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Typical IAQ problems and improvement strategies for health facilities

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Clinics & health centres in Hong Kong

- Whole building
  - Provide various services including general and specialist out-patient clinic services, pharmacy, diagnostics and imaging, dental service, etc.
  - Served by *mechanical ventilation and air conditioning (MVAC) system*
- Part of the existing commercial building
  - Provide several medical services, mostly general out-patient clinic services, pharmacy, diagnostics and imaging
  - On one or several floors
  - Served by *MVAC system*
  - *Share public facilities* (e.g. lift, toilet, lobby) with other businesses
  - Patients may need to travel for several floors for various services
- Small local clinics in residential areas
  - Usually provide only out-patient clinic services and pharmacy
  - In mall or on the street in residential areas
  - Served by *MVAC, window type or split type air-conditioner*

IAQ pollutants in clinics & health centres

- Carbon dioxide (CO_2)
- Carbon monoxide (CO)
- Formaldehyde (CH_2O)
- Volatile organic compounds (VOCs)
- Respirable suspended particulates (PM)
- Radon

Common IAQ pollutants

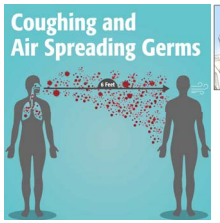
- Glutaraldehyde ($C_5H_8O_2$)
- Nitrous oxide (N_2O)
- Latex allergens
- Airborne bacteria/ mould

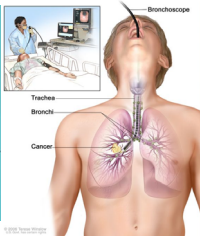
IAQ pollutants specific to healthcare facilities

Reference: Leung, M., & Chan, A. H. (2006). Control and management of hospital indoor air quality. Medical Science Monitor, 12(3), 23.

Cause of IAQ problems

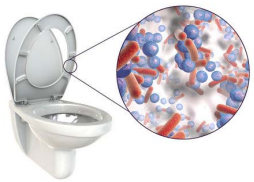
- Use of *disinfectant/ chemicals* which contain volatile organic compounds (VOCs)
- *Patients* as sources of airborne particles (e.g. airborne viruses and bacteria and fungus spores)
- Specific *medical procedures* (e.g. endoscopic procedures, tracheal intubation, nebulized therapy and bronchoscopy)
- Poor *design of HVAC system* originally for office usage
- *Recycled air* for energy efficiency
- Poor *filtration* performance
- *Improper maintenance/ lack of cleaning* of HVAC system





Consequences of poor IAQ

- Sick hospital syndrome (SHS)
  - Headache, fatigue, eye and skin irritation
  - Lower productivity
- Hospital acquired infections
  - Patient-patient and healthcare worker-patient cross-infection
- Spreading of diseases among different floors through common building facilities
  - Lift, door, toilet, HVAC system,



Patients and healthcare workers

- Higher risk for vulnerable populations
  - Elderly and children
  - Patients with long-term illnesses
  - Patients with immunodeficiency disorder
- Healthcare workers are also prone to health risks due to prolonged exposure to IAQ pollutants and occupationally harmful biological pollutants

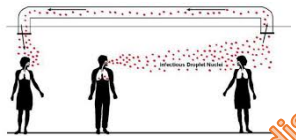
Hong Kong's classic example - SARS

In 2003, SARS outbroke in General Inpatient Ward caused by a SARS patient be given with nebulized treatment

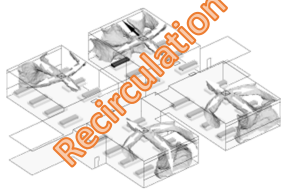
- Aerosolized coronavirus particles re-circulated in the whole ward, infecting 277 staff and patients, leading to the community outbreak in HK

In 2004, HK Government approved the construction of the 1st Infection Disease Control centre in HK

- 17-storeys with 108 negative pressure isolation beds
- Started operation in 2007



Infections droplet nuclei travel within environment



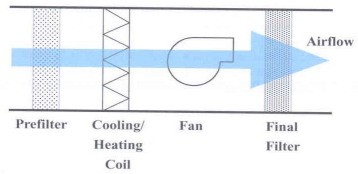
Transmission paths for the pathogenic between general inpatient ward cubicle

1st Infection disease centre in HK

IAQ improvement methods

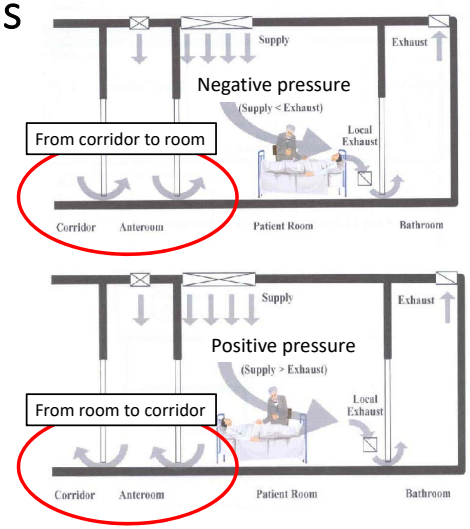
- Mechanical ventilation
  - Diluting indoor air pollutants
  - Exhaust the contaminated indoor air
  - Introduce clean outdoor air into an air-conditioning building
  - Air change rates for outdoor air and total air are recommended by ASHRAE (1999,2001,2004,2007), AIA (2001) and CDC (1994)
- Filtration
  - Trap particulate contaminants
  - Various grade of filters can be used to achieve different degrees of cleanliness
    - Prefilter of 25% dust spot efficiency to remove large particles
    - Final filter should have at least 90% efficiency to collect nearly all fungal spores of 2-5μm diameter and bacteria in colony-forming units of 1μm diameter
  - Filtration requirements of some hospital areas are provided by ASHRAE (1999) and AIA (2001)

Area	Outdoor ACH	Total ACH	Outdoor air requirement	
	ACH	ACH	Cfm/p	L/s/p
Patient room	2	4	25	13
Operating theatre	15	15	30	15
Infectious isolation room	2	6		
Laboratory	2	6		
Pharmacy	2	4		
Darkroom	2	10		



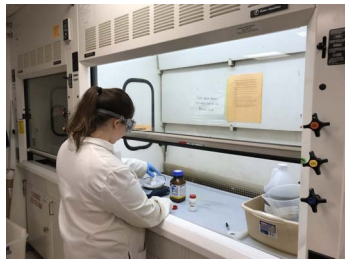
IAQ improvement methods

- Differential pressure control/ Directional airflow control
  - Maintain a differential pressure between two adjacent areas can restrict the air leakage in a single direction through the door undercut
  - Ensure clean-to-less-clean airflows: air movement should be from clean zones to zones of progressively greater contamination



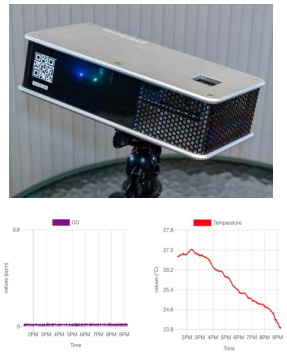
IAQ improvement methods

- Local exhaust ventilation
  - Chemical fume hoods to control critical emission sources of chemical vapours
  - Ensure adequate removal of the pollutant
  - Air cleaner with HEPA filter
- Ultraviolet light Irradiation
  - Upper-room irradiation
  - Duct irradiation
  - Mobile irradiation system



IAQ monitoring

- IoT real-time monitoring
  - Automatic, low cost and manpower required
  - All-in-one multiple sensor module for representative pollutants
  - Compact design, mobile and easy to set-up
  - Real-time and smart analysis
- IAQ Certification Scheme



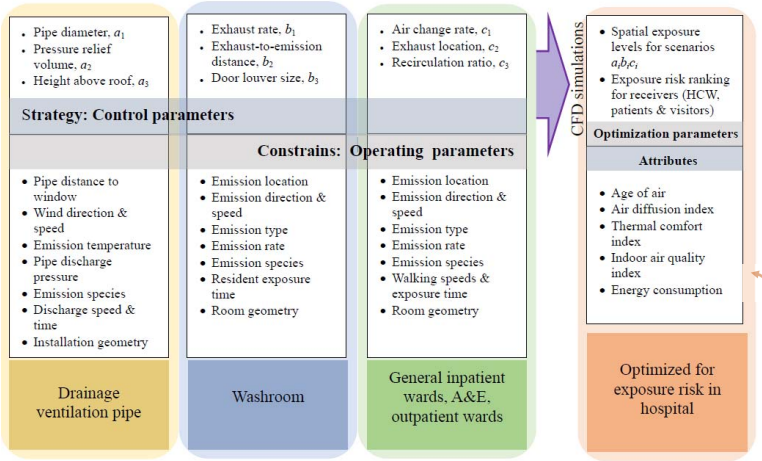
My research in improving IAQ in hospitals

Project Title: ***Effective Ventilation Strategies for Mitigating Infection Risks in Hospitals***

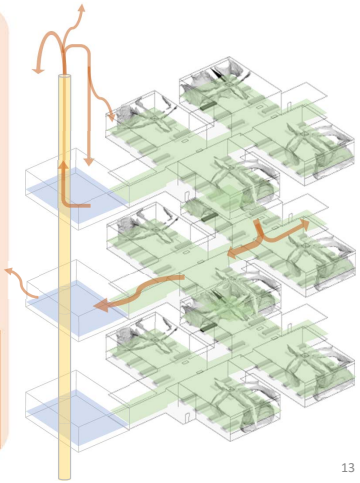
Objectives:

- Understand the spatial distribution of pathogenic bioaerosols in General Human Occupied Areas (GHOAs)
- Identify the temporal influence of possible combinations of control and operational parameters on the estimation of infection risk within the mechanically ventilated enclosure in hospital
- Evaluate and update current air change requirements (ACH) in hospital
- Provide proper ventilation strategies which mitigate the risk of airborne infection transmission for GHOAs

What we need to take care of?



Air flow should never go from dirty to clean



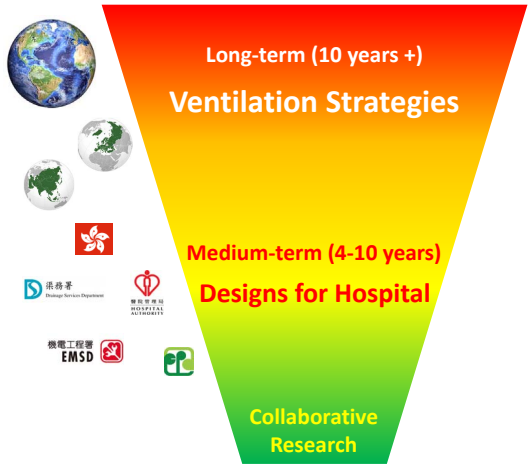
Overall strategy and collaborative effort

- Data collection (Control and Operational parameters) and Computational Fluid Dynamics (CFD) simulation to understand spatial and temporal distribution of pathogenic bioaerosols under different ventilation strategies and emission scenarios
- Exposure Risk Assessment that helps to identify high risk zone in hospital
- Optimization of ventilation energy usage based on exposure risk

Deliverable: formulating ventilation strategies that **minimize the risk of exposure to airborne infections** in hospitals

Pathway to impact

- Inter-institutional collaboration locally and internationally
- Policy and regulations
- Improve international ventilation standards, codes of practice
- Ventilation strategies
- Reference and guideline
- Better hospital design



Summary

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

Question & answer?

Acknowledgement: This project **Effective Ventilation Strategies for Mitigating Infection Risks in Hospitals** (No.: C5108-20GF) is funded by RGC CRF COVID-19 Collaborative Research Fund (RGC CRF) 2020