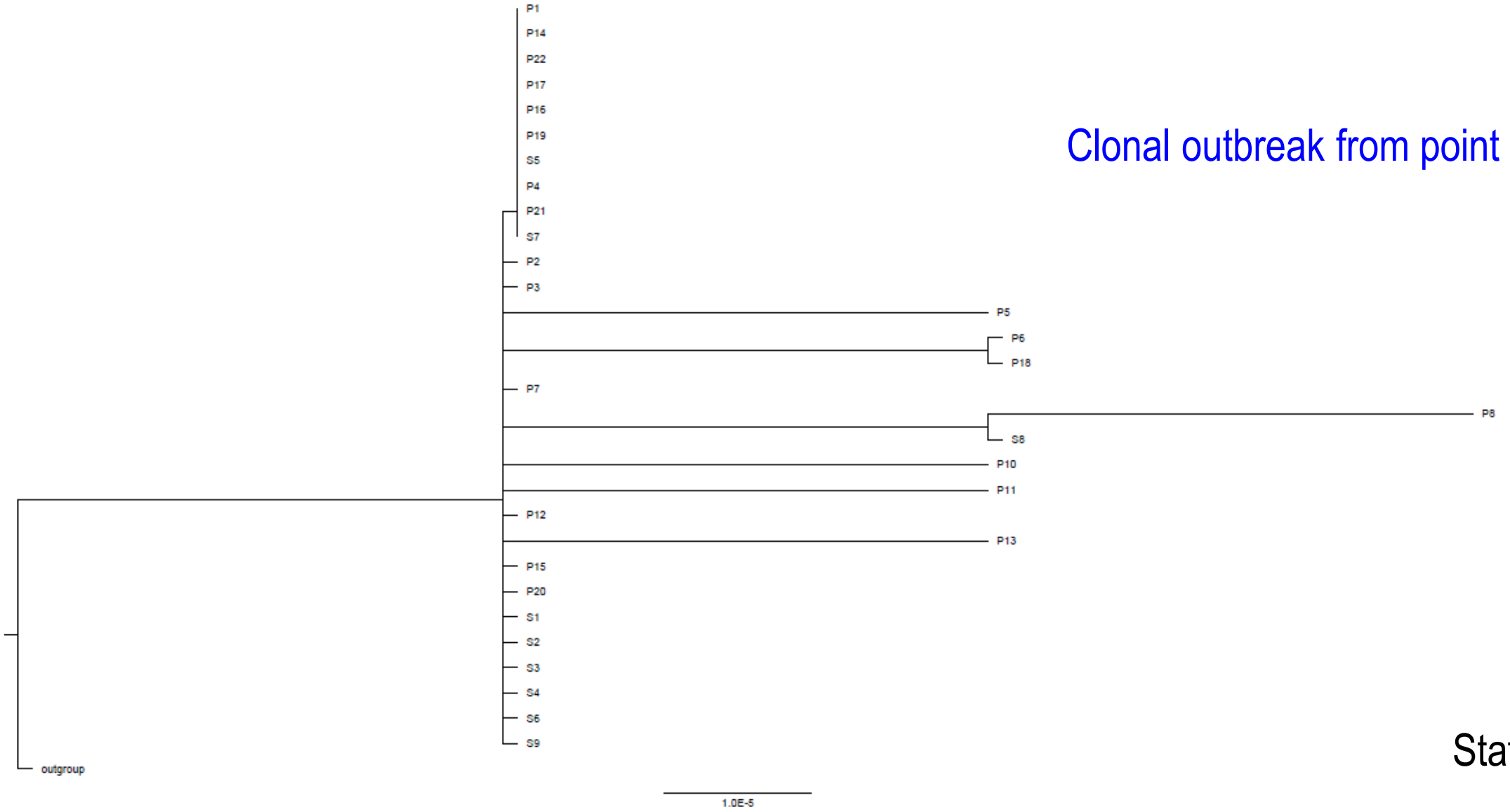
CABINET
STORE RM 5
STORE RM 4
FULL HEIGHT SELF-CLOSING DOOR
EXISTING FOLDING WINDOW & EXISTING PROTECTIVE BARRIER
FULL HEIGHT SELF-CLOSING DOOR
SERVICE STATION
PASSAGE
(NO SEATING ACCOMMODATION SHOULD BE ALLOWED TO THE PASSAGE)+(CAP. 1PX1)
CABINET
SERVICE COUNTER
VIP
FULL HEIGHT FOLDING PARTITION
FOLDING PARTITION
SOFA
SEATING AREA 2
SOFA
12.700
WOODEN PARTITION
1100MM HIGH COUNTER TOP
W.T. TABLE
ICE BIN
WATER FILTER
B
W.T. FRIDGE (E)
ICE MAKER (E)
BAR (FOR DRINK ONLY)
FB
12.800
W.T. FRIDGE (E)
WINE CELLAR
LADDER
CABINET OVER
STORE RM 3
CASHIER (2.355SQ.M.) (1P)
UP 102
1000mm HIGH SELF-CLOSING DOOR
W.T. TABLE
S
SHELF OVER
SHELF OVER
WATER HEATER (E)
GLASS WASHING MACHINE (E)
P.D.

3D spatial arrangement of the Restaurant



Unpublished data
Courtesy to Jia Wei and Prof YG Li

NGS analysis of restaurant by QEH/HKCH



Clonal outbreak from point source

ɔns: **22**

Staff: **10**

Evidence to support long-range airborne transmission

Indicated by fulfillment of any one of the following condition

1. An outbreak occurred that could be directly attributed to the **lack of ventilation** air introduction into, and circulation within, an enclosed space

2. The incidence of the infection in susceptible hosts was **inversely associated** with the ventilation rate per person

3. A disease outbreak occurred in an enclosed space, most likely due to air transport of infectious droplet nuclei over a **distance greater than 2m**

A guide to application for restaurant licences
May 2020

Ventilation

39. The intention of ventilation is to ensure an adequate supply of fresh/outside air for human occupation and effective extraction of exhaust air arising from activities in premises. Ventilation can be provided by natural means, natural with mechanical assistance or wholly mechanical.

Natural Ventilation

40. Premises having unobstructed window openings of total area equivalent to one-tenth of the gross floor area of the premises are considered as having adequate means of natural ventilation.

Mechanical Ventilating System

41. Although it is not a statutory requirement that a restaurant must be provided with a mechanical ventilating system including an air-conditioning system, such provision is common. Ventilating systems also include simple mechanical ventilating systems involving the use of ducting and trunking connected to cooking hoods. All mechanical ventilating systems in restaurants are controlled by the *Ventilation of Scheduled Premises Regulation (Cap.132CE)* and approval for the installation of a ventilating system by both the FEHD and the FSD is one of the licensing requirements for a restaurant licence. To avoid delay in the processing of an application for a restaurant licence, where an air-conditioning system is to be provided or where ducting and trunking are intended for the exhaust system, an applicant is advised to apply for approval to install the system at the same time he sends in his application for the restaurant licence. Except in the case of window type air-conditioners as described in paragraph 51, application for approval of a mechanical ventilating system is normally made on behalf of an applicant by a registered specialist contractor (ventilation works category). It is therefore important for an applicant to appoint a suitable contractor/consultant.

Points to Note in Design and Installation of a Ventilating System

Health/hygiene Requirements

42. To protect public health safety at premises with mechanical ventilation system, the system shall be able to supply a minimum amount of 17m^3/hr/person of fresh air to the premises as laid down in the Schedule 2 to the *Public Health and Municipal Services Ordinance (Cap.132)*.

43. Under section 8 of the *Ventilation of Scheduled Premises Regulation (Cap.132CE)*, a ventilating system, which shall be independent of any ventilating system provided for the public parts of any scheduled premises, shall be provided for the kitchens, latrines and any other parts of such premises as may be considered necessary by the Director of Food and Environmental Hygiene.

44. An exhaust system and a fresh air intake system shall be provided to each and every kitchen, food preparation space/room, and scullery space/room. Ventilation hoods and devices shall be designed to prevent grease or condensate from dripping onto food or food preparation surfaces. Intake air ducts shall be designed and maintained so as to prevent the entrance of dust, dirt, insects or other contaminating materials. Air ducts shall be free from obstruction and be changed gradually in section to achieve minimum pressure drop.

Mechanical ventilation system:

- Supply minimum amount: 17m^3/hr/person
- Fresh air

Second Schedule

[ss. 2, 93 & 102]

Scheduled Premises

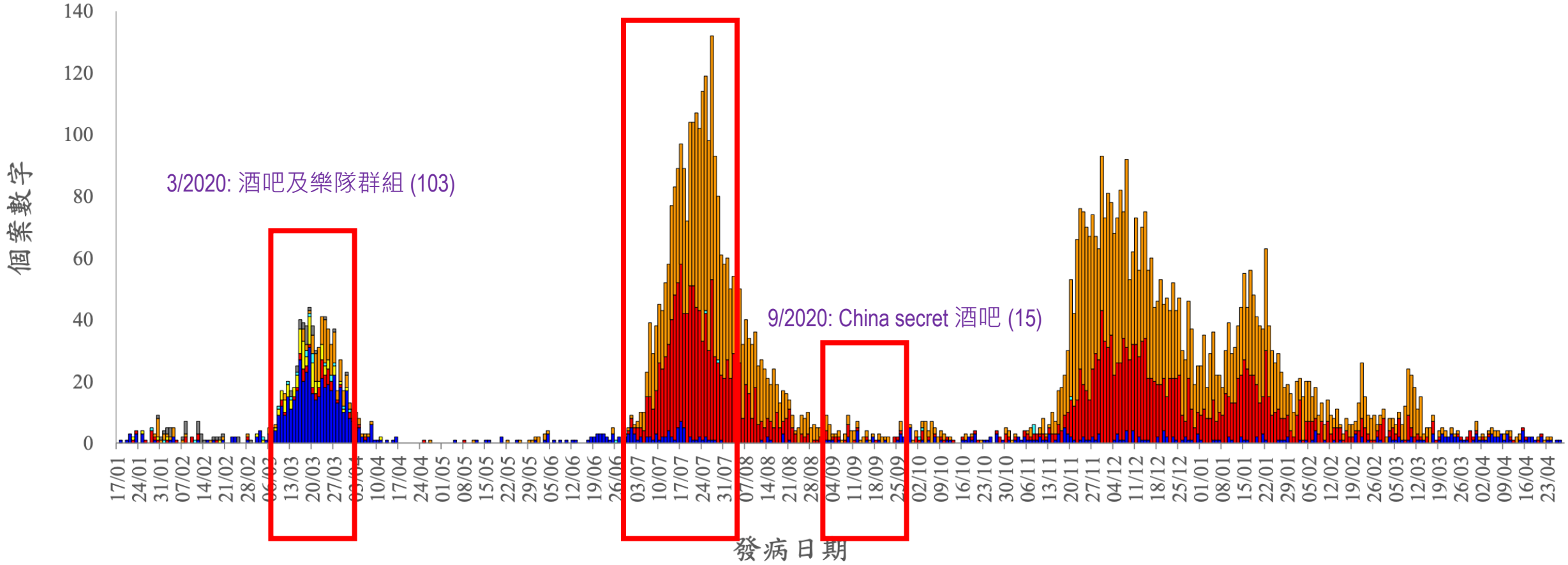
(Format changes—E.R. 4 of 2019)

Class of premises	No. of cubic metres per hour for each person who may be accommodated in the premises
Cinemas	13
Dancing establishments	17
Factory canteens	17
Funeral parlours	17
Restaurants	17
Theatres	13

(Amended 61 of 1974 s. 12; L.N. 89 of 1979; L.N. 366 of 1989; E.R. 4 of 2019)

Sequence of event

7/2020:
彬記/新發/ 建榮 (46)
慈雲山中心翠河 (38)
雅蘭中心稻香 (42)
屯門中央廣場富臨酒家 (44)
新都會廣場潮庭 (20)
慈雲山中心百匯軒 (32)
旺角維景酒店海港酒家 (15)



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慈雲山中心百匯軒 (32)
旺角維景酒店海港酒家 (15)

16/10/2020
「每小時 6次換氣量或裝置空氣淨化設備」自願申報制度

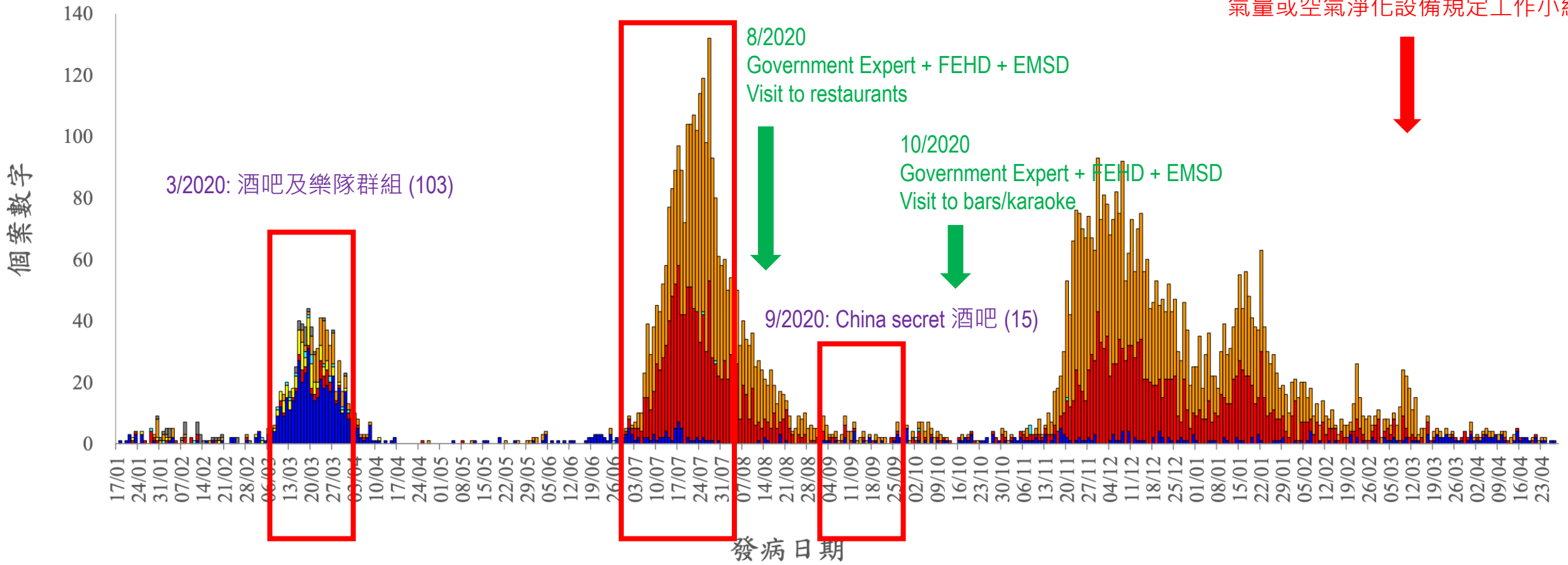
16/3/2021
第599F章下在提供堂食食肆實施換氣量或空氣淨化設備規定工作小組

8/2020
Government Expert + FEHD + EMSD
Visit to restaurants

10/2020
Government Expert + FEHD + EMSD
Visit to bars/karaoke

3/2020: 酒吧及樂隊群組 (103)

9/2020: China secret 酒吧 (15)



Dealing with airborne pathogen

Principle	Mechanism
Dilution	Ventilation → mixing with fresh air
Filtration	Physical removal of particles from air stream by high grade filters: - Interception - Impaction - Diffusion - Electrostatic force
Germicidal	UV damage of genetic materials of microorganisms

香港特別行政區政府
食物環境衞生署

字型大小 | Eng 简 |

公共服務 >

關於我們 >

公用表格

堂食餐飲處所換氣量及空氣淨化設備指引

食物及衞生局局長早前根據《預防及控制疾病（規定及指示）（業務及處所）規例》（第599F章）向餐飲業務發出指示，訂明提供堂食的餐飲處所在換氣量或空氣淨化設備方面須遵守的規定，為順利落實該規定而成立的工作小組已公布「餐飲處所換氣量及空氣淨化設備指引」，以供餐飲處所負責人及通風設備承辦商作為參考。上述指引可於以下食環署網頁下載。

Increase ACH >6

UV-C

HEPA filter

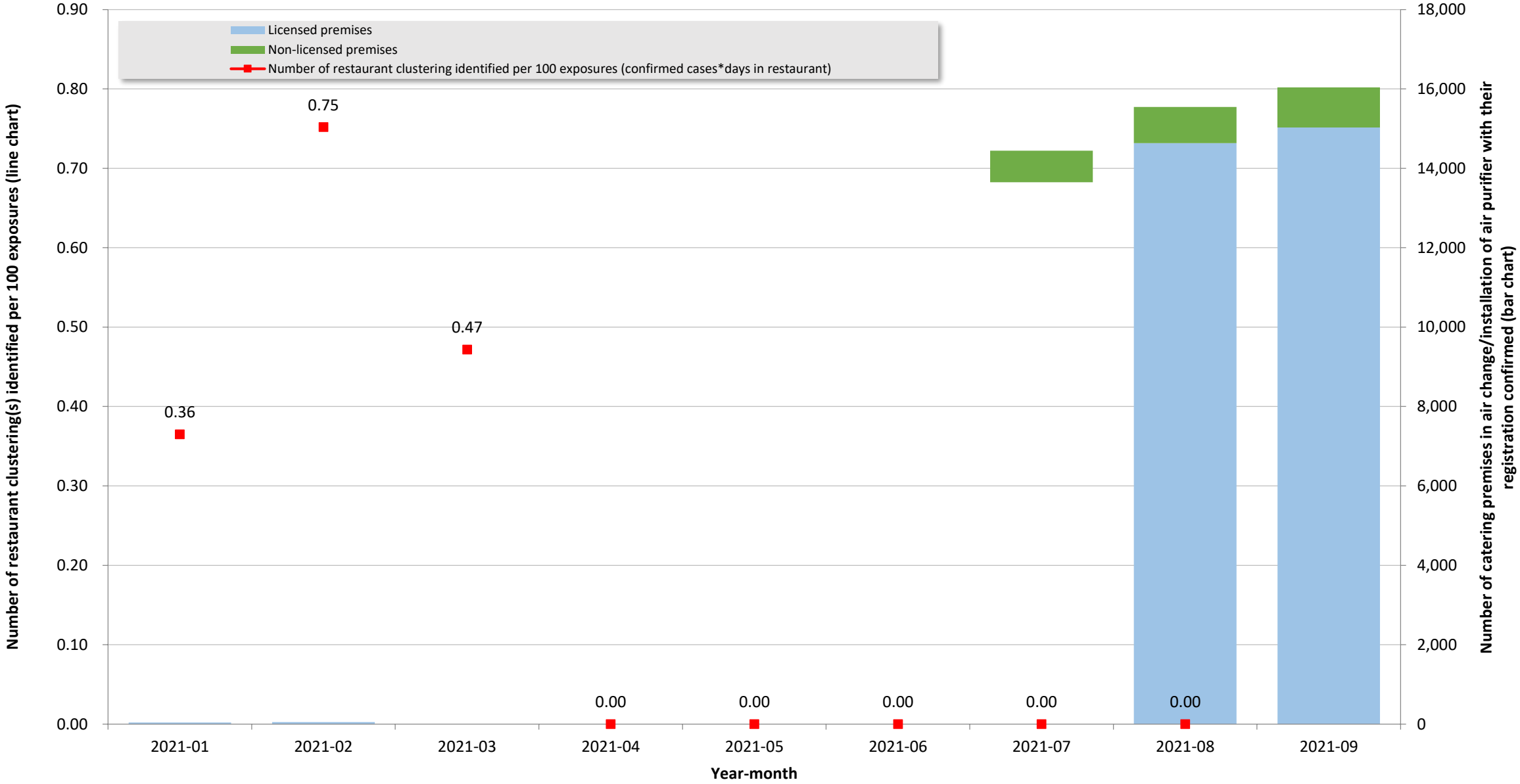
HEPA + UV-C

https://isd.wecast.hk/vod/?id=11997

Local and international recommendation on ventilation requirement in various premises

Standards/Regulations	Year	m^3/hr/person 立方米/每人每小時	L/s/person 公升/每人每秒	ACH at 3m height Ceiling @1.5m^2/person	ACH at 2.3m height Ceiling @1.5m^2/person
公眾衞生及市政條例(第132章)第93(1)條及附表2 (食肆)		**17.0**	**4.7**	**3.8**	**4.9**
Chartered Institution of Building Services Engineer (**CIBSE**) Guide A (for Restaurants)	2015 edition (May 2019 reprint)	36	10	8.0	10.4
ASHRAE Standard 62.1 The Standards for Ventilation and Indoor Air Quality(for Restaurants)	2019	18.7	5.1	4.2	5.4
國家市場監督管理總局、中國國家標準化管理委員會(國家標準) GB37488-2019	4 April 2019	30	8.3	6.7	8.7
Scottish Government Coronavirus (COVID-19): ventilation guidance	18 Dec 2020	28.8 - 36	8-10	6.4 - 8	8.3 - 10.4
WHO Roadmap to improve and ensure good indoor ventilation in the context of COVID-19 (non-residential settings)	1 March 2021	36	10	8	10.4
屋宇署 作業備考編號 2 (辦公室)	May 2011	36	10	8.0	10.4
持牌餐飲處所換氣量自願申報計劃	Oct 2020	27	7.5	6	6

Number of restaurant clustering(s) identified per 100 exposure
Number of catering premises in air change/installation of air purifier with their registration confirmed



Quarantine Hotel

社會新聞

新冠肺炎｜確診外傭住灣仔帝盛「尾房」　同層13人須送檢疫中心

撰文：鄧穎琳

出版：2021-08-17 18:31　更新：2021-08-18 16:19

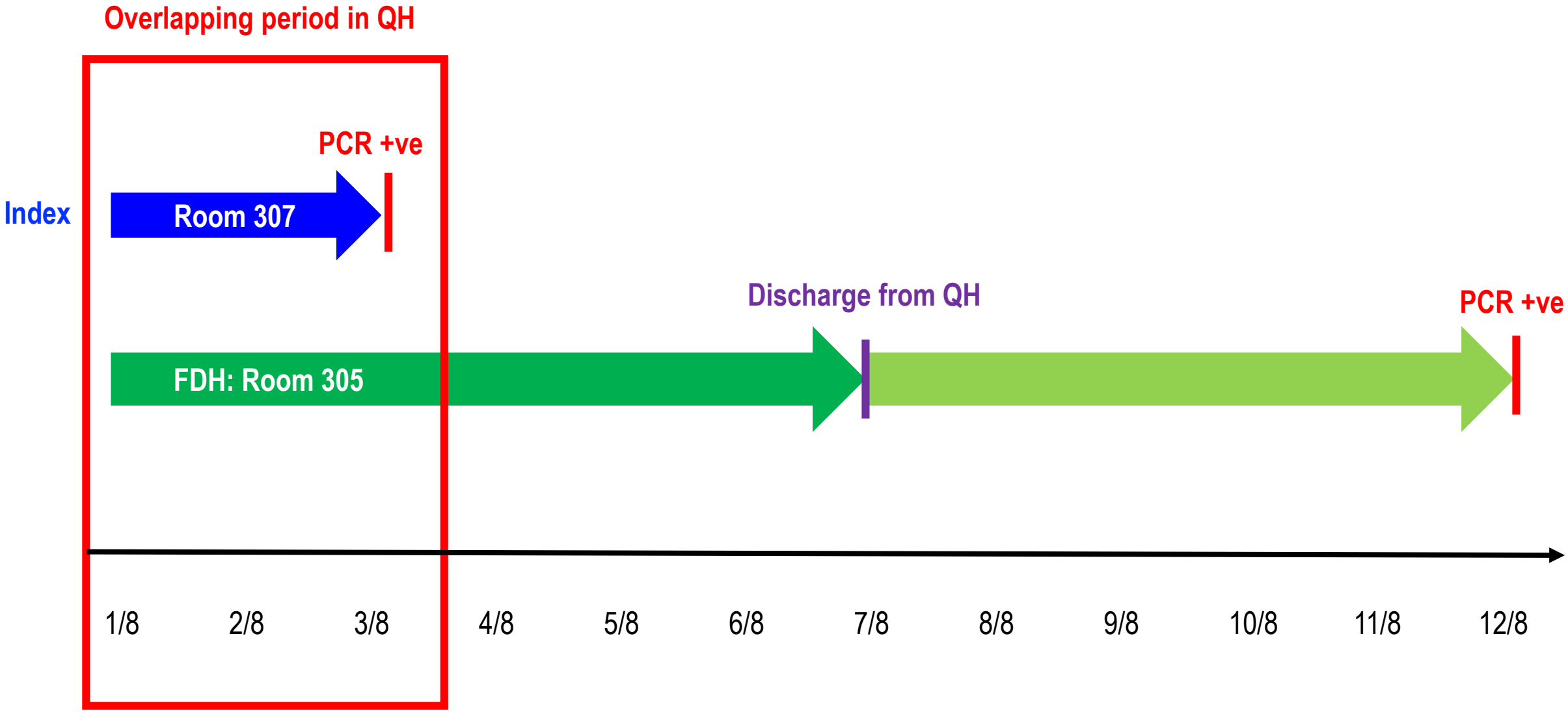
Domestic helper returned to HK from USA

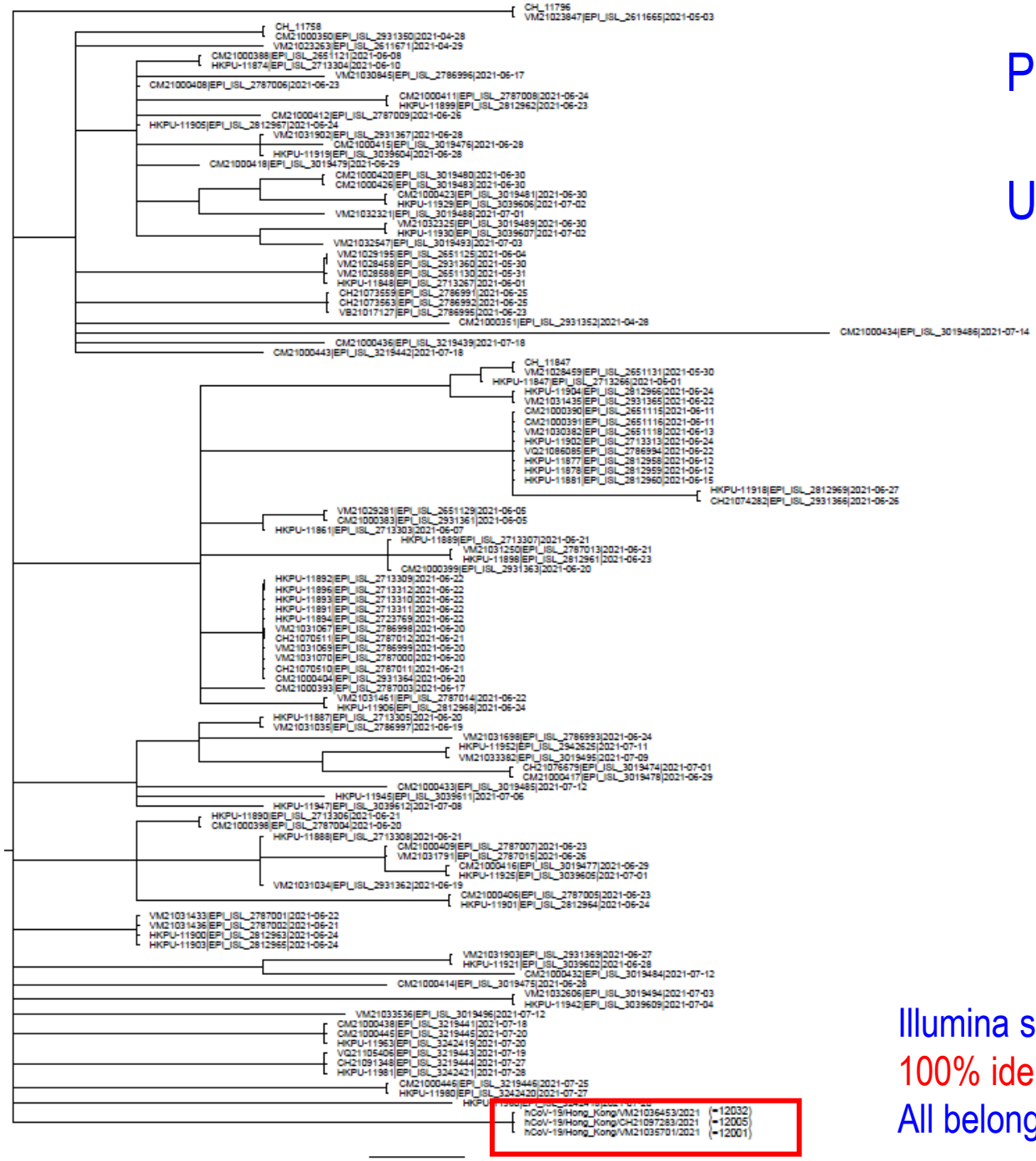
Quarantine in hotel for 7 days

Discharged afterwards

Turned positive on day 12 surveillance

Sequences of event





Phylogenetic tree constructed by HKCH

Using all B.1.617.2 strain available in HK open source

Illumina sequencing of Canadian couple and FDH done

100% identical

All belonging to B.1.617.2.3 (AY.3)

Airflow direction: into guest room
(when windows closed)

305

307

PART PLAN OF 2/F

Room of index couple: with windows opened

Guest signed consent,
but **windows were opened** while they opened the door

Collection of DTS specimen packs by staff

Door remained opened for >1 minutes 15 seconds

Smoke test: **reverse airflow (outwards)** when door and windows opened at the same time

PCR positive on 3/8 with high viral load (Ct13)

Room of FDH: door opened and window closed

Collection of DTS specimen pack by staff

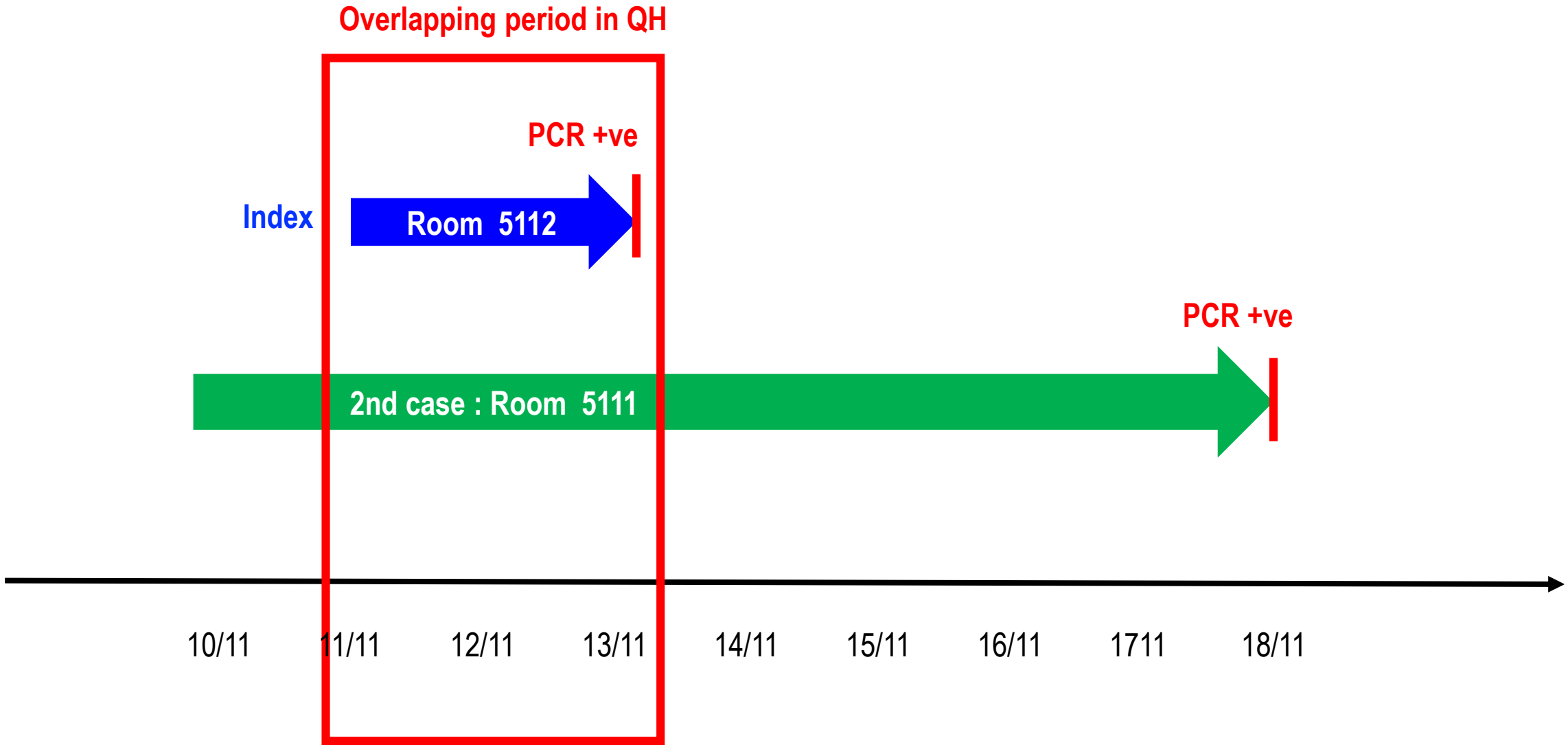
Window remained locked and **closed**

Smoke test demonstrated **inward airflow**

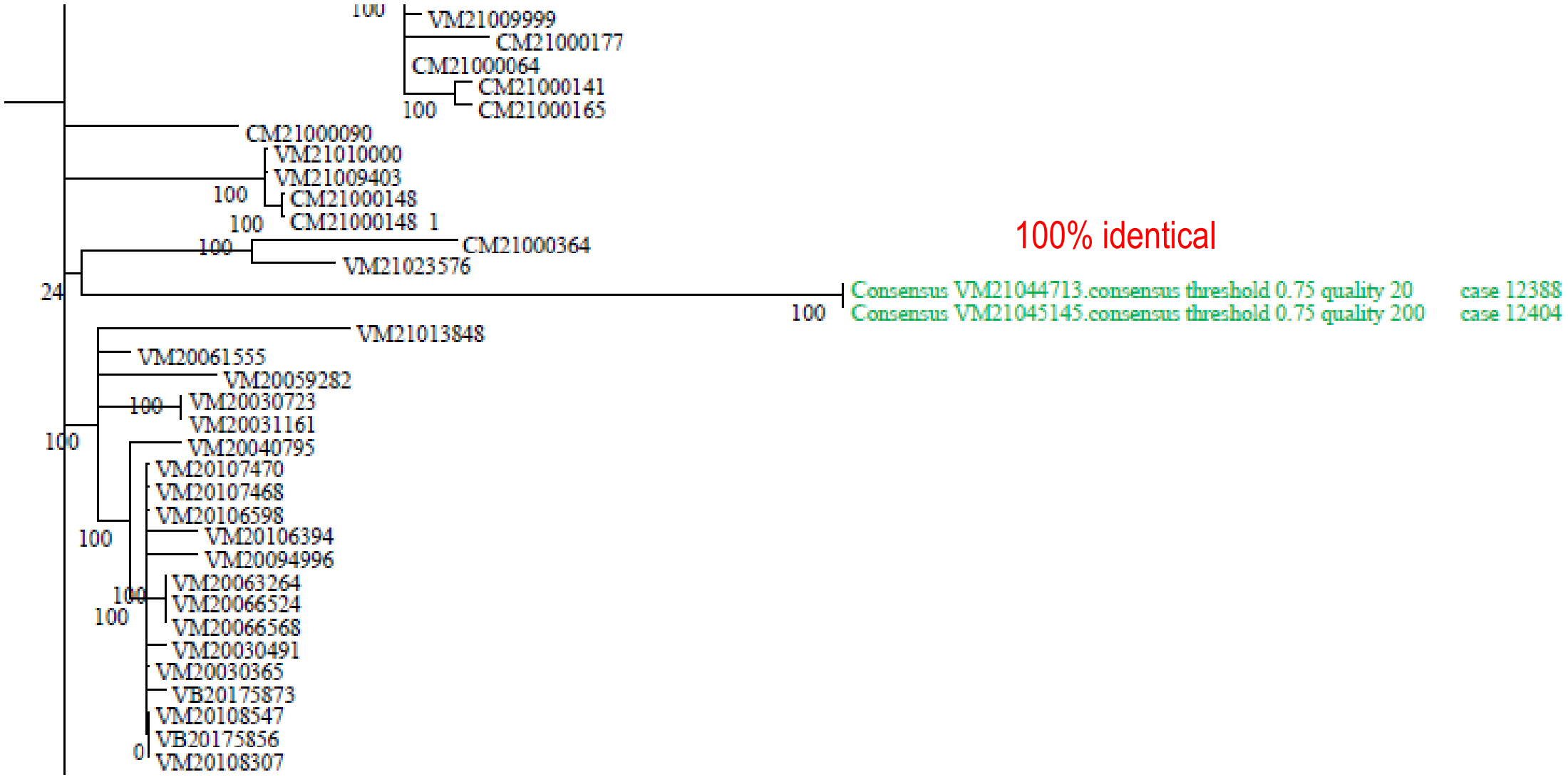
Infectious materials in the corridor can rush in as the room is located at the end of the corridor

Second example

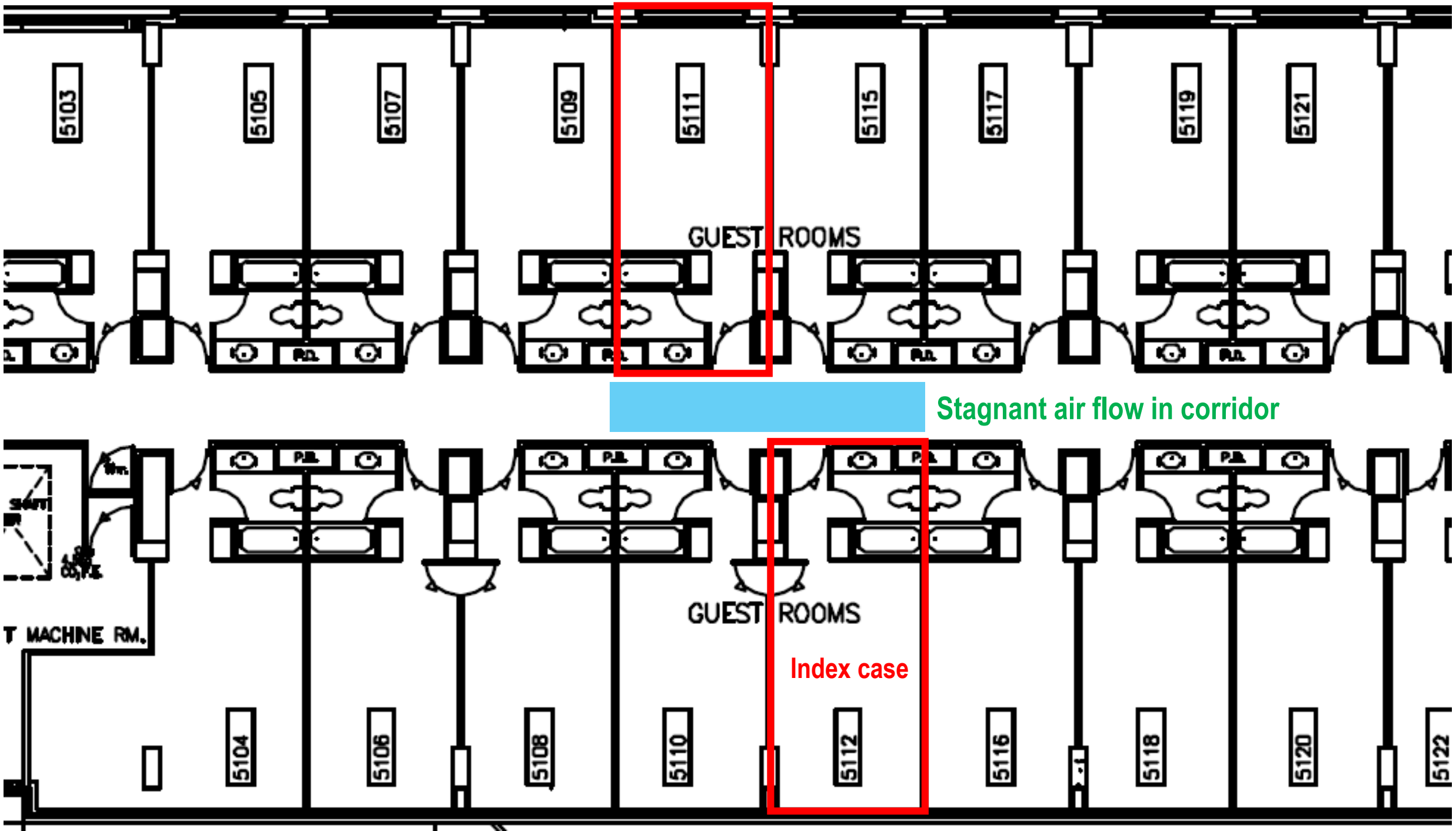
Sequences of event



WGS finding: 100% identical




Air purifier
Rm 5111
Stagnant air
Rm 5112
PAU: fresh air


5103
5105
5107
5109
5111
5115
5117
5119
5121
GUEST ROOMS
Stagnant air flow in corridor
T MACHINE RM.
GUEST ROOMS
Index case
5104
5106
5108
5110
5112
5116
5118
5120
5122

Valve linen mask wore by index

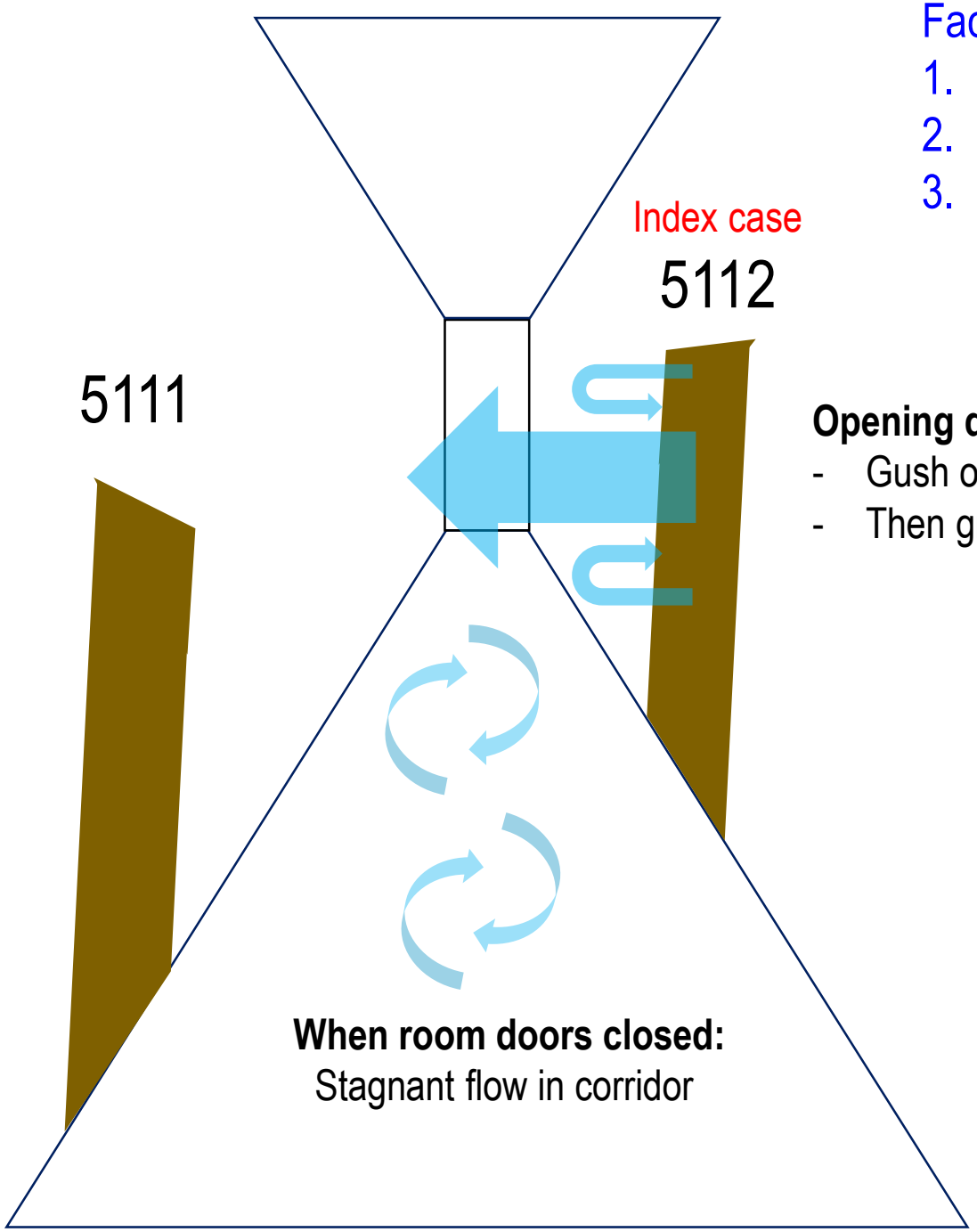
(filtered during inhalation, but no filter while exhalation)

https://www.nist.gov/news-events/news/2020/11/new-airflow-videos-show-why-masks-exhalation-valves-do-not-slow-spread

Ventilation

Facts:

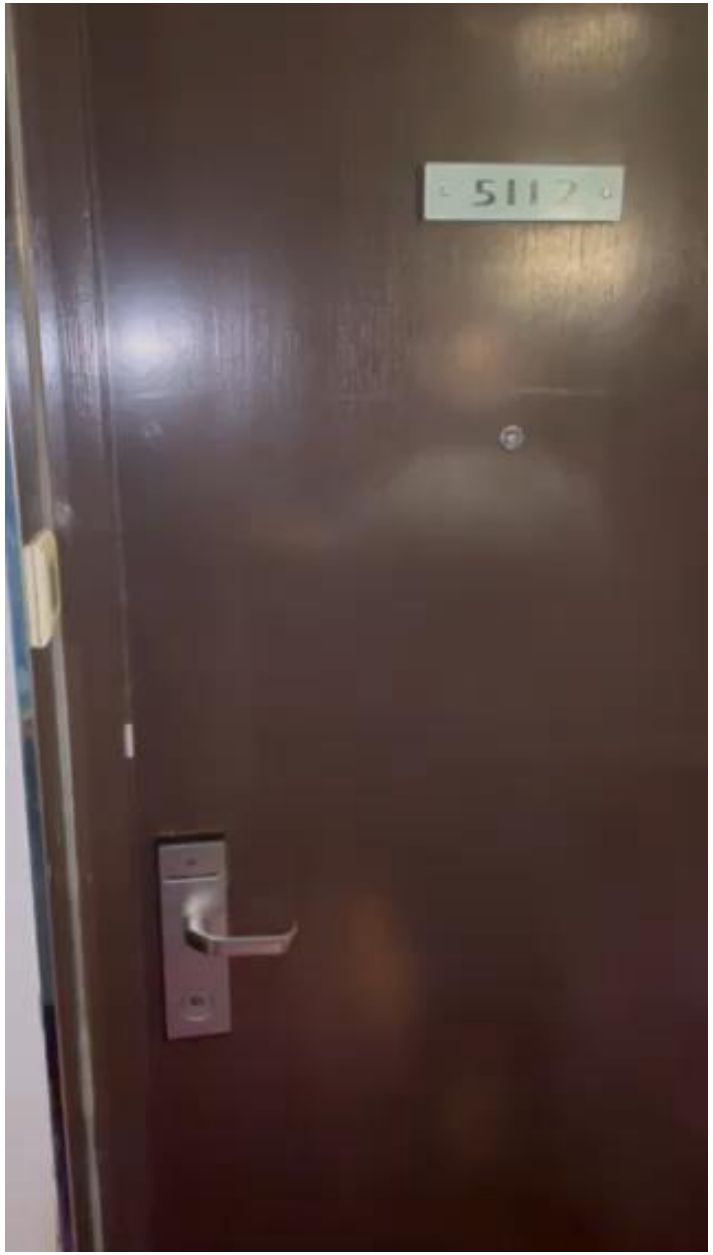
1. Corridor stagnant flow
2. Guest room: -ve pressure
3. Guest room corridor temperature difference



Opening door abruptly

- Gush of air moving rapidly outwards
- Then gradually inward flow

HKU, Dept of Microbiology, Accepted manuscript
The Lancet Regional health – Western Pacific



Door abruptly opened

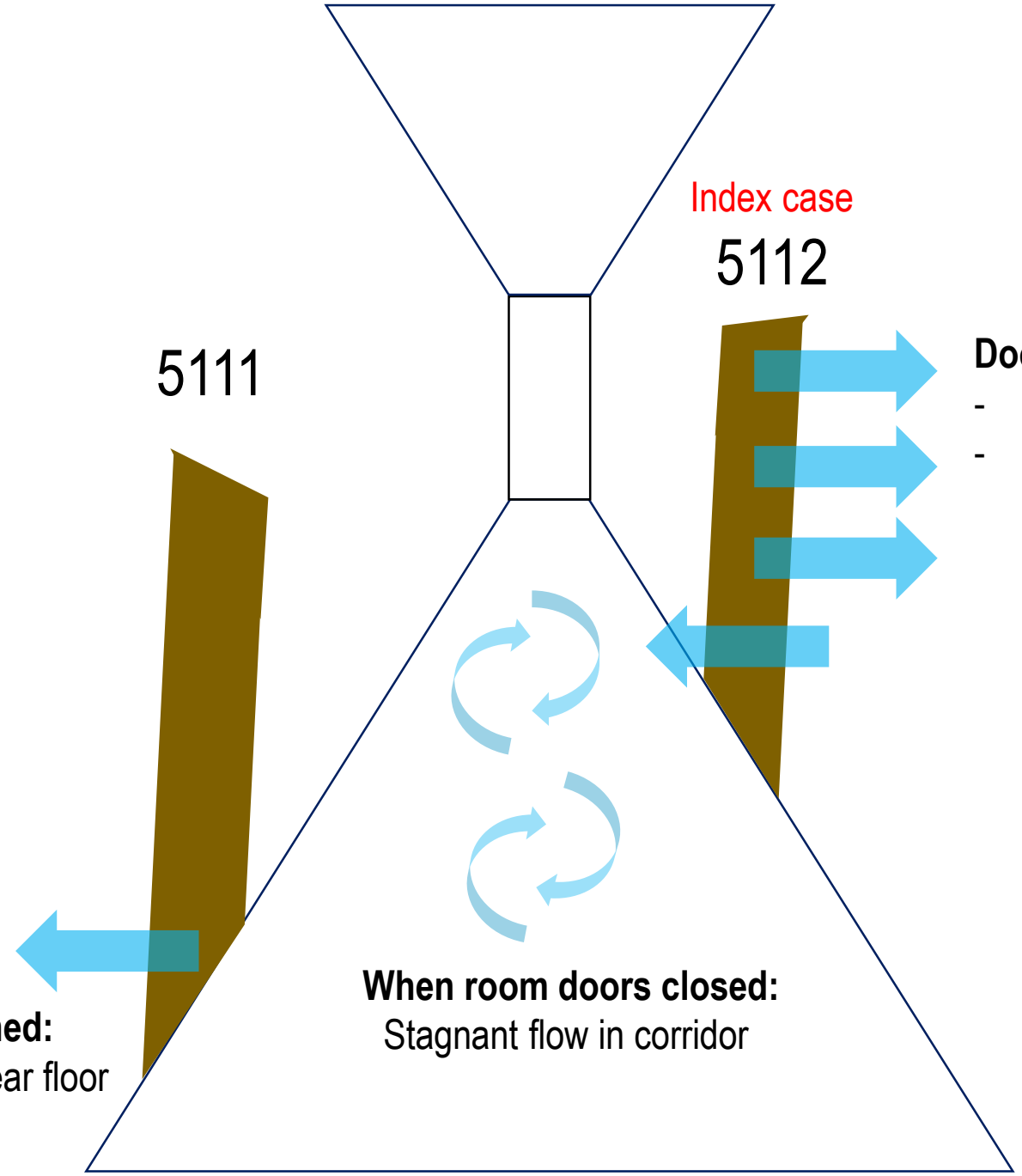
Gush of air rushing out from the room when door opened abruptly

Then gradually moving inwards again

Phenomenon more prominent when toilet door closed

When toilet door opened: air still rush out but less prominent

Ventilation



Door wide open:
- Inward flow in the upper 2/3 of the room door
- Outward flow near floor level

When room doors closed:
Stagnant flow in corridor

Door slightly opened:
- slightly inwards near floor

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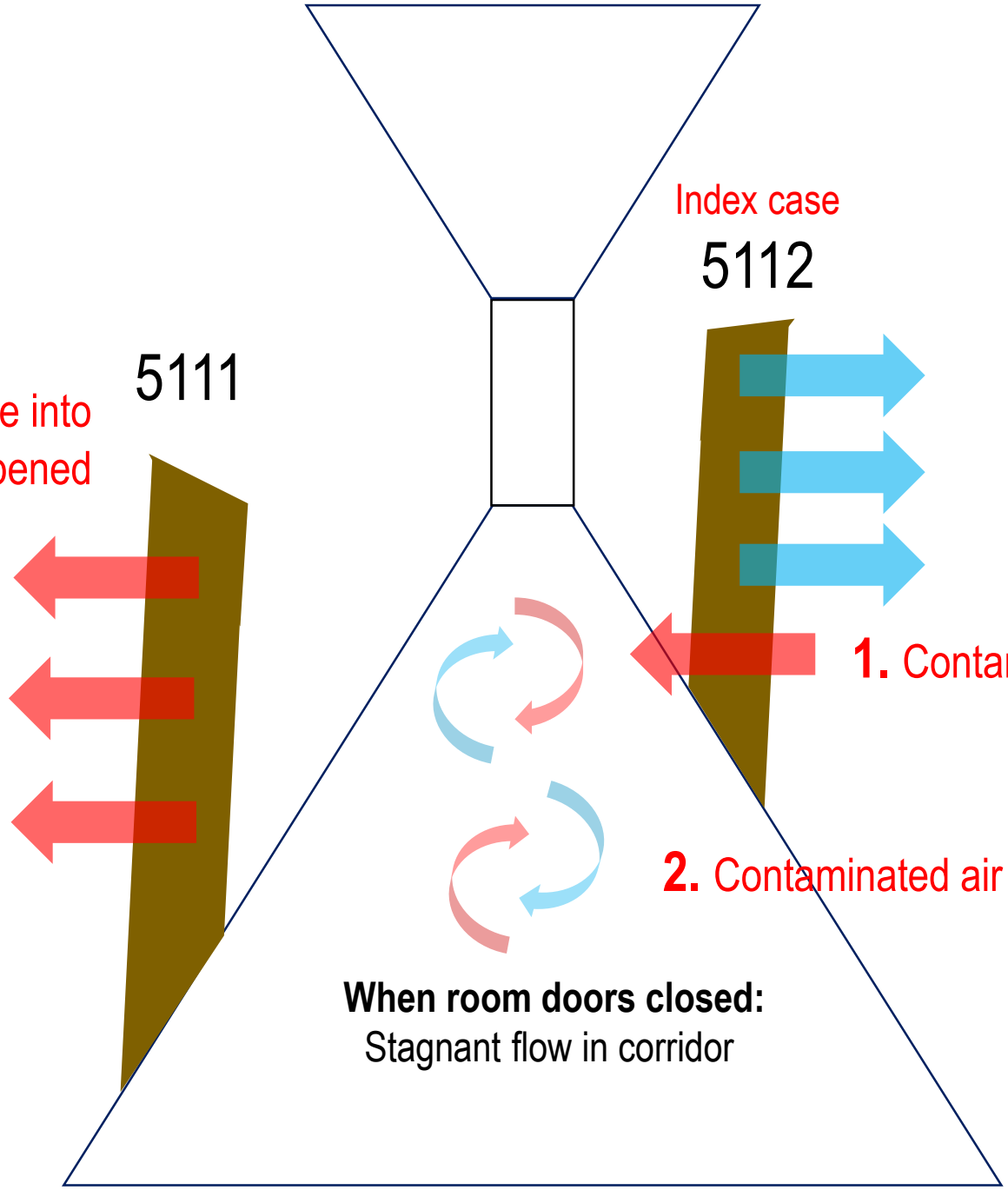
Door open

Inward flow in the upper 2/3 of the room door

Outward flow near floor level (lower 1/3)

Due to turbulence airflow (temperature difference)

Ventilation



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Toilet

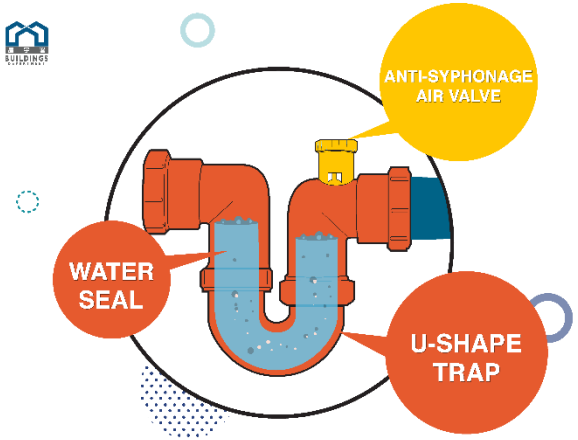
Anatomy of toilet and drains

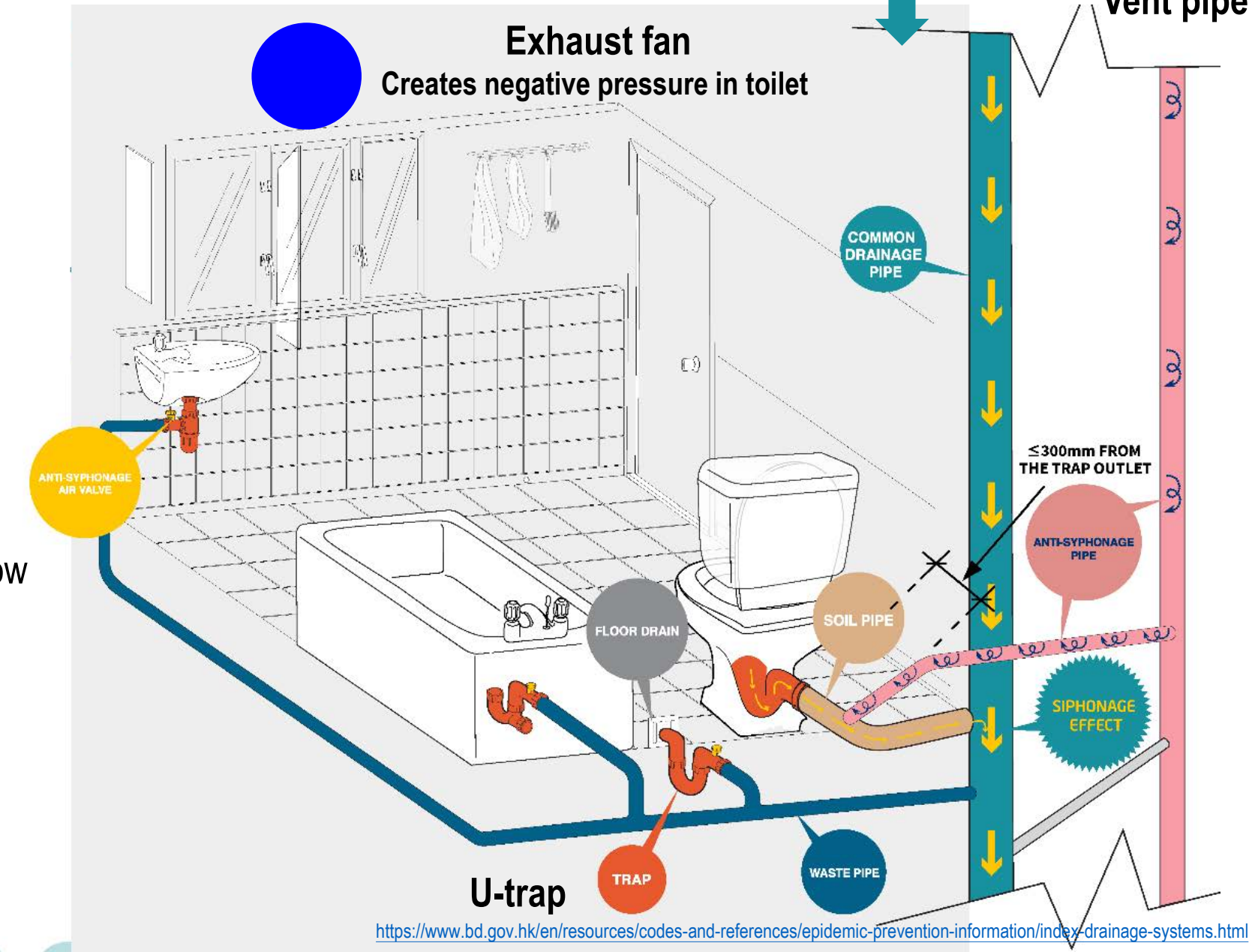
Anatomy of toilet and drains

Main sewage pipe and vent pipe:
- **Connected**
- Opens to floor drain
- Pipes are not 100% airtight

Exhaust fan in toilet:
- Creates negative pressure
- Windows/door closed
  - > **Strong –ve pressure**

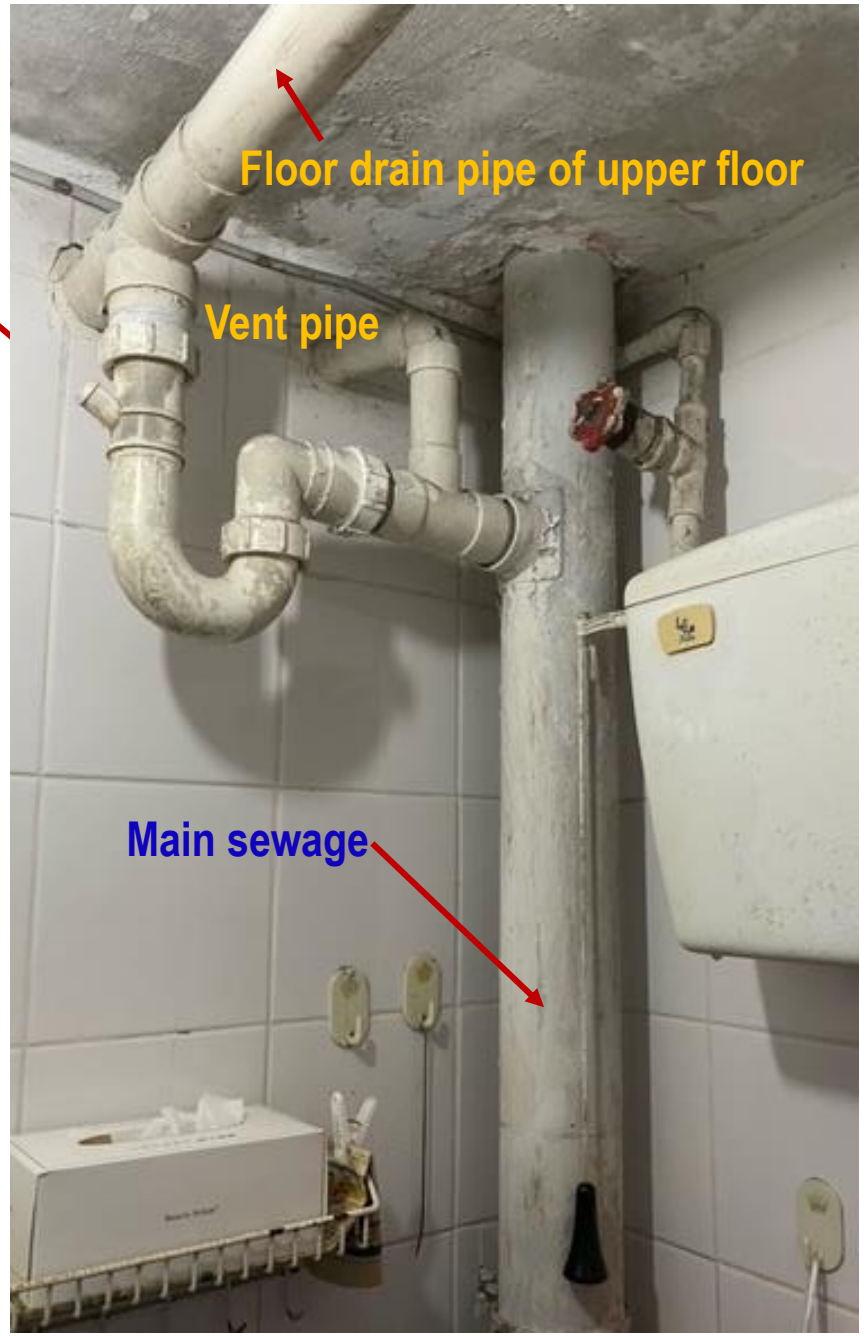
U-trap:
- Water seal prevents air/aerosols back flow





https://www.bd.gov.hk/en/resources/codes-and-references/epidemic-prevention-information/index-drainage-systems.html

Typical unaltered layout of public housing toilet



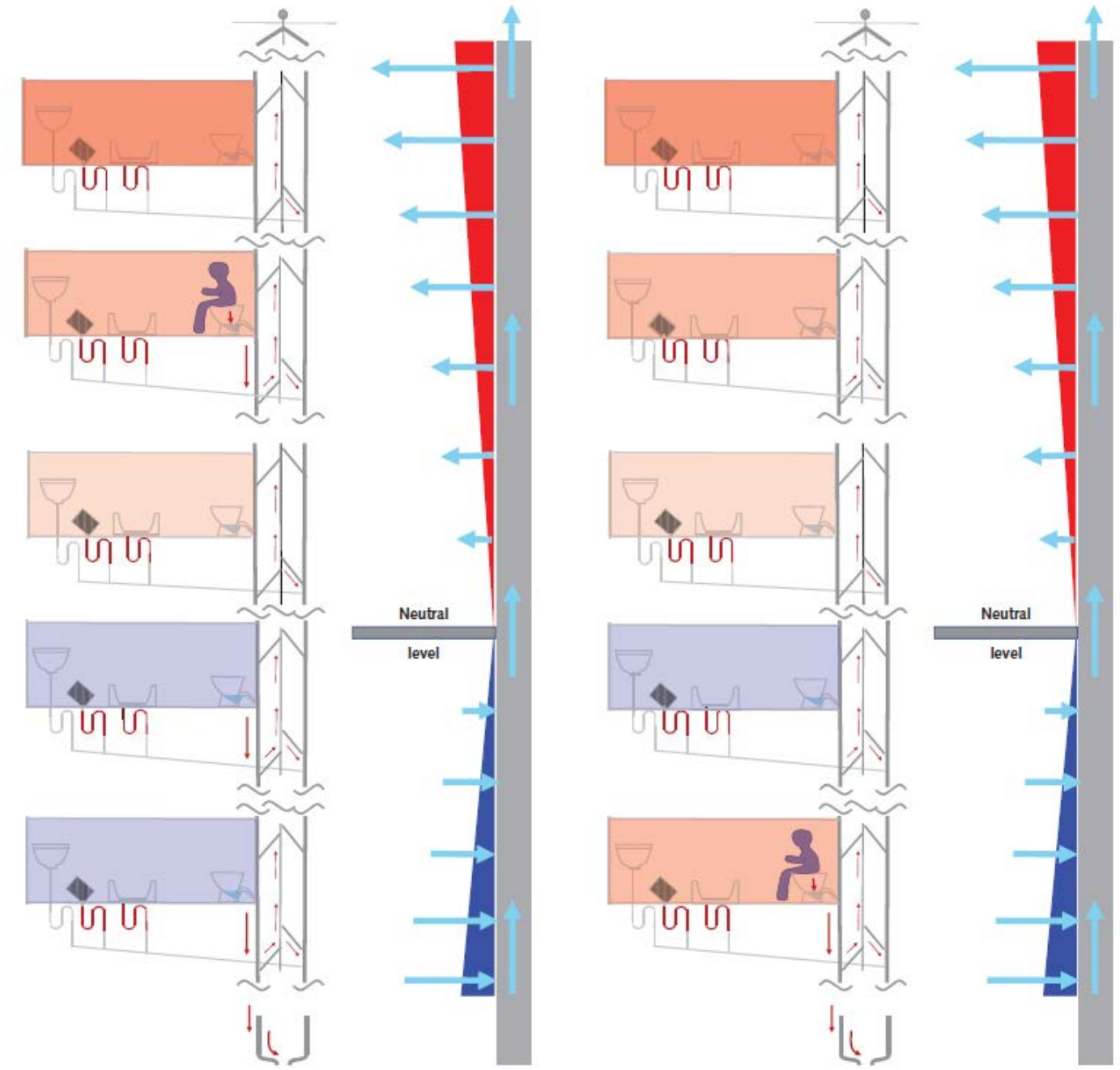
Chimney effect
煙囪效應

Ceiling temperature: **high**

Floor temperature: **low**

Vertical flow of air: **cold** → **hot**

Upwards flow along vertical stack can carry **infectious aerosols**



Vertical stack

Example of vertical transmission

惠利大廈爆垂直傳播　天井密封　袁國勇：04室單位須撤離

撰文：李恩慈 歐陽德浩

出版：2021-02-08 15:58　更新：2021-03-31 21:01

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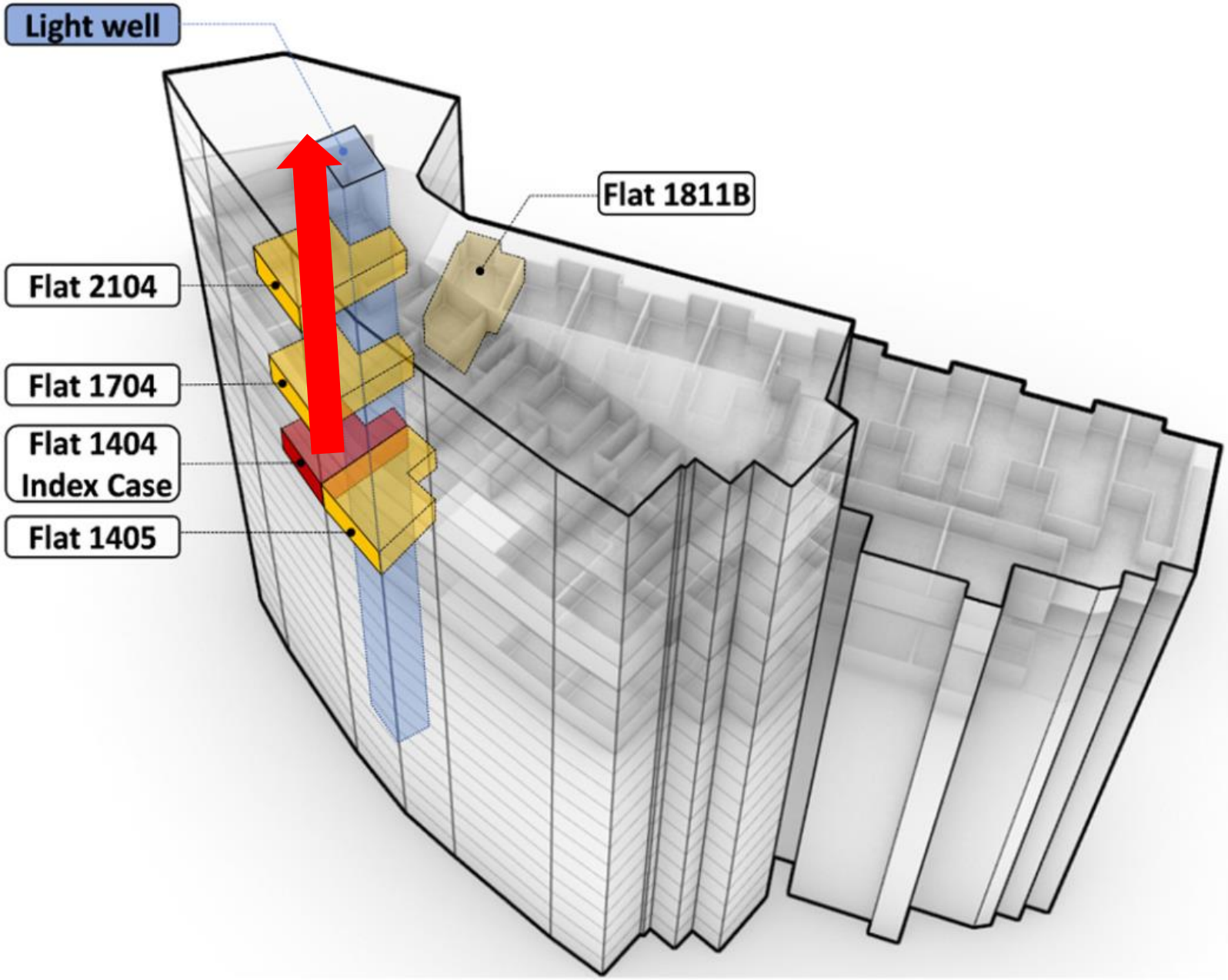
Vertical transmission

Ascending pattern

Wai Lee Building

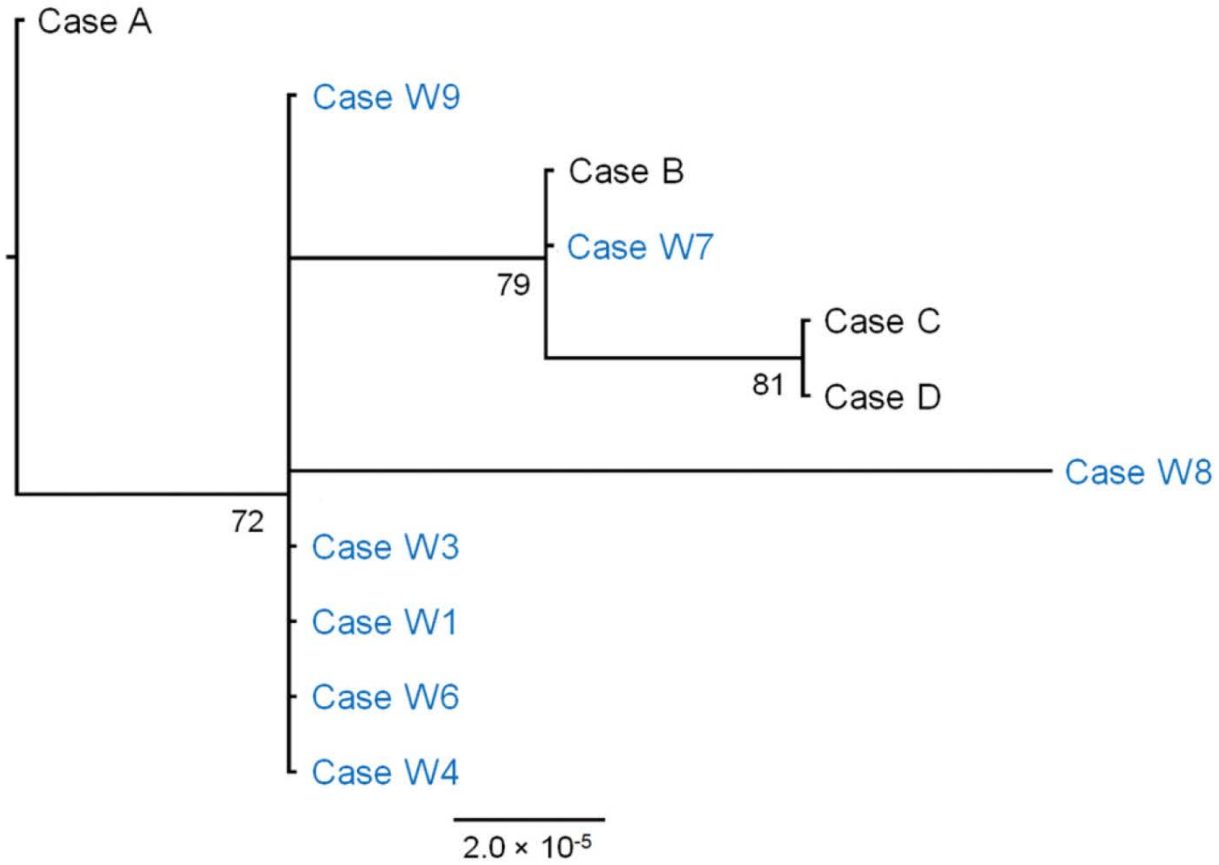
Vertical transmission pattern

Ascending upwards



https://doi.org/10.1016/j.jhazmat.2021.126799

NGS done by QEH/HKCH team



Sequencing result:

- clonal spread from a point source

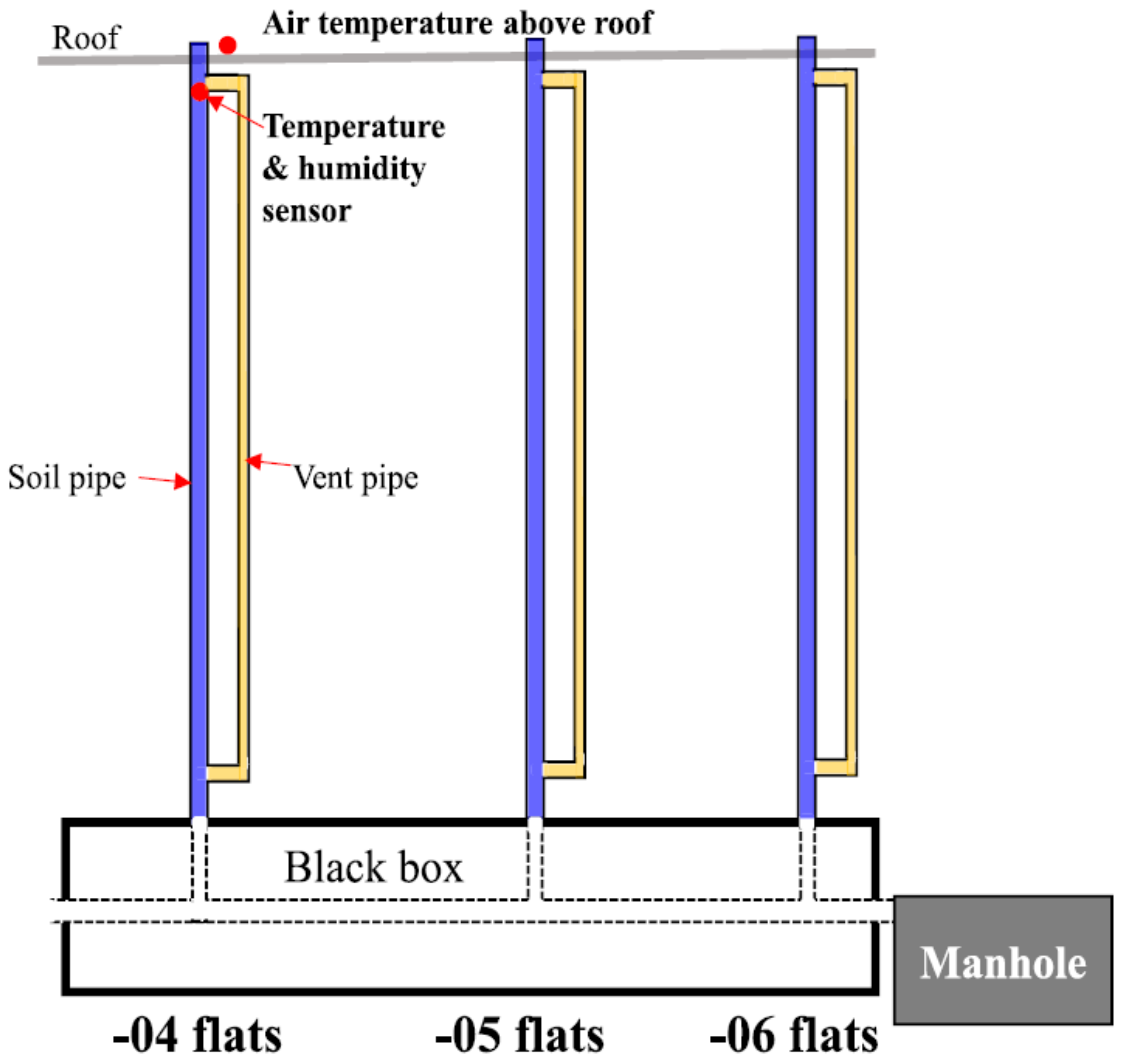
- along the vertical column

Stack aerosols

Discharge of waste water containing faeces (virus)

- Generate stack aerosols

Can aerosols leak to other flats?



Tracer gas experiment

Peak tracer gas concentration near **floor drain in toilet**

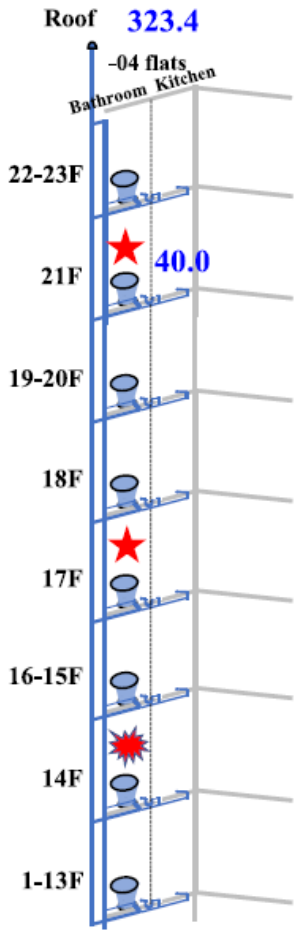
Tracer gas injected at toilet of index case

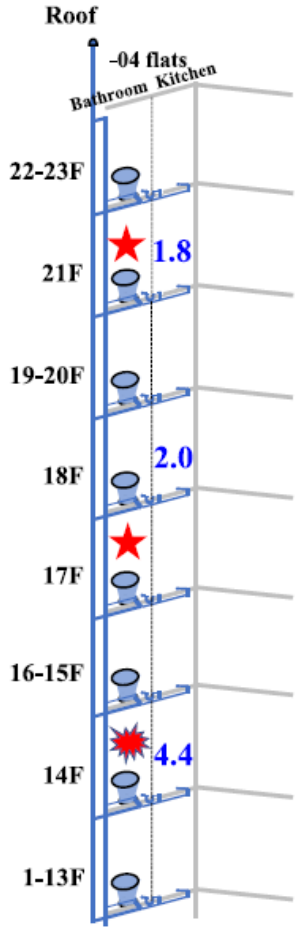
Tracer gas concentration monitored along the facades of infected and non-infected flats

- Detected at bathroom floor drain at different floors
- Detected at light well

Leak demonstrated through drainage system in infected and non-infected flats

Stack aerosols can spread to indoors through **pipe leaks along same vertical column**





Peak tracer gas along **facades in light well**

Summary

1. Opportunistic airborne transmission of COVID-19:
   - Can occur in **poorly ventilated premises**, especially in **mask off setting**

2. Airflow direction:
   - An important factor accounting for airborne transmission of COVID-19

3. Drainage pipes: discharged waste water contains SARS-CoV-2 virus:
   - **Stack aerosols** can spread indoor via through pipe leak

The end