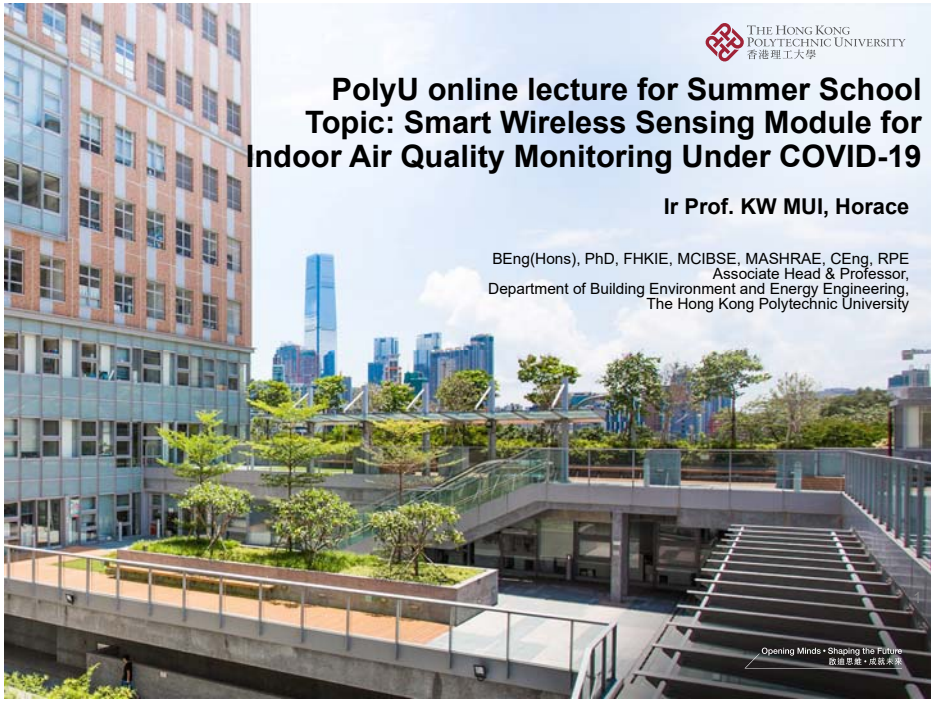

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PolyU online lecture for Summer School
Topic: Smart Wireless Sensing Module for Indoor Air Quality Monitoring Under COVID-19

Ir Prof. KW MUI, Horace

BEng(Hons), PhD, FHKIE, MCIBSE, MASHRAE, CEng, RPE
Associate Head & Professor,
Department of Building Environment and Energy Engineering,
The Hong Kong Polytechnic University

Opening Minds • Shaping the Future
啟迪思維 • 成就未來

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General Principles….

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High Risk Premises

Mask Off
Close Proximity
Long Term Exposure
Enjoyable Loud Talking

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Vulnerable Groups

Schools and Elderly Homes:
Physically vulnerable segment with long term close interaction

Possible Out break if Teachers are infected and their offices become a hub

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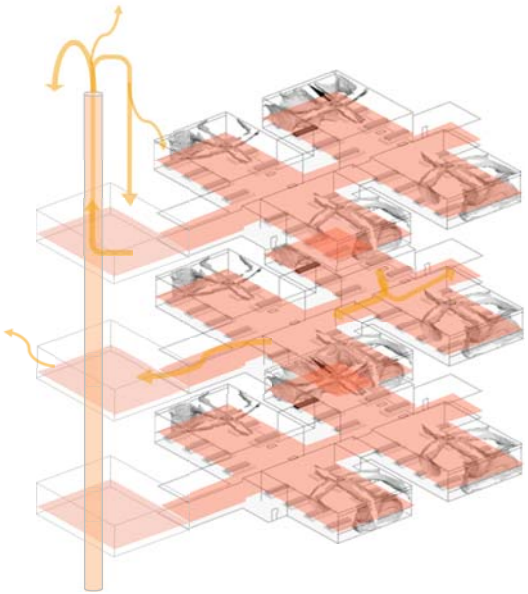
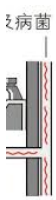
What we need to take care?



Air flow should never go from dirty to clean



圖片來源：Goggle資訊

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Any solutions?

Problems today

- COVID-19 Virus is more viable than SARS in normal thermal condition
- Transmission of the virus through carrier in air seems to be effective
- The most effective way of precaution is to cut off all possible connections between people (not desirable)
- All interpersonal activities are halt and caused damage to most schooling (classroom, teacher's office)
- Difficult to perform effective risk assessment (Hidden paths of transmission are very hard to determine)
- Situations change so rapidly. When emergency out break takes place, how to respond?
- Actual Virus test in real environmental is not desirable

What is needed?

- Simple assessment method
- Minimal disturbance to tenants and occupants
- Rapid response and deployment
- Provide all possible ways of dispersion profile
- Provide an easy-to-understand presentation of the current situation to the occupants
- Provide suggestions of remedy for effective precaution (i.e. seating plans modification, occupant allocation, operation scheduling, air purifications, system modifications)

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Ventilation & Transmission

Any Technologies?

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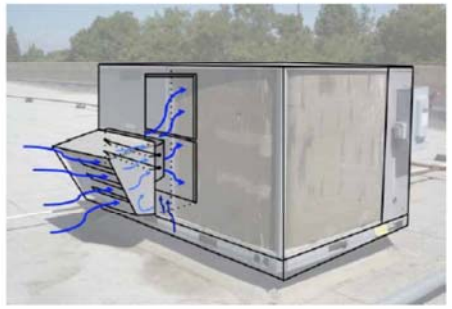
Ventilation Principles

- Ventilation is the supply of outdoor air to a building



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Ventilation Principles

Why is building ventilation needed?

- Ensure comfort and satisfaction
  - Remove odor
  - Avoid stuffiness
- Maintain overall indoor air quality
  - Remove indoor air pollutants (e.g., formaldehyde emitted from building materials, furnishings)
- Support health and productivity of occupants

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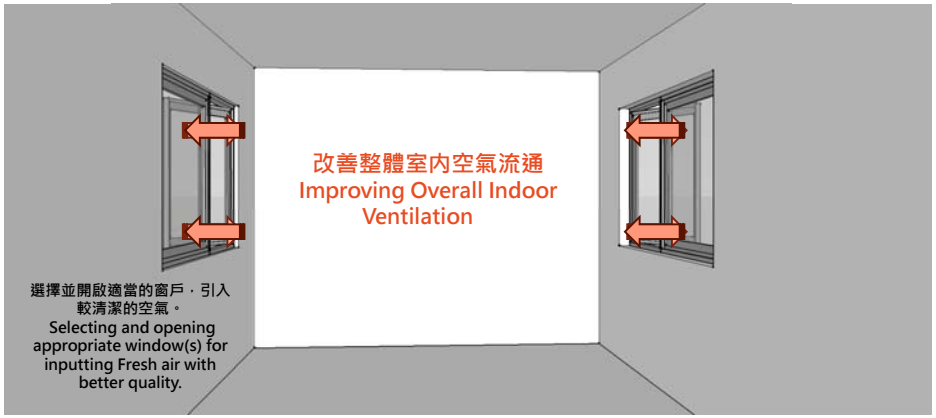
Ventilation Principles

渠漏解決師 LEAKY DRAIN BUSTERS

通風系統 Ventilation System :
優質的室內環境
Quality Indoor Environment

窗戶
Window at Light Well
開 OPEN | 關 CLOSE



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Ventilation Principles

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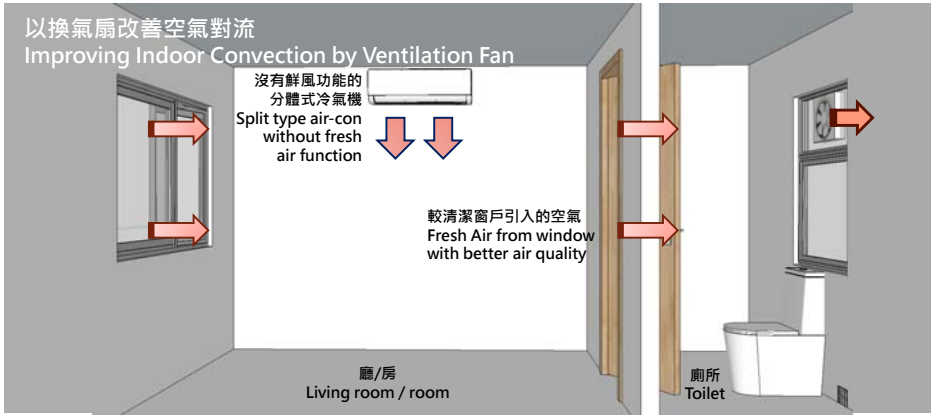
優質的室內環境
Quality Indoor Environment

換氣扇
Air-Conditioner
開 ON | 關 OFF

窗戶
Window at Light Well
開 ON | 關 OFF

廁所門
Toilet Door
開 OPEN | 關 CLOSE



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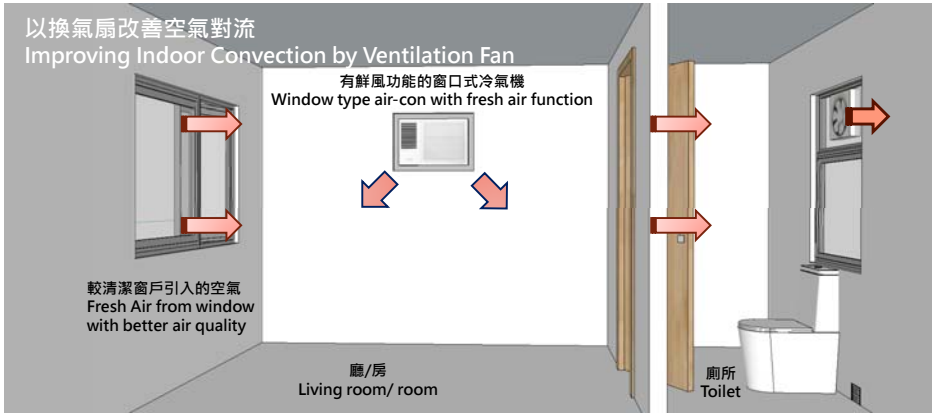

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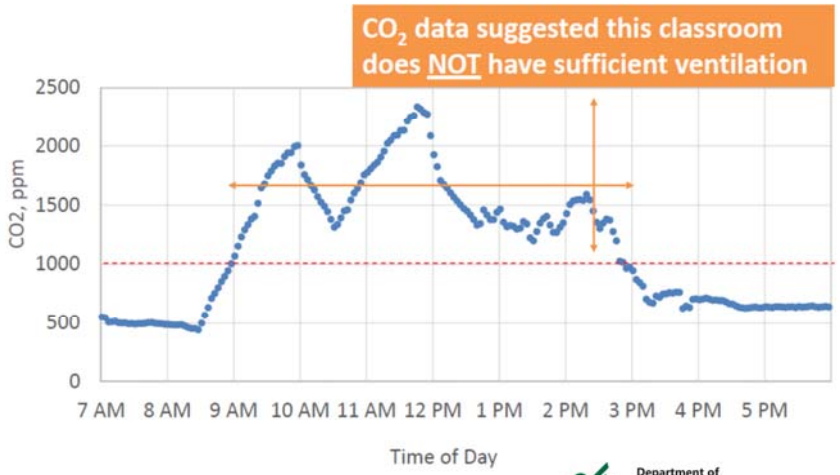
Ventilation … any indicator?

Carbon Dioxide (CO_2) as Proxy for Ventilation Rates

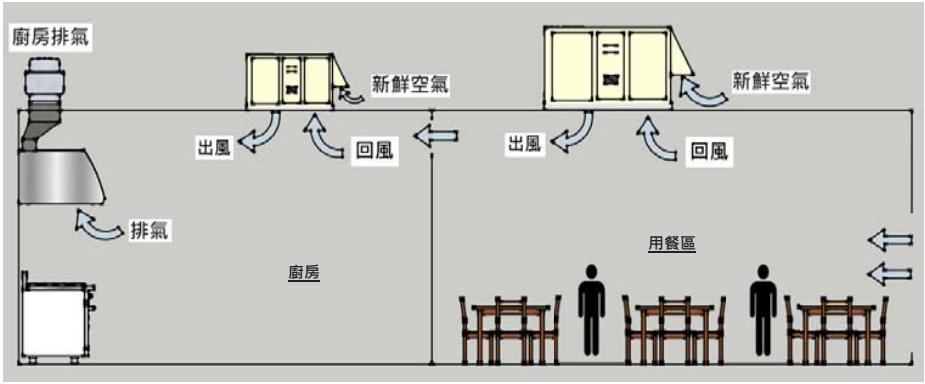
- CO_2 concentrations are often used as an easily measured proxy for ventilation rates
  - When unoccupied, indoor CO_2 approaches outdoor background level (0.04%, or 400 parts per million (ppm))
  - When people enter the space, CO_2 increase over time because we exhale CO_2 (4%)
  - Peak indoor CO_2 concentration above **1,000 ppm** indicates ventilation rates less than 7 L/s (15 cfm) per person (building ventilation requirement)
- Research suggests exposure to elevated level of CO_2 can also impact cognitive performance

Ventilation … any indicator?

CO_2 Concentrations Measured in a Classroom



Restaurant Ventilation



換氣率 (Air Change Rate) = 每小時每人立方米新鮮空氣 (m^3/hour/person fresh air) x 人數 (person) / 餐廳的體積 (m^3)

Restaurant Ventilation

A Guide to Application for Restaurant Licences (fehd.gov.hk)

HEALTH REQUIREMENTS FOR THE ISSUE OF PROVISIONAL GENERAL/LIGHT REFRESHEMENT RESTAURANT LICENCE

STANDARD REQUIREMENTS

1. **Ventilation** : When natural ventilation is insufficient (i.e., where openings and windows to the open air are less than 1/10th of the floor area), a ventilating system shall be provided to give not less than 17 cubic metres of outside air per hour for each person that the premises are designed to accommodate. A ventilating system, which shall be independent of any ventilating system provided for the seating accommodation, shall be provided for the kitchens and toilet rooms of the premises.

2. **Toilets** : At least one toilet compartment, one urinal and one wash-hand basin shall be provided on the premises for the use of customers and staff. If the premises are designed to accommodate more than 25 customers, at least 50% of the provision required for the issue of a full licence have been provided.

Ventilation

How to calculate the Air Change Per Hour (ACH)

Use	Factor used in determining the population
Seating Area	1 m^2/person
Food Room Area	4.5 m^2/person
Dancing Area	0.75 m^2/person

ACH

$$= \frac{\text{Number of occupants (person) x fresh air quantity } (m^3/h/\text{person})}{\text{Volume of the space } (m^3)}$$

換氣率 (Air Change Rate) = $\frac{\text{每小時每人立方米新鮮空氣 } (m^3/\text{hour/person fresh air}) \text{ x 人數 (person)}}{\text{餐廳的體積 } (m^3)}$

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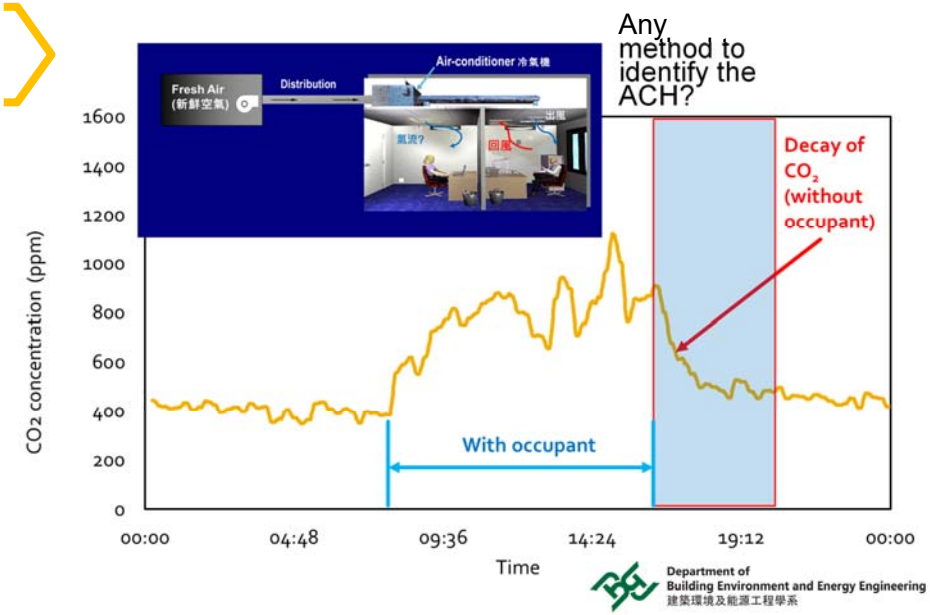
What is decay test??

Any method to identify the ACH?



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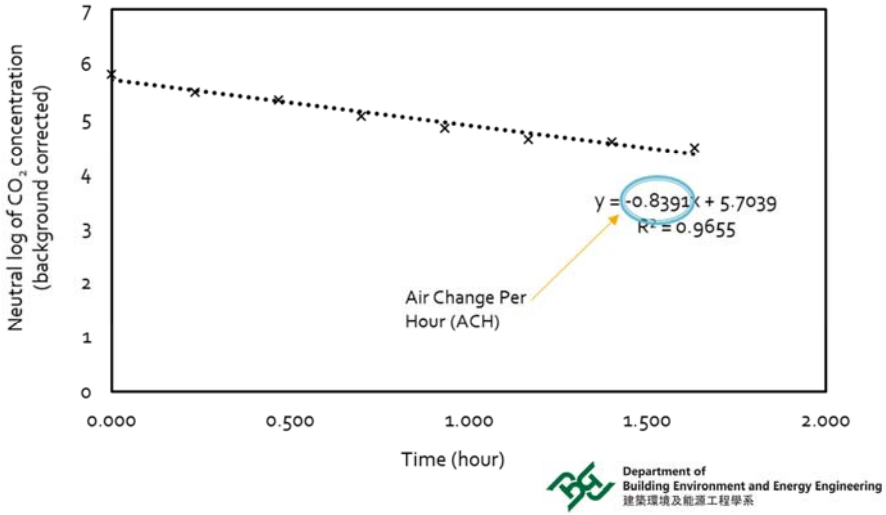
Ventilation calculation

Any method to identify the ACH?



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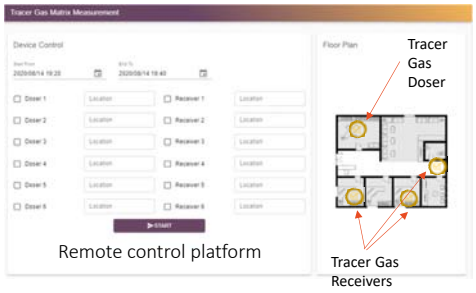
Ventilation calculation

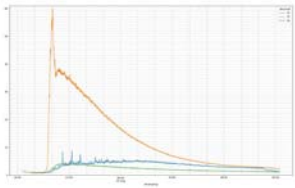


- ACH analysis by Decay Mode
- Source apportionment analysis by Constant Injection Mode
- Cross Flow/Contamination analysis by Matrix Mode (Multi-Dosers/Receivers Sycnchronized Dosing Matrix)

Tracer Gas Matrix Surveying System

- Rapid deployment for Instant response
- Minimal training required for deployment
- Remote real time analysis possible
- Environmentally friendly R134A applied as easily available tracer gas

Real Time Tracer Gas Profile at 3 defined locations



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Ventilation (Example)

Ventilation (Example)

Tracer Gas Doser

Tracer Gas Receiver

Tracer Gas Receiver

Tracer Gas Receiver

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Ventilation (Example)

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This is the update technology??

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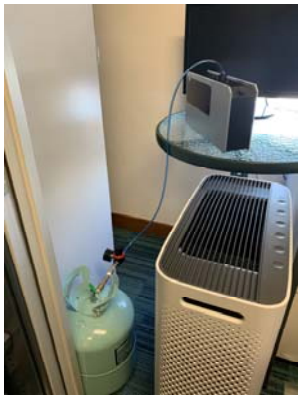
Ventilation and transmission path – How to measure?

Tracer Gas Matrix Measurement

Pathogen Source Dispersion Analysis
Contaminants Apportionment Analysis



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Identification of transmission path – How to measure?

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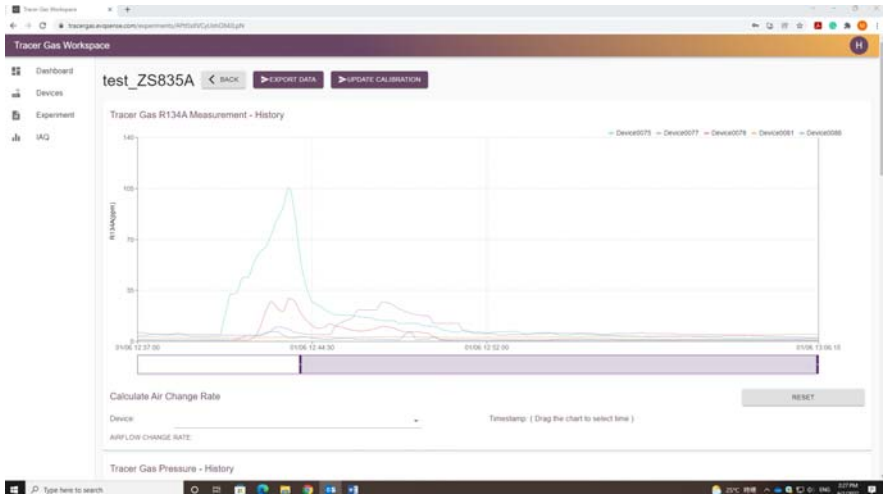
Identification of transmission path – How to measure?



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Identification of transmission path – How to measure?

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Identify the dispersion of COVID-19

- Applicable to special situation, for instant during a pandemic, to conduct monitoring in wet market and restaurants where transmissions are observed, even clean-up has been done
- Once the equipment is set-up, the system will release and track the tracer gas **remotely** without the presence of technician. Much less manpower and time are needed
- **No personnel is required** to be on-site. Data will be automatically transmitted to server for analysis
- Compare to traditional method which takes about half a day to collect and analysis the data, this **new approach takes only 2 hours** to report the pathogenic bioaerosol dispersion pathway

The Tracer Gas Measurement Exercise helps to

- Define better seating arrangement at with respect to the existing ventilation profile
- Determine the potential pathogen dispersion coverage
- Determine the existing risk level deduced by the ACH evaluating
- Determine the optimized occupation number
- Conduct cross platform analysis with long term IAQ monitoring data
- Define emergency control plan
- Define ventilation system modification plan

Any more examples?

On Stage Tracer Gas Air Flow Analysis
for
Risk Assessment of Potential Pathogen Dispersion Profile

In Association with
Hong Kong Philharmonic Orchestra

Objective for HK Phil On Stage Air Flow Analysis

- Determine the spreading path of potential pathogen from any player on stage
- Determine the potential risk level for other occupants on stage
- Determine the ventilation rate of the current system settings
- Help defining an optimized seating plan to minimize risk level
- Determine the best way of deployment of air purifiers if necessary
- Determine the best arrangement of barrier settings
- Evaluate the risk level at the common areas where the players may gather
- Define all possible measures that could provide a safe environment for the next performance

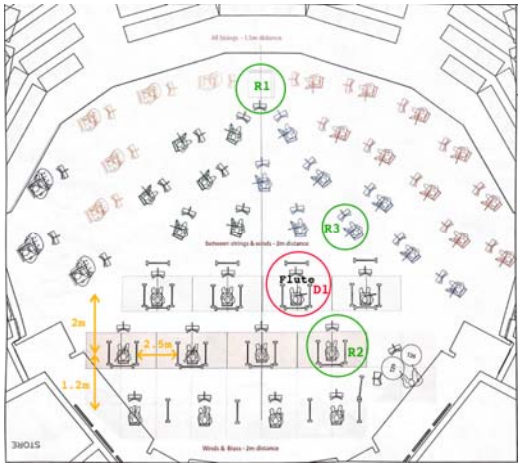
- https://pc.watch.impress.co.jp/docs/news/1282701.html

Tracer gas profile against Individual Barrier

Test Upon Individual Barrier Setting

Experimental condition

- Doser: Flute player
- Receiver
  - R1 – 54: conductor
  - R2 – 55: back-right
  - R3 – 56: front-left
- Tracer gas operation
  - Release at: 10:56:10
  - Stop at: 11:07:01



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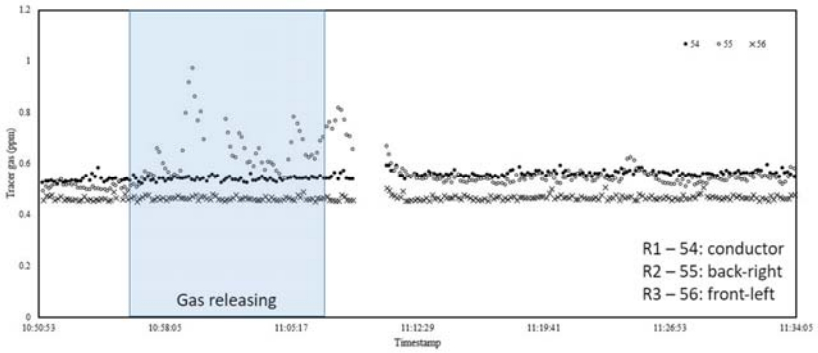
Tracer gas profile against Individual Barrier



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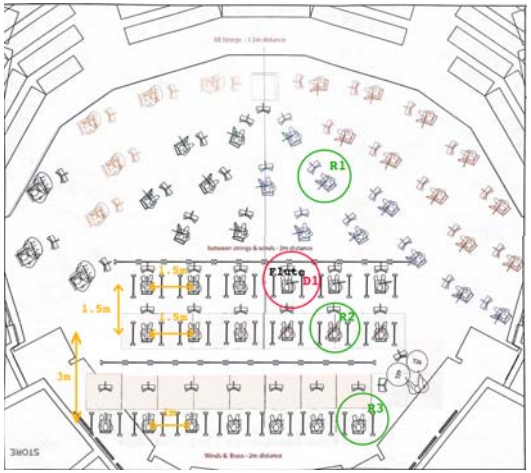
Tracer gas profile against Optimised Seatings with Inline Barriers

Test upon Optimized Seatings with Inline Barriers

Experimental condition

- Doser: Flute player
- Receiver
  - R1 – 54: front-right
  - R2 – 55: back-right
  - R3 – 56: further back-right
- Tracer gas operation
  - Release at: 14:53:00
  - Stop at: 15:03:36



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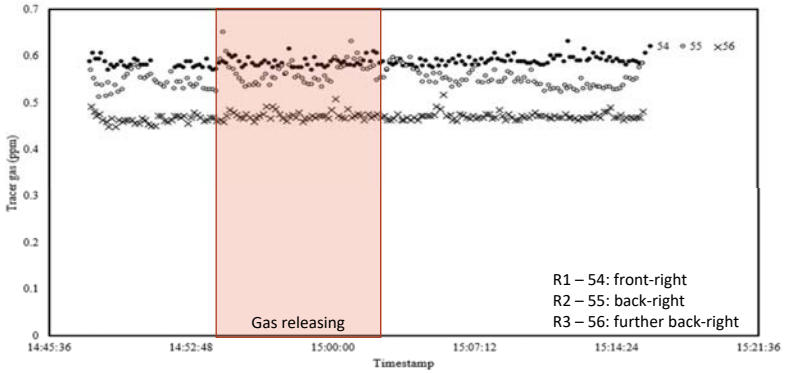
Tracer gas profile against Optimised Seatings with Inline Barriers



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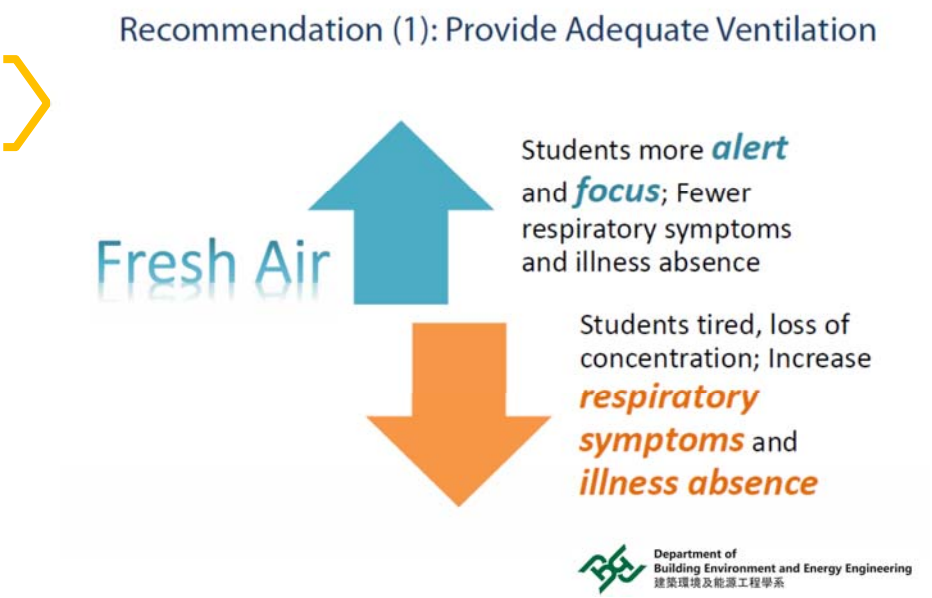
So…?



In conclude …

Embrace more health-conscious design, and work cooperatively as an international community to solve problems, pave the way for a healthier future

Question & answer?

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