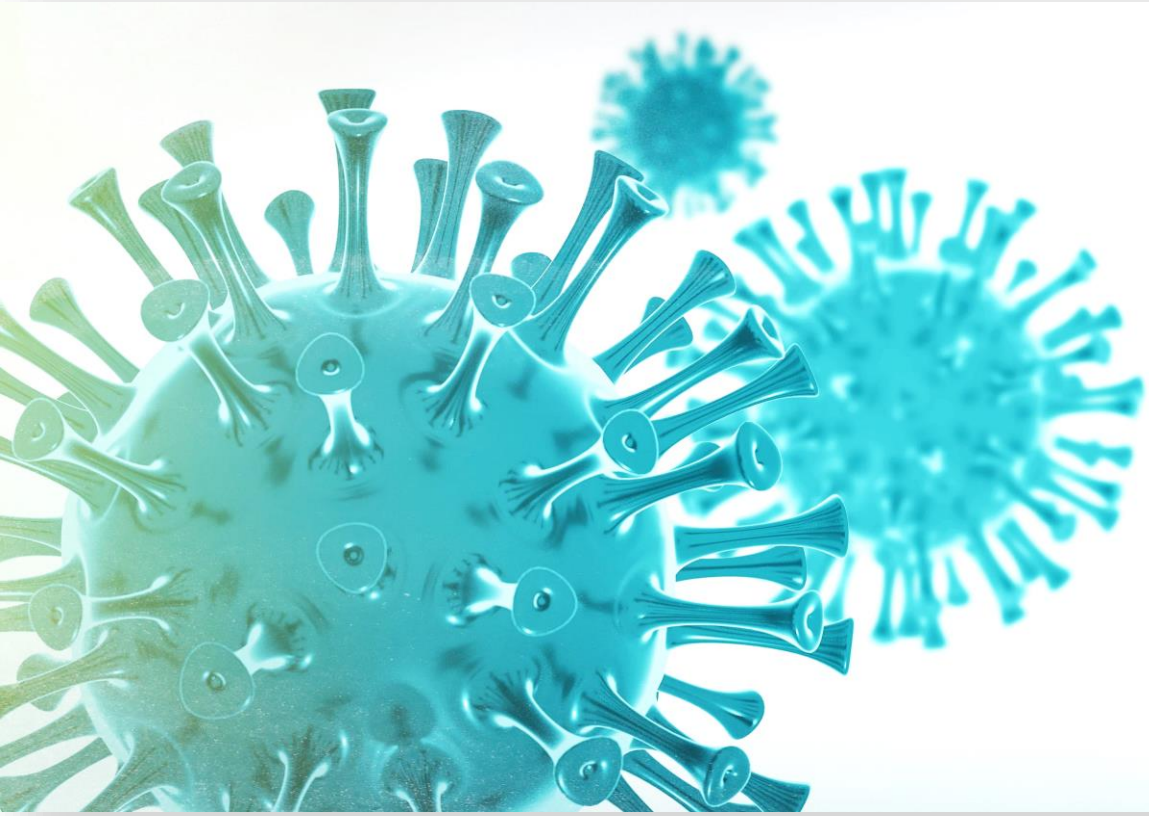


Role of Ventilation and Prevention of COVID-19

10 December 2021

Ir Eric LEE
Chief Engineer
Electrical & Mechanical Services Department
The Government of HKSAR

機電工程署
EMSD

Introduction

2 main roles of Electrical and Mechanical Services Department (EMSD):

Regulatory Services Branch

- enforcement of 15 E&M related ordinances (e.g. electrical, gas, lift & escalator safety, etc.) to protect public safety.

Trading services branch

- provision of E&M related engineering and advisory services to the Government and other statutory organizations.

Role of EMSD in Tackling COVID-19

To be well prepared for the COVID-19 Pandemic…

1

EMSD Together with the HA Developed the MMHU

Conversion of General Wards to 2nd tier Isolation Wards

Community Treatment Facility in Asia World-expo

4

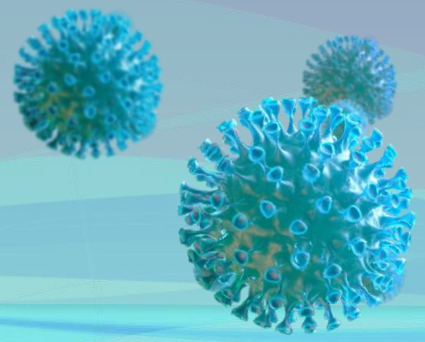
North Lantau Hospital Hong Kong Infection Control Centre (HKICC)

Setup of Community Testing and Vaccination Centres

6

Assessment of Ventilation Systems for quarantine facilities and premises with infectious cases

Role of Ventilation in Infection Control



Role of Ventilation in Infection Control

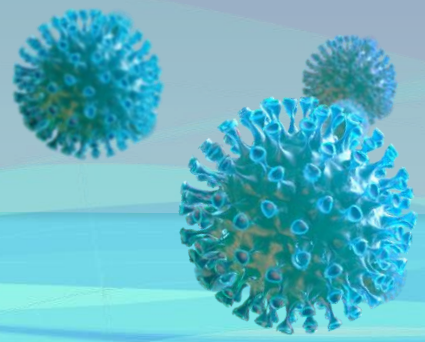
Two Objectives:

1. MAKE the "Zone" clean

- Remove contaminants in the air from the "Zone"

2. KEEP the "Zone" clean

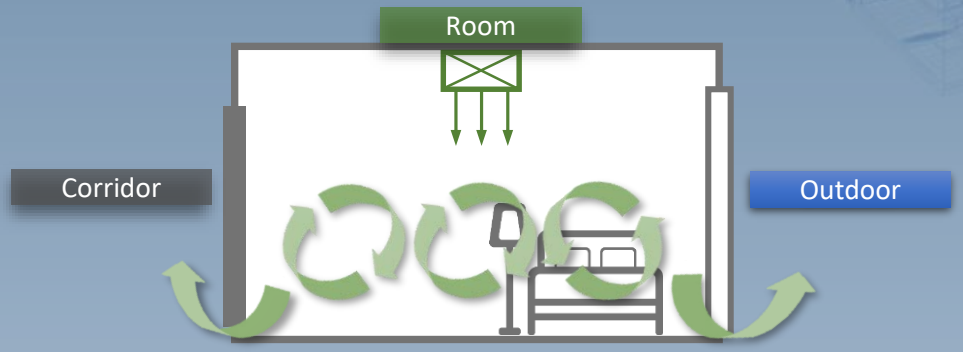
- Prevent contaminants from entering the "Zone"

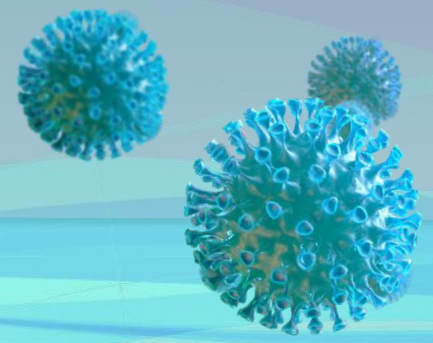


“Make the Area Clean”
Dilution Ventilation & Displacement Ventilation

1. Dilution Ventilation

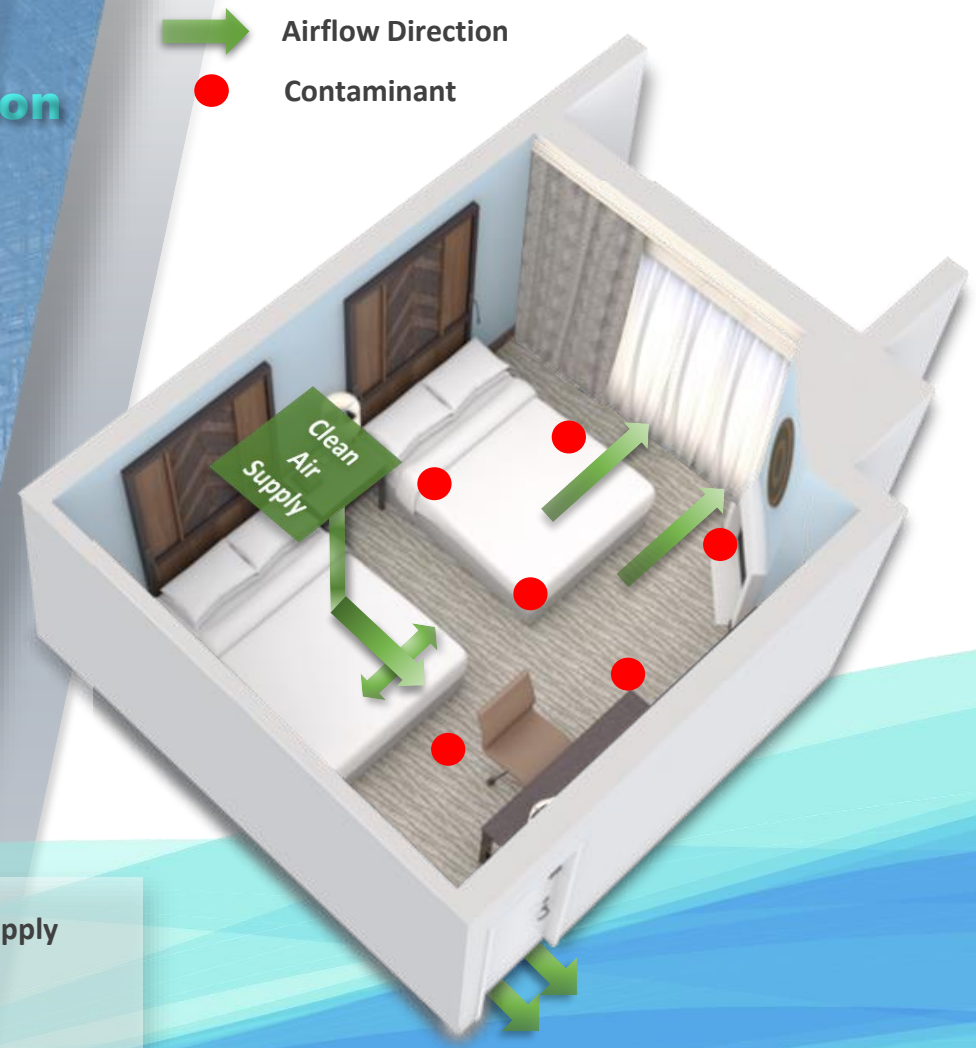
   Dilute concentration of the contaminant with incoming clean air.





Legend

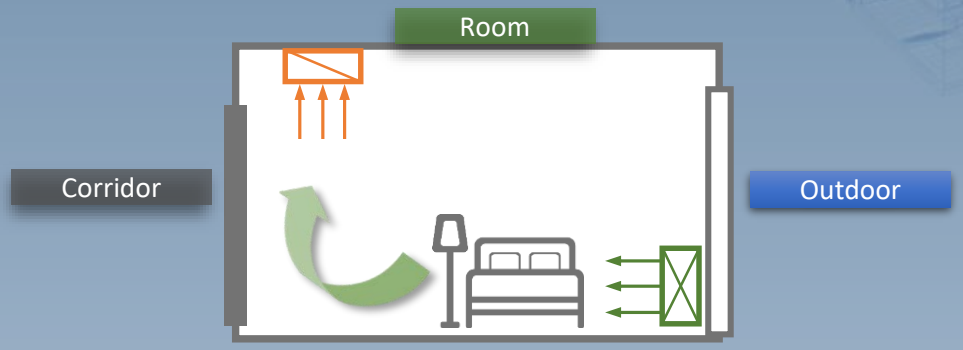
- Airflow Direction
- Clean Air Supply
- Door
- Window

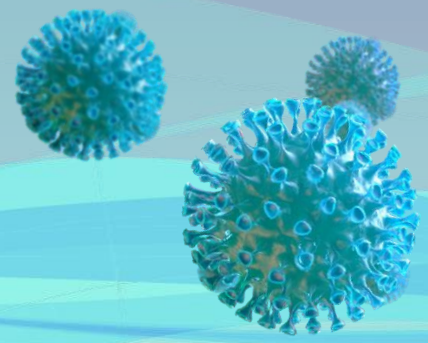


“Make the Area Clean”
Dilution Ventilation & Displacement Ventilation

2. Displacement Ventilation

Contaminants are removed by the air exhaust at high level of the space





Legend

- Airflow Direction
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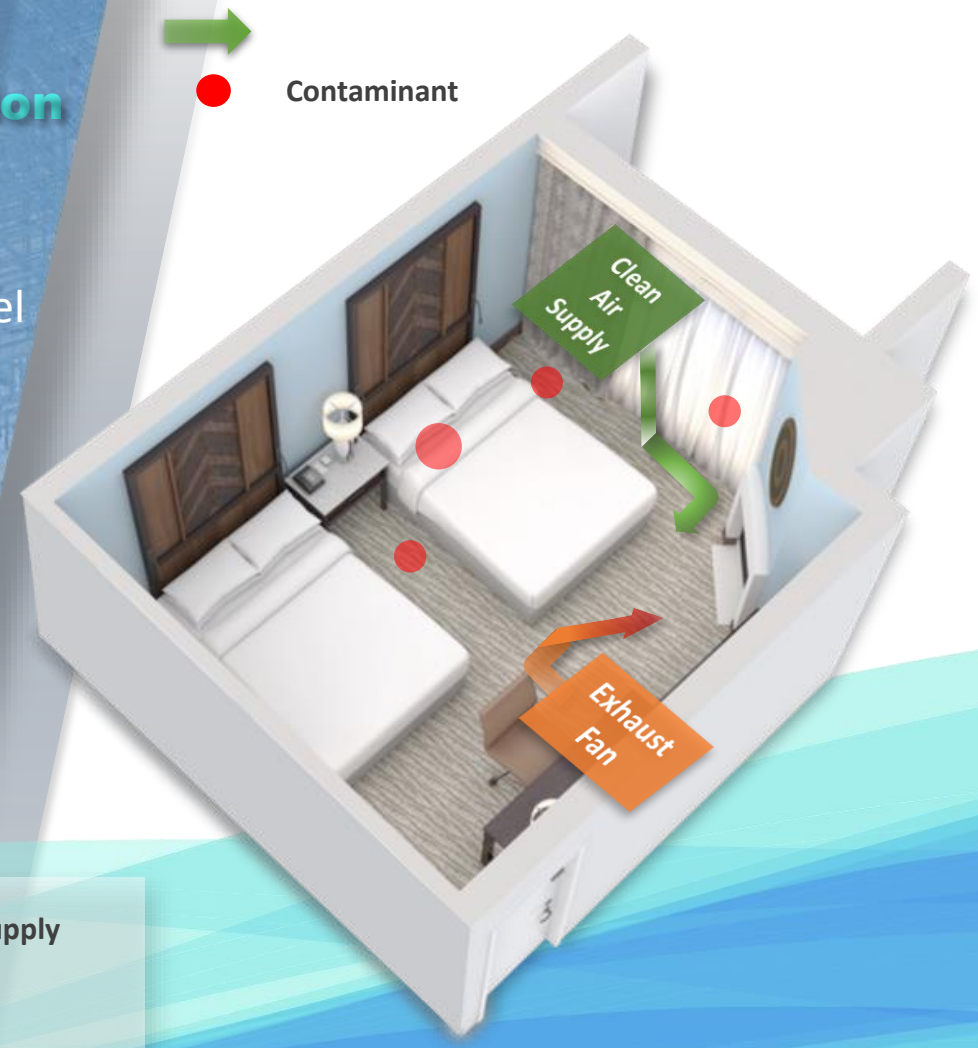
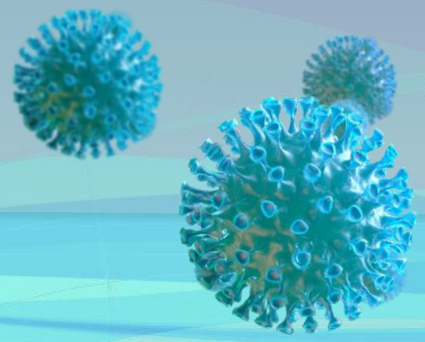
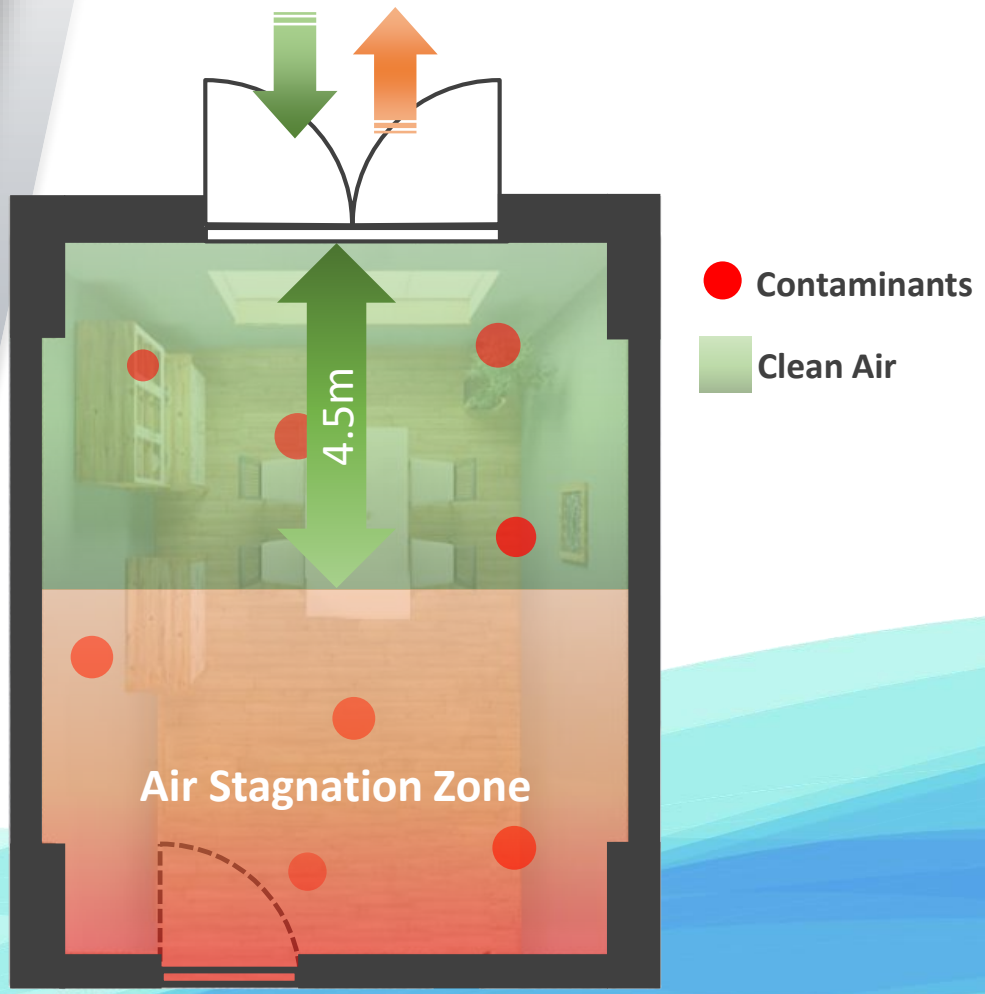


Ventilation Plays an Important Role in Infection Control

3 Principles for Good Ventilation:

- Volume Flow Rate (Amount of Fresh Air)
  ↑ Amount ➡ ↓ Virus Concentration
- Even Distribution of Ventilation
  Ensure Air in the Whole Room is "Changed"
- An Airflow Pathway (From Clean to Dirty Zone)





Typical Room with Single-side Window for Natural Ventilation

Ventilation Plays an Important Role in Infection Control

3 Principles for Good Ventilation:

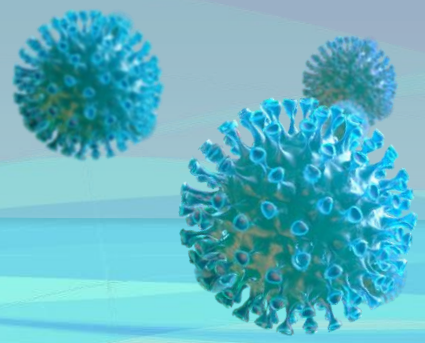
- Volume Flow Rate (Amount of Clean/ACH)
  ↑ Amount ➡ ↓ Virus Concentration
- Even Distribution of Ventilation
  Ensure Air in the Whole Room is "Changed"
- An Airflow Pathway (From Clean to Dirty Zone)
  ↓Chance of Contact with the Virus

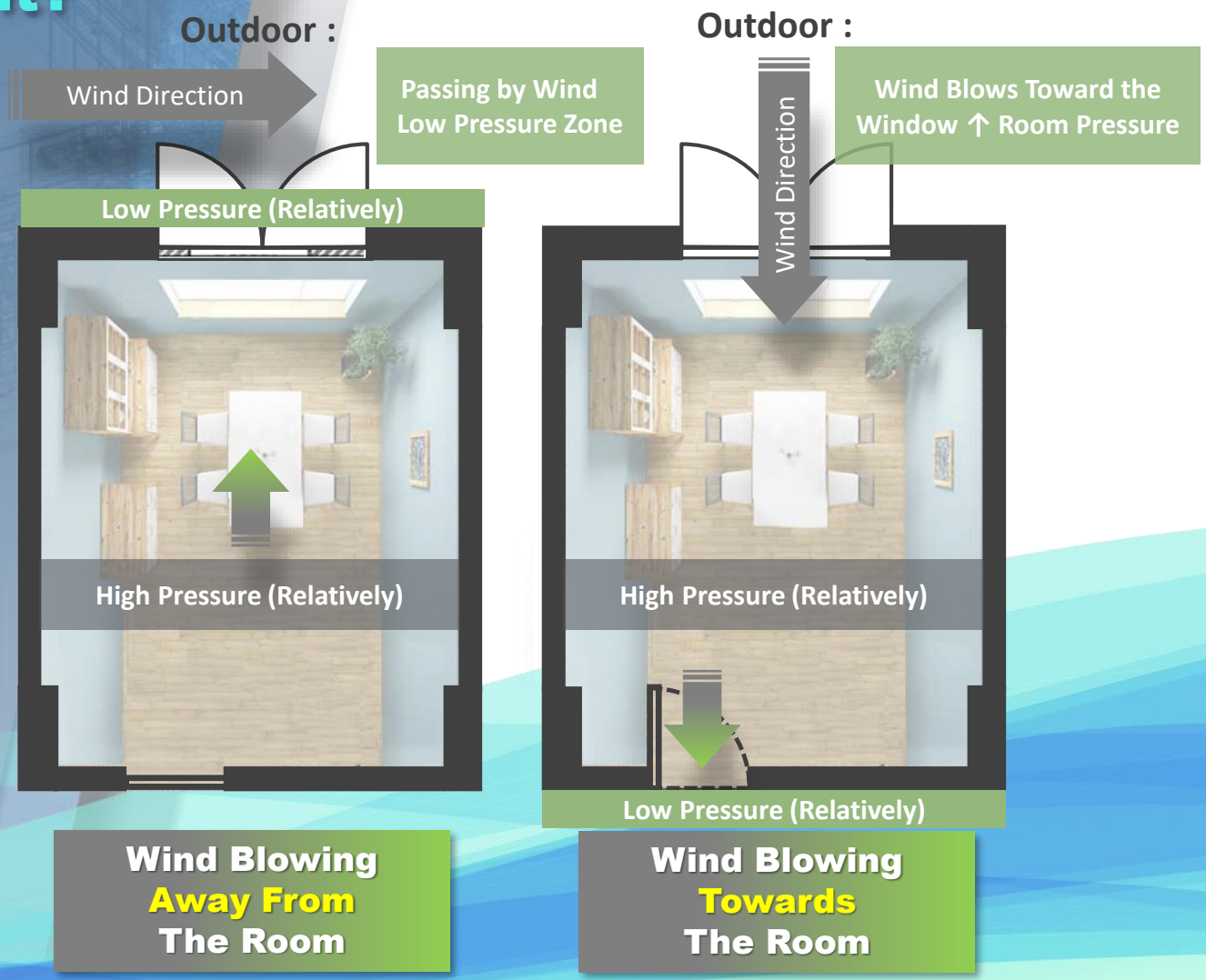
What drives the air movement?

What drives the air movement?

- Wind
- Differential air pressure

High P → Low P



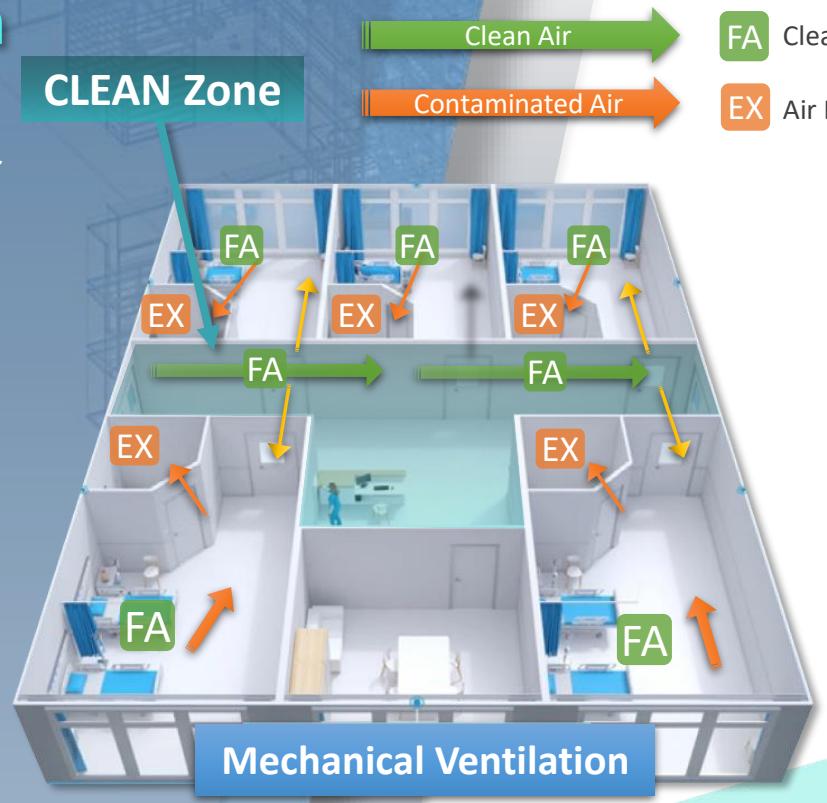


Mechanical Ventilation

Recall: Pressure (P) difference creates air movement

- **High P → Low P**

Mechanical Equipment (Fans) → Create Pressure Difference → Control Air Movement



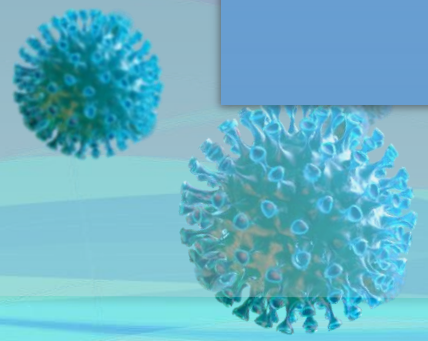
CLEAN ZONE → DIRTY ZONE → EXHAUST

***↑Airflow direction controllability windows should be CLOSED

Mechanical Ventilation (**Fans**) Used to **Control Pressure** of Different Zone → **Airflow Path Design: Low Risk Zone → High Risk Zone → Air Exhaust** → **Minimized the Risk of Spreading Virus**

Natural Ventilation VS Mechanical Ventilation

	Pros	Cons
Natural Ventilation	• High ventilation rate may sometimes be achieved (climate dependent) • Lower energy consumption	• Depends on Weather Condition (e.g. Wind speed and direction) • Difficult to control
Mechanical Ventilation	• Volume Flow Rate can be controlled • Filtration / purification systems can be installed • Airflow path can be controlled • Even air distribution can be achieved	• High cost • Consume energy • Require space for equipment and duct work • Requires proper operation and maintenance



Ventilation Terminology

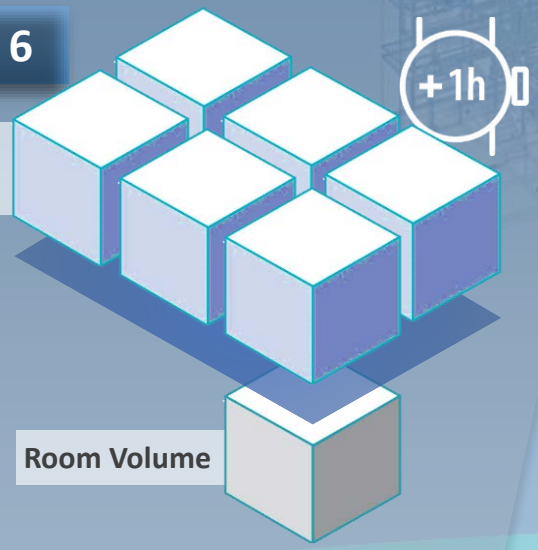
Statutory Regulations & Engineering Standards

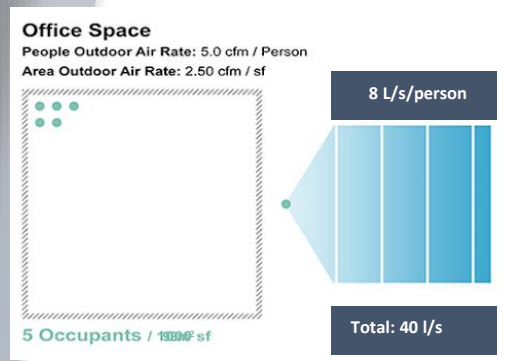
Air Changes Per Hour - ACH ⟷ **Ventilation Flow Rate (L/s)**

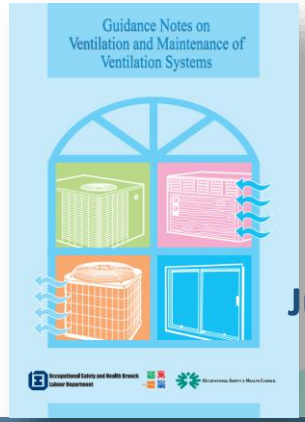
Vary with the occupancy status and types of work activity

e.g. ACH = 6

Volume of Air Flowing into the Room within an Hour







July 2005

Types of Work Activity	Minimum Ventilation Rate
Private offices	0.6 m^3/min/person or 10 L/s/person
Conference rooms	1 m^3/min/person or 16.7 L/s/person
Hotel rooms	18 L/s (exhaust)

ACH is the Ratio of Volumetric Flow Rate to Room Volume

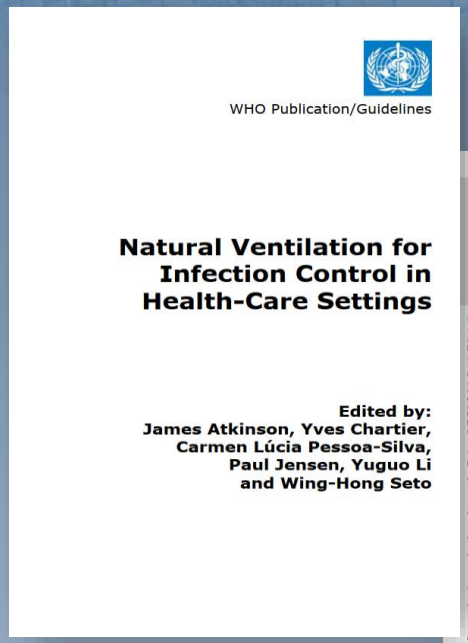
$$ACH = \frac{\text{Volume of Outdoor Air Flowing into the Room per Hour } (m^3)}{Room\ Volume\ (m^3)}$$

$$ACH = \frac{Ventilation\ Rate\ \left(\frac{L}{s}\right) \times 3600\left(\frac{s}{hr}\right) \times 0.001\left(\frac{m^3}{L}\right)}{Room\ Volume\ (m^3)}$$

Formula from WHO guideline

International Guidelines on Ventilation – WHO

Droplet Nuclei Concentration Decay & Infection Risk



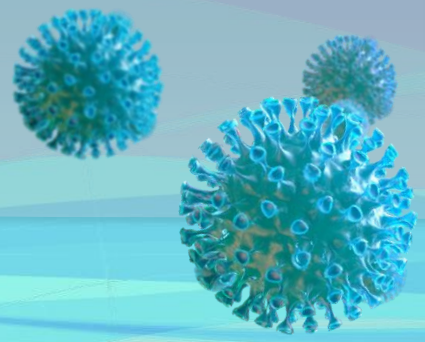


Table E.1 Decay of droplet nuclei concentration in an isolation room for different ventilation rates and duration of time

Time (minutes)	Ventilation rate (ACH) (%) 6	12	18	24
				100.00
				1.83
				0.03
				0.00
				0.00

What happen when ACH = 12 ?

% of Pollutant Remaining in a Space

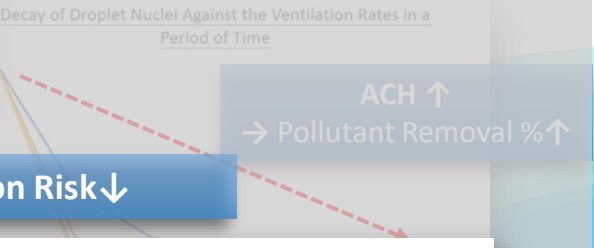
Table E.2 Infection risk with 15 minutes exposure with different ventilation rates and quanta generation for an infector entering an enclosed space with a dimension 6 m × 6.7 m × 2.7 m

Quanta generation (quanta/min)	Ventilation rate (air changes per hour) (%) 1	3	6	12	15	18	24	30
	0.05	0.02	0.01	0.00	0.00	0.00	0.00	0.00
	0.10	0.03	0.02	0.01	0.01	0.01	0.00	0.00
	0.14	0.05	0.03	0.01	0.01	0.01	0.01	0.01
	0.19	0.07	0.03	0.01	0.01	0.01	0.01	0.01
	0.23	0.08	0.04	0.02	0.02	0.01	0.01	0.01
	0.27	0.10	0.05	0.03	0.02	0.02	0.01	0.01
	0.30	0.11	0.06	0.03	0.02	0.02	0.01	0.01
	0.34	0.13	0.07	0.03	0.03	0.02	0.02	0.01
	0.37	0.14	0.07	0.04	0.03	0.03	0.02	0.02
	0.40	0.16	0.08	0.04	0.03	0.03	0.02	0.02

No. of Quanta increases ↓

Risk decreases →

ACH ↑ → Infection Risk↓



ACH ↑ → Pollutant Removal %↑

However… =

- ACH ↑ fr 1 to 12 (+11) → ↓Risk = 0.4 → 0.04 (↑ 10 Times (0.36))
- ACH ↑ fr 15 to 24 (+9) → ↓Risk= 0.03 → 0.02 (↑1.5 Times (0.01 ONLY))

Ventilation Terminology

Standard	EN 1822	Efficiency
EPA	E10	≥ 85%
	E11	≥ 95%
	E12	≥ 99.5%
HEPA	H13	≥ 99.95%
	H14	≥ 99.995%
ULPA	U15	≥ 99.9995%
	U16	≥ 99.99995%
	U17	≥ 99.999995%

HEPA Filter

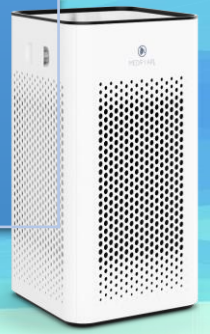
High-Efficiency Particulate Air Filter

Special Requirement on Fan →
Enough power to move air through the filter

International Guidelines on Ventilation – WHO

Roadmap to improve and ensure good indoor ventilation in the context of COVID-19

	Minimum Requirements	Healthcare Settings (where AGP are performed)	Healthcare Settings (General application)	Non residential / Residential Settings
WHO recommendation	Ventilation Rate (L/s/person)	160	60	10
	ACH	12	6	Not specified
WHO top up provision if the ACH cannot be met	Filter grade air purifier if cannot meeting the requirement above	HEPA	HEPA	MERV 14



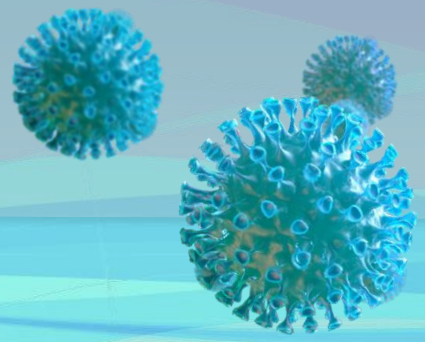
Air Purifier

Comparison of Ventilation System in Different Settings

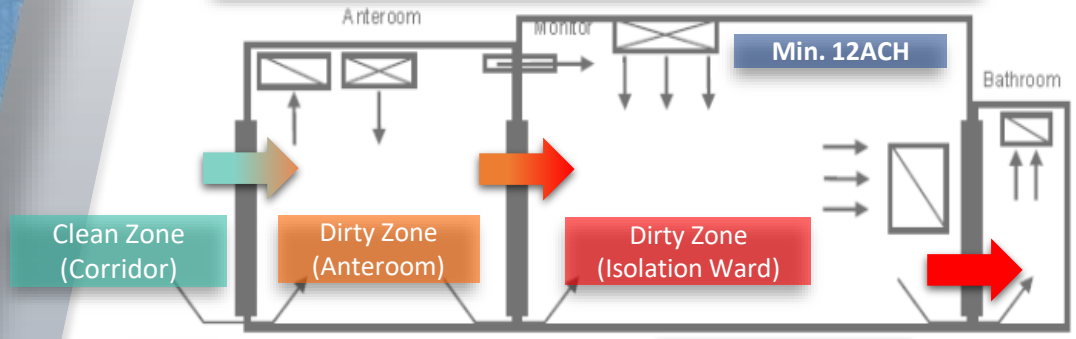
Example: Elderly Home

High Pa — Negative Pressure Differential — Low Pa

CLEAN ZONE → LESS CLEAN ZONE → DIRTY ZONE → EXHAUST



Typical Negative Pressure Isolation Room



0 Pa | 2.5Pa | 5 Pa

High Pa — Negative Pressure Differential — Low Pa

CLEAN ZONE → LESS CLEAN ZONE → DIRTY ZONE → EXHAUST

Legend

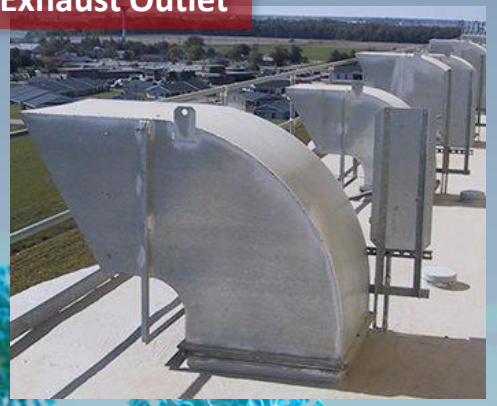
- Airflow Direction
- Min X Pa — Differential Pressure
- Clean Supply
- Air Exhaust

Fresh Air Source & Air Exhaust

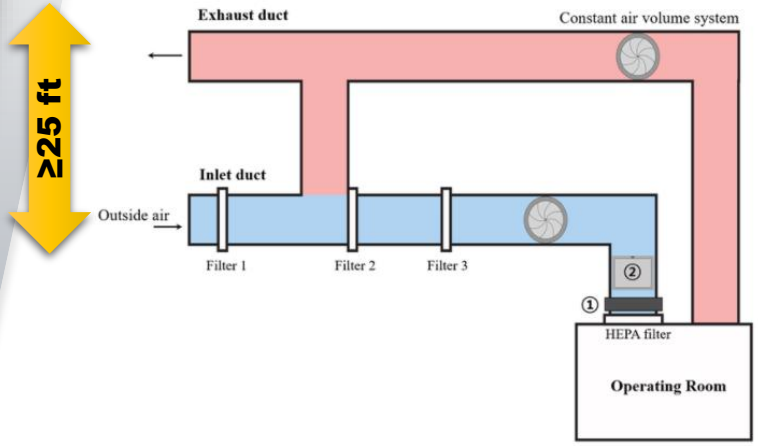
Distance between fresh air inlet and any sources of air contamination should be ≥25 ft

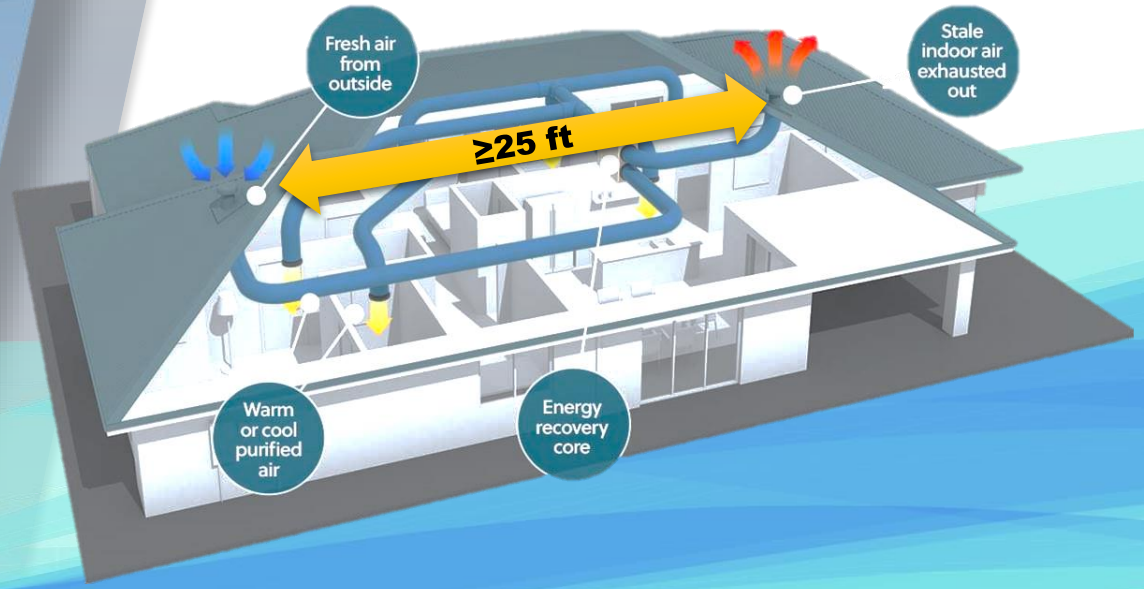
Safe Distance: ≥25 ft

Exhaust Outlet

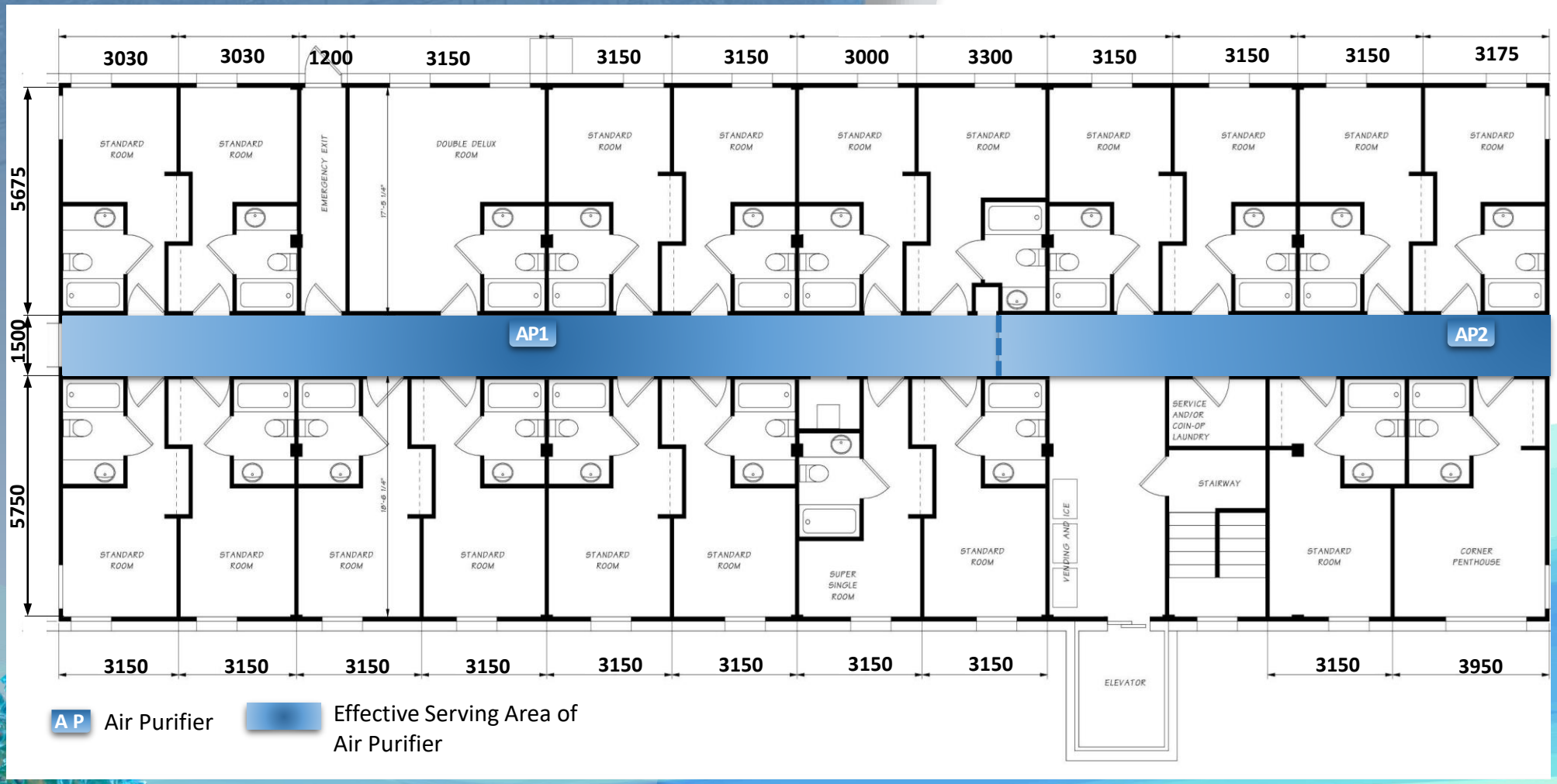


Drainage Vent Pipe Outlet





Using Air Purifier as an Alternative of Clean Air Supply



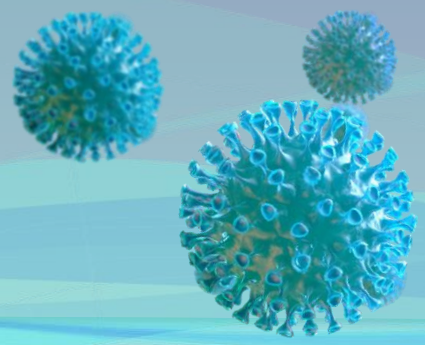
Air Exchange Through Doorways

Scenario 1

Room 19.8˚C | Corridor 23.6˚C
Room ~ 4 ˚C Colder

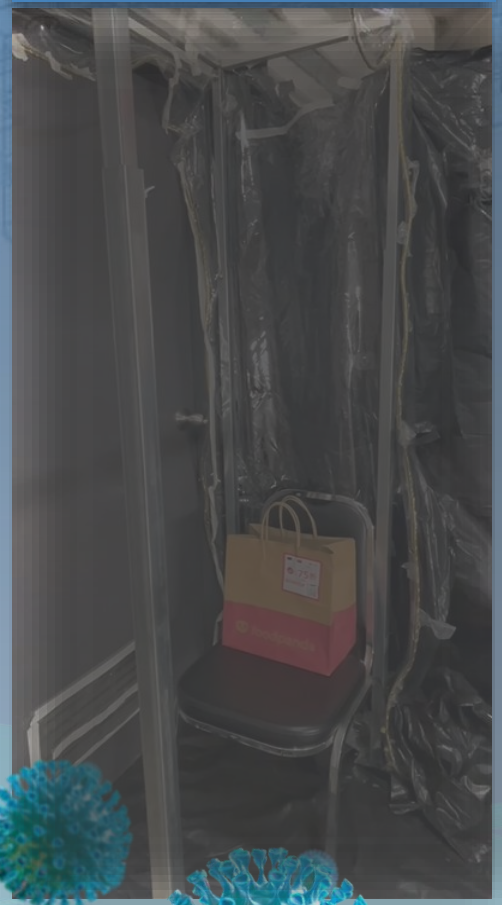
Scenario 2

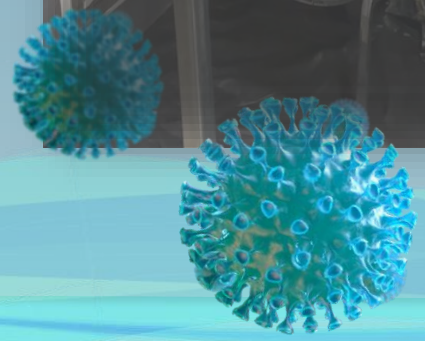
Room 23.6˚C | Corridor 23.6˚C
Room = Corridor



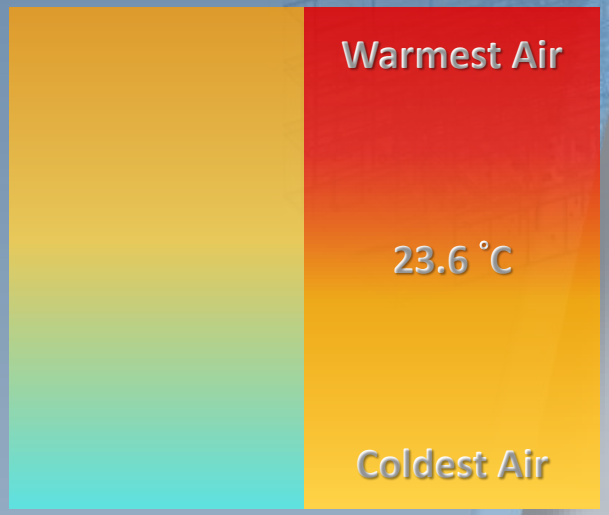
Air Exchange Through Doorways

Scenario 1

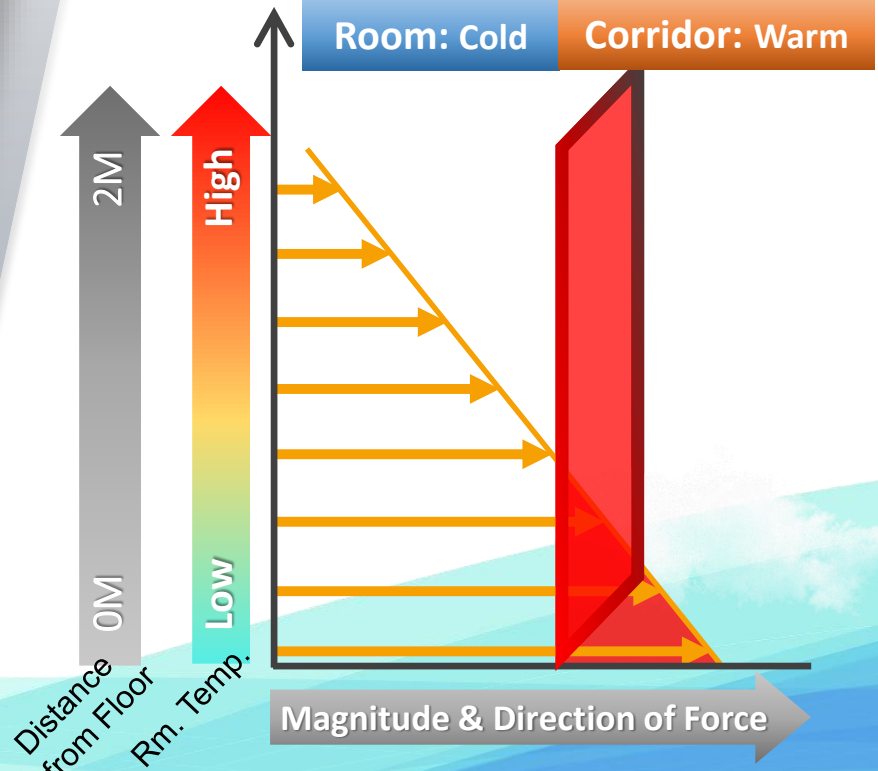




Room: Cold	Corridor: Warm



Room 19.8˚C | Corridor 23.6˚C
Room ~ 4 ˚C Colder



Why We Use Sliding Door For Isolation Ward?

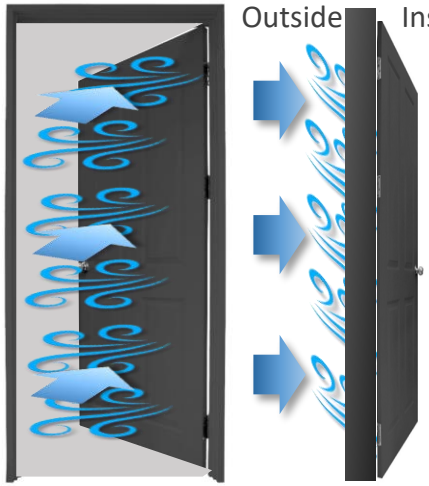
Scenario Simulation

What happen if swing door is used?

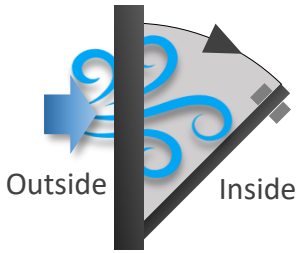
Air Outside the Room

Vacuum zoom

1

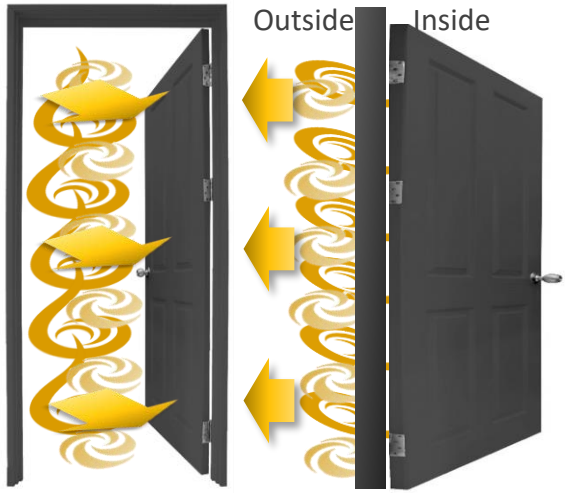


1. Small amount of air outside the room is dragged inward by the vacuum zone created by the door movement.

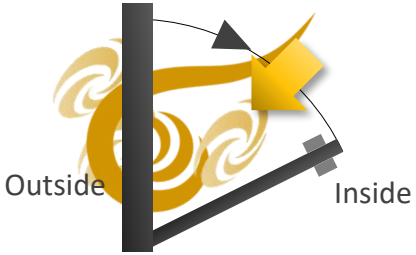


2

Air inside the Room



2. The air inside the room is forced to move outward to fill up the wake / vacuum zone behind the door (outward side of the door)



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What Role Do YOU Play?

Engineering Control is effective and reliable if it is properly maintained and operated!

Users of the Venue should always…

- Proper housekeep to ensure the ventilation system operates as designed and desired
- Identify opportunity for upgrading the ventilation system
- Upkeep proper maintenance of mechanical ventilation
- Appoint the right person to check the ventilation
- have a contingency plan for cases when ventilation system breaks down

Thank You