AIVC workshop Tokyo
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Countermeasures against Indoor Aerosol Infection in Japan

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Contents

1. Introduction

2. Countermeasures against COVID-19 in indoor spaces by the Japanese government

① The first analysis on indoor environment in COVID-19 cluster cases
(the Ministry of Health, Labour and Welfare(MHLW), Cluster Control Team, 27 February 2020)

② Effective Ventilation Methods in “Closed and Poorly-Ventilated Indoor Spaces” in Commercial Facilities, etc. (MHLW,30 March 2020)

③ Measures against COVID-19 Concerning Summer Indoor Environment in Japan (National Institute of Public Health(NIPH), May 2020)

④ Effective Ventilation Methods in “Closed and Poorly-Ventilated Indoor Spaces” in Winter (MHLW, 27 November 2020)

⑤ Opinion by Advisory Board on COVID-19 Control (MHLW,30 July 2020)

⑥ Infection Routes of SARS-CoV-2 (National Institute of Infectious Diseases (NID), 28 March 2022)

⑦ Effective Ventilation Methods in an Emergent Proposal (Subcommittee on Novel Coronavirus Disease Control,14 July 2022)

3. Investigations on the building environment in COVID-19 outbreak cases

① Wards for uninfected patients in hospitals

② Ice arenas for ice hockey

③ Office spaces used as call centers

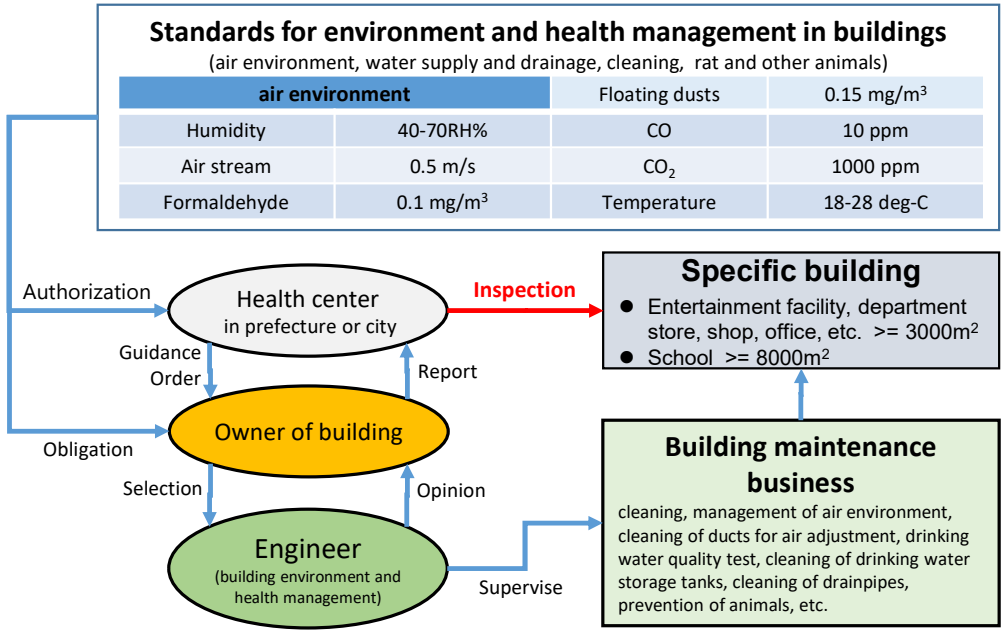
4. Infection control and Energy Conservation in Buildings for Post-COVID-19

"Committee on Air Conditioning, Ventilation in the Post-COVID-19“ by Institute for Building Environment and Carbon Neutral for SDGs

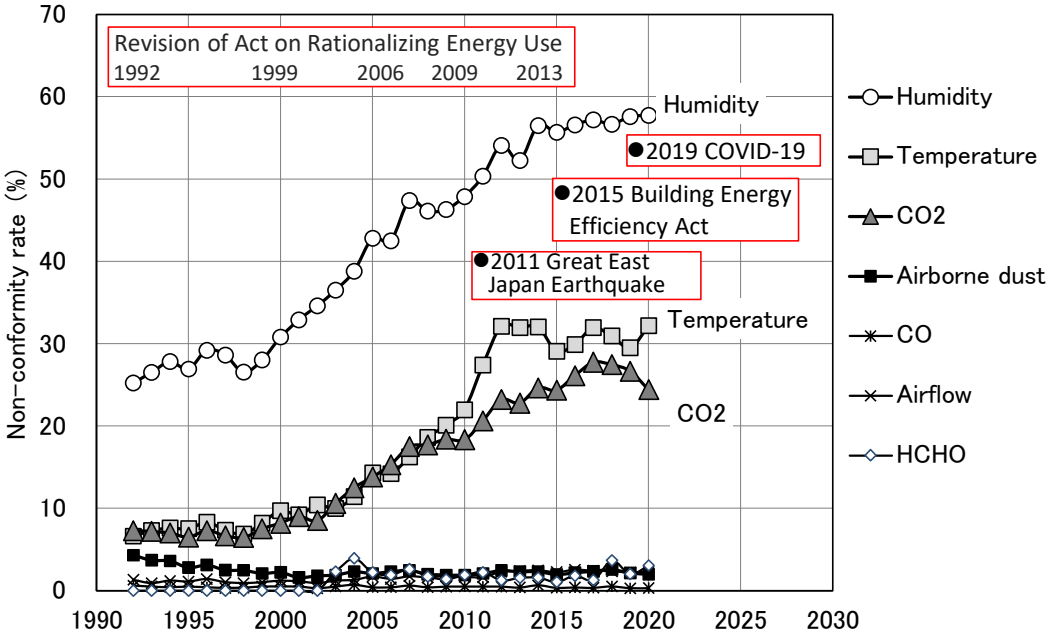
1.Introduction

The law for environmental health in buildings (LEHB) in 1970

- It was believed that sick building syndrome could be prevented by LEHB in the 1970s.
- The recent studies showed that the rate of sick building syndrome in offices is not low.
- One of the factors in the nonconformity rates of indoor air environment is thought to be energy saving in buildings since the 1990s.



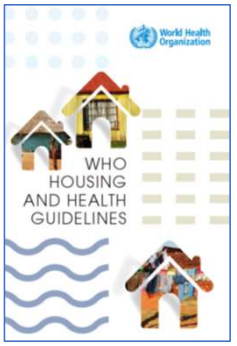
System based on the law for environmental health in buildings (LEHB)

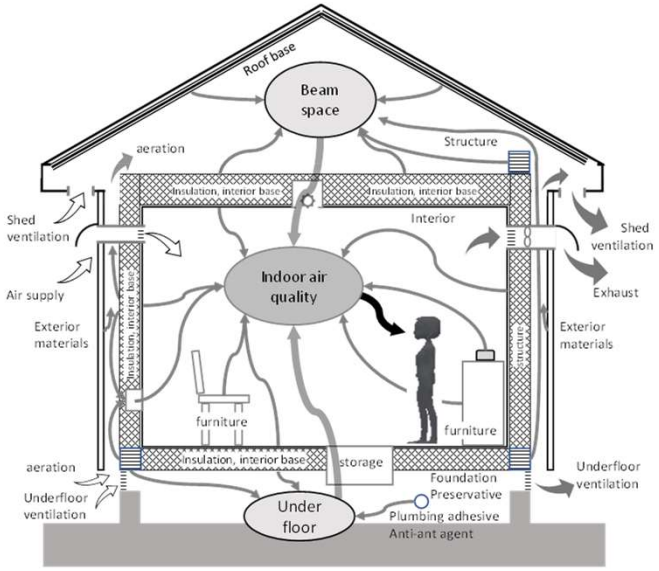


Non-conformity rate of indoor air environment

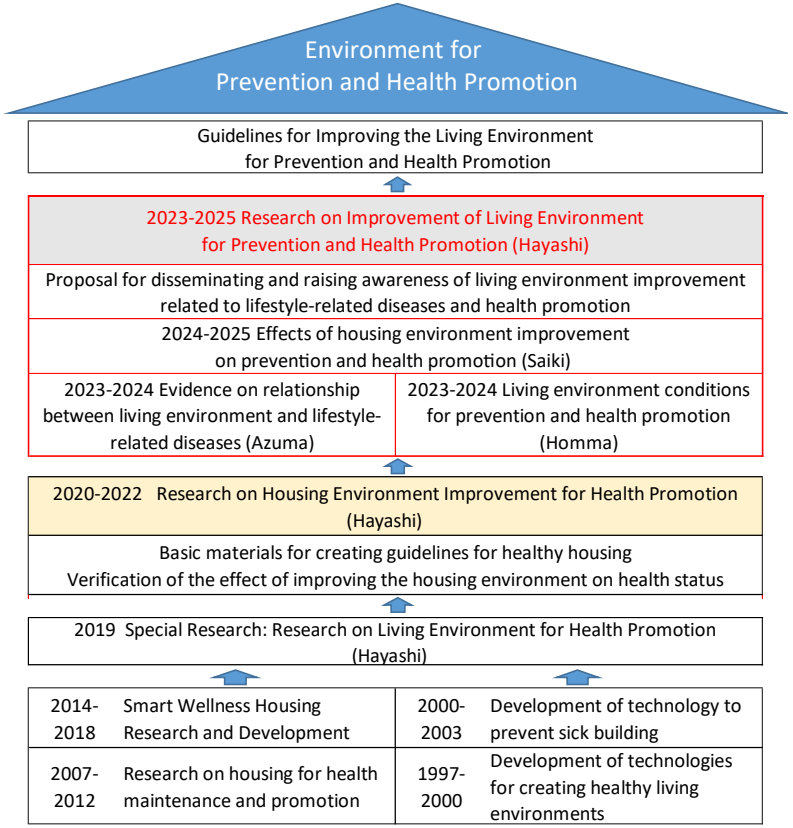
Health risks in Japanese houses caused by adaptation to new living style in cold and hot seasons

- Japanese houses based on wooden axis structure are suitable to to Japanese hot humid summer.
- Low insulation and much air leak caused low indoor temperature in winter and chemical pollution through the year .
- Housing improvement is necessary for healthy and sustainable living in today's high aged and carbon neutral society.

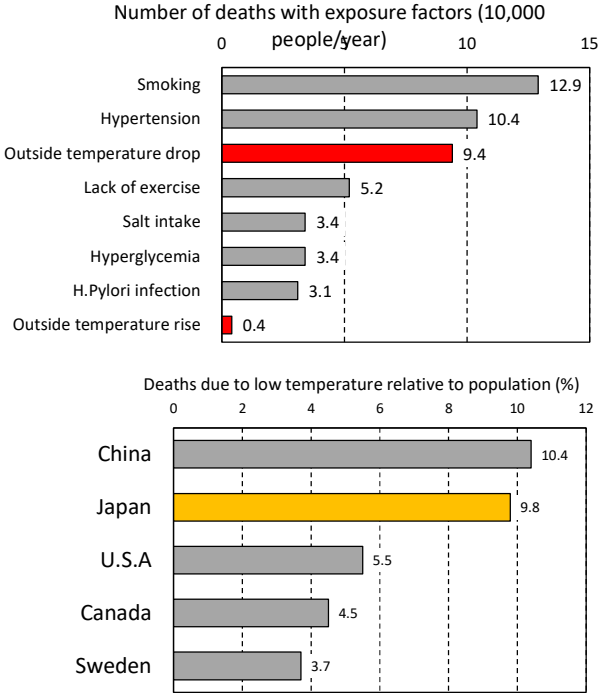




Sick house mechanism in Japanese houses



Project on Improvement of Houses for Health



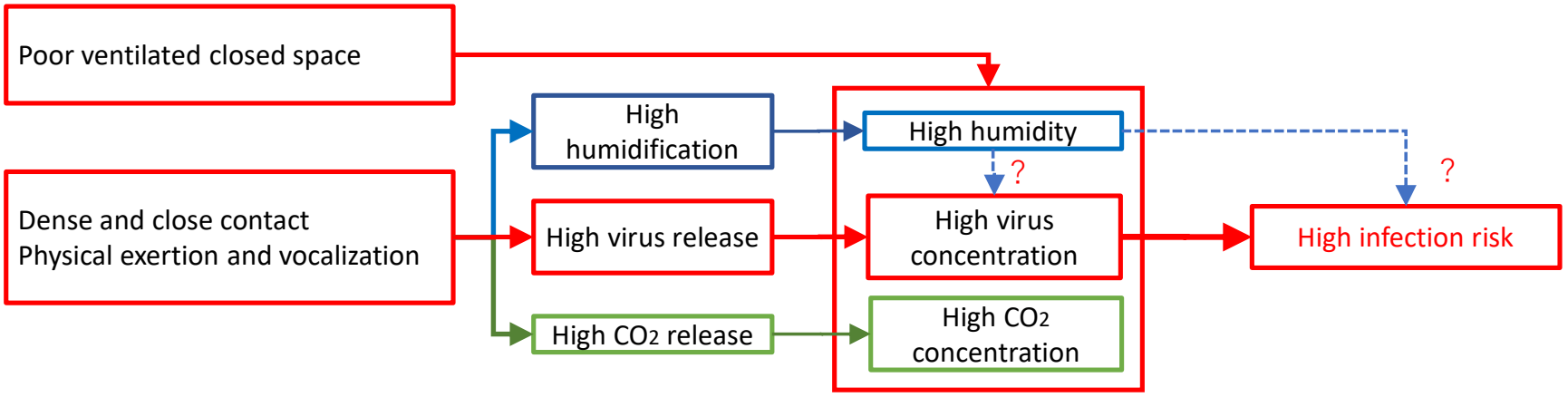
Influence of environments upon health

2. Countermeasures against COVID-19 in indoor spaces by the Japanese government

① The first analysis on indoor environment in COVID-19 cluster cases (MHLW Cluster Control Team, 27 February 2020)

The first analysis on the influences of indoor environment upon indoor infection

- Initial infection clusters occurred in a houseboat, a sport gym, a hospital and a temporary venue in Snow Festival.
- In all cases ventilation was poor and humidity was high.
- When people gather and have a lot of activity, they release vapor, CO_2 and virus.
- Poor ventilation leads to high humidity, the high concentrations of CO_2 and virus.
- Density and physical activities make the volume of virus release and suction larger.
- Influence of humidity upon virus inactivation and infection was unknown.



Analysis on Indoor environment and cluster infection

② Effective Ventilation Methods in “Closed and Poorly-Ventilated Indoor Spaces” in Commercial Facilities, etc. (MHLW,30 March 2020)

Three conditions of COVID-19 outbreaks

- The expert meeting against COVID-19, showed three conditions common in the spaces where outbreaks occurred (9 and 19 March 2020) .
- The emergency head-quarters of MHLW showed recommended ventilation methods “closed and poorly-ventilated spaces” in commercial facilities many people use.

3 conditions of COVID-19 outbreak

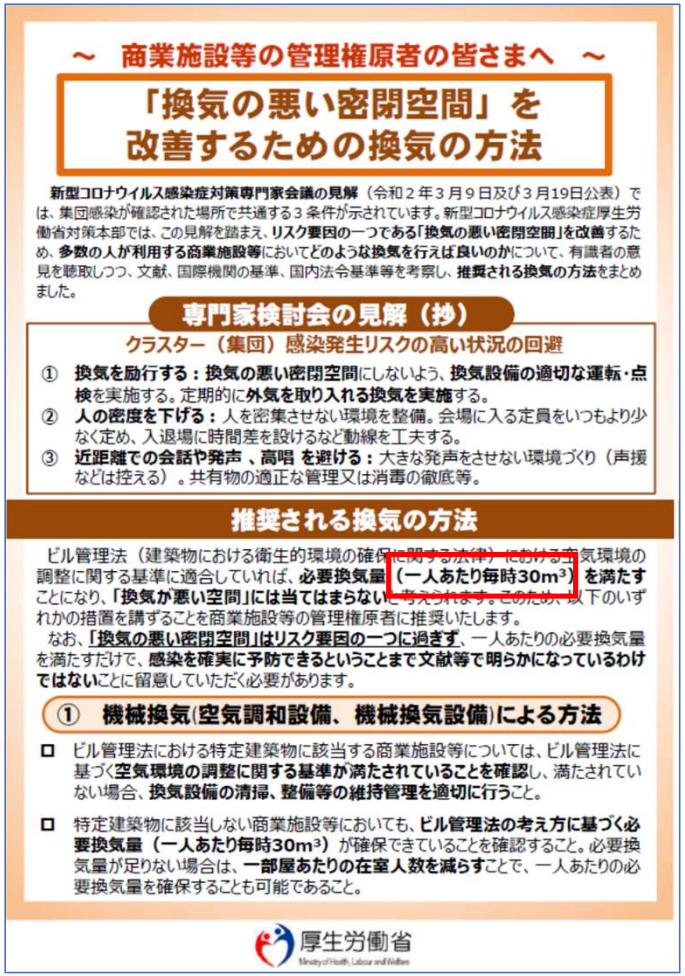
Ventilation methods in “closed and poorly-ventilated spaces”

As for mechanical ventilation systems

- The required ventilation rates in the Act on Maintenance of Sanitation in Buildings (30 m^3 per hour per person) should be assured.
- If the ventilation rates are lower, the number of persons in the space should be reduced.

As for opening windows

- Ventilation times should be twice or more per hour (opening a window wide for several minutes once or more per half an hour).
- If two or more windows are in a space, windows facing each other should be open to make an air current.



Effective Ventilation Methods in “Closed and Poorly-Ventilated Indoor Spaces” in Commercial Facilities, etc.

③ Measures against COVID-19 Concerning Summer Indoor Environment in Japan (NIPH, May 2020)

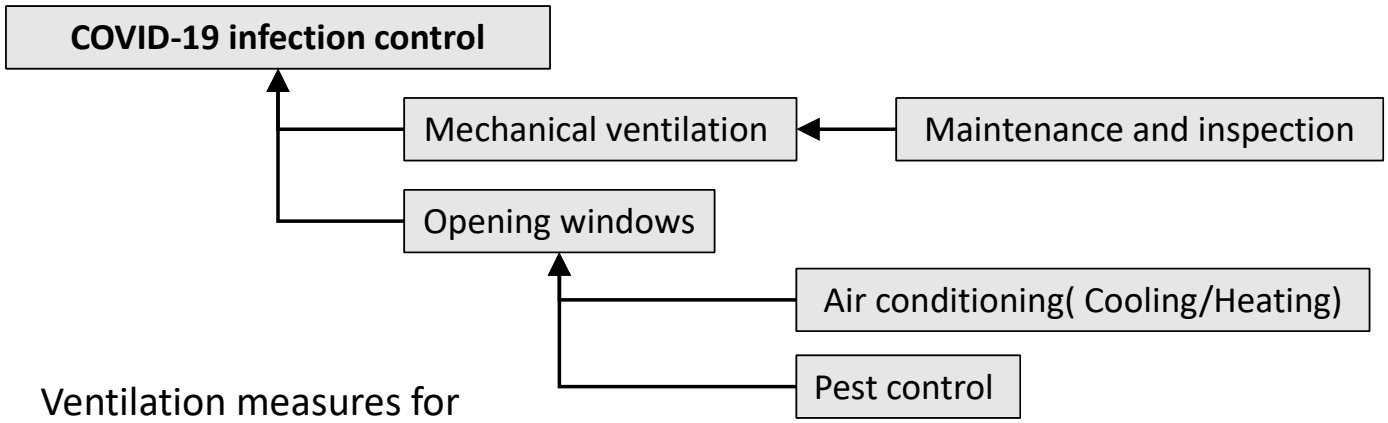
Motoya Hayashi, U Yanagi, Kenichi Azuma, Naoki Kagi, Masayuki Ogata, Shoichi Morimoto, Hirofumi Hayama, Taro Mori, Koki Kikuta, Shin-ichi Tanabe, Takashi Kurabuchi, Hiromi Yamada, Kenichi Kobayashi, Hoon Kim and Noriko Kaihara

[In every indoor space]

- In summer, air-conditioning is essential for good health, such as heat stroke prevention.
- General air-conditioners do not function as ventilators.
- When windows are open, it is necessary to prevent animal or insect pests from coming in.

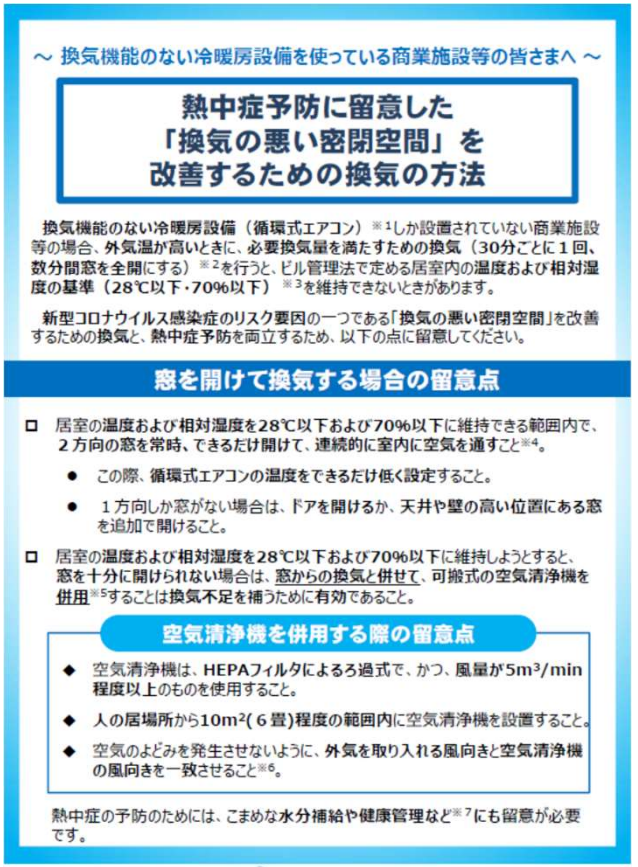
[In case an air-conditioner and a ventilation system are equipped]

- The designed ventilation rates should always be gained by the inspection and maintenance of the equipment.



Ventilation measures for summer air-conditioning

Jpn Archit Rev | October 2020 | vol. 3 | no. 4 | 423-434


～ 換気機能のない冷暖房設備を使っている商業施設等の皆さまへ ～

熱中症予防に留意した
「換気の悪い密閉空間」を
改善するための換気の方法

換気機能のない冷暖房設備（循環式エアコン）※1しか設置されていない商業施設等の場合、外気温が高いときに、必要換気量を満たすための換気（30分ごとに1回、数分間窓を全開にする）※2を行うと、ビル管理法で定める居室内の温度および相対湿度の基準（28℃以下・70%以下）※3を維持できないときがあります。

新型コロナウイルス感染症のリスク要因の一つである「換気の悪い密閉空間」を改善するための換気と、熱中症予防を両立するため、以下の点に留意してください。

窓を開けて換気する場合の留意点

- 居室の温度および相対湿度を28℃以下および70%以下に維持できる範囲内で、2方向の窓を常時、できるだけ開けて、連続的に室内に空気を通すこと※4。
  - この際、循環式エアコンの温度をできるだけ低く設定すること。
  - 1方向しか窓がない場合は、ドアを開けるか、天井や壁の高い位置にある窓を追加で開けること。
- 居室の温度および相対湿度を28℃以下および70%以下に維持しようとすると、窓を十分に開けられない場合は、窓からの換気と併せて、可搬式の空気清浄機を併用※5することは換気不足を補うために有効であること。

空気清浄機を併用する際の留意点

- 空気清浄機は、HEPAフィルタによるろ過式で、かつ、風量が5m³/min程度以上のものを使用すること。
- 人の居場所から10m²(6畳)程度の範囲内に空気清浄機を設置すること。
- 空気のよどみを発生させないように、外気を取り入れる風向きと空気清浄機の風向きを一致させること※6。

熱中症の予防のためには、こまめな水分補給や健康管理など※7にも留意が必要です。

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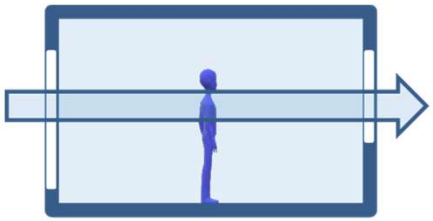
Ventilation Methods in “Closed and Poorly-Ventilated Indoor Spaces” In summer, for heat stroke prevention

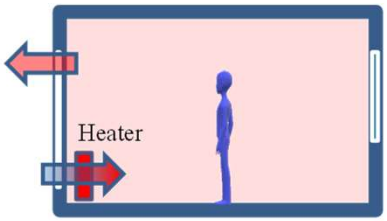
④ Effective Ventilation Methods in “Closed and Poorly-Ventilated Indoor Spaces” in Winter (MHLW, 27 November 2020)

Effective ventilation and the prevention of the negative influence of low indoor temperature on health.

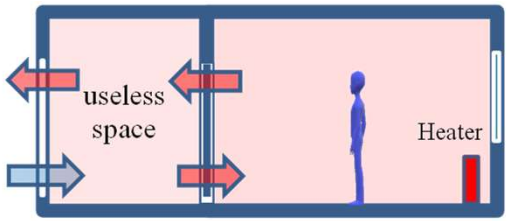
- ✓ Continuous window opening, heating and adequate temperature and humidify (18 ℃ or higher and 40% or higher.)
- ✓ CO_2 monitor (under 1000 ppm) and air cleaners (HEPA filter, 5 m^3 /min/10 m^2)



Ventilation using two sides opening



Ventilation using one side opening

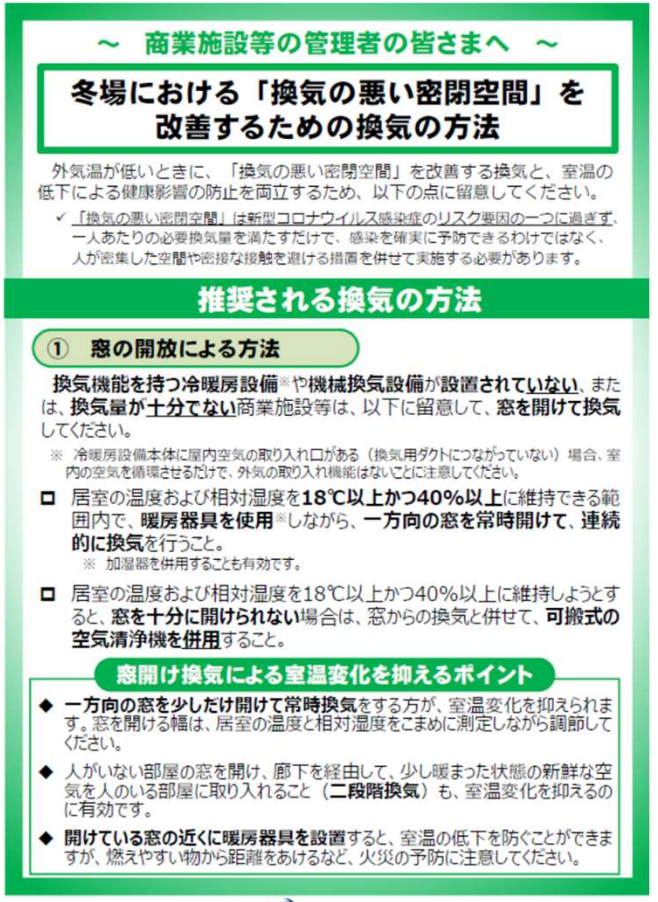


Ventilation using one side opening and useless spaces

Season	Indoor condition*	Continuously opening	Contemporary opening	Ventilation methods and the characteristics
Cooling season	≦28°C (≦RH70%)	Two side Small opening	Two side Large opening	• Ventilation rates change with outside wind speed and direction. • Ventilation rates will be larger with two sides opening. • Opening area has to be controlled according to weather conditions (wind, rain, snow, etc.).
Mild season	18～28°C (RH40 ～70%)	Two sides Large opening		
Heating season	18°C≦ RH40%≦	One side Small opening	One side Large opening	• Ventilation rates change with the temperature difference between inside and outside. • Ventilation rates will be steady with one side opening and steady indoor temperature. • Supply air has to be heated using a heater near an opening and/or using the next space.
* Temperature and humidity have to be controlled according to people’s physical condition.				

Window opening methods in cooling season, heating season and mild season

Jpn Archit Rev | October 2021 | vol. 4 | no. 4 | 608–620



～ 商業施設等の管理者の皆さまへ ～

冬場における「換気の悪い密閉空間」を改善するための換気の方法

外気温が低いときに、「換気の悪い密閉空間」を改善する換気と、室温の低下による健康影響の防止を両立するため、以下の点に留意してください。

✓「換気の悪い密閉空間」は新型コロナウイルス感染症のリスク要因の一つに過ぎず、一人あたりの必要換気量を満たすだけで、感染を確実に予防できるわけではなく、人が密集した空間や密接な接触を避ける措置を併せて実施する必要があります。

推奨される換気の方法

① 窓の開放による方法

換気機能を持つ冷暖房設備※や**機械換気設備**が**設置されていない**、または、**換気量が十分でない**商業施設等は、以下に留意して、**窓を開けて換気**してください。

※ 冷暖房設備本体に屋内空気の取り入れ口がある（換気用ダクトにつながっていない）場合、室内の空気を循環させるだけで、外気の取り入れ機能はないことに注意してください。

□ 居室の温度および相対湿度を**18℃以上かつ40%以上**に維持できる範囲内で、**暖房器具を使用**※しながら、**一方向の窓を常時開けて、連続的に換気**を行うこと。

※ 加湿器を併用することも有効です。

□ 居室の温度および相対湿度を18℃以上かつ40%以上に維持しようとすると、**窓を十分に開けられない**場合は、窓からの換気と併せて、**可搬式の空気清浄機を併用**すること。

窓開け換気による室温変化を抑えるポイント

◆ **一方向の窓を少しだけ開けて常時換気**をする方が、室温変化を抑えられます。窓を開ける幅は、居室の温度と相対湿度をこまめに測定しながら調節してください。

◆ 人がいない部屋の窓を開け、廊下を経由して、少し暖まった状態の新鮮な空気を人のいる部屋に取り入れること（**二段階換気**）も、室温変化を抑えるのに有効です。

◆ **開けている窓の近くに暖房器具を設置**すると、室温の低下を防ぐことができますが、燃えやすい物から距離をあけるなど、火災の予防に注意してください。

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Ventilation Methods in “Closed and Poorly-Ventilated Indoor Spaces” In winter

⑤ Opinion by Advisory Board on COVID-19 Control (MHLW,30 July 2020)

Three conditions of COVID-19 outbreaks

- At the first stage of the COVID-19 pandemic, its infection route was assumed to be through “droplets containing virus” and “contact with virus”.
- However, **in Japan, around the time when the basic policies toward COVID-19 were adopted in February 2020**, other infection routes were pointed out and the measures were taken.
- Recently “**micro-droplet infection**” has been recognized in the world. However, while walking outside, shopping or dining at a shop or a restaurant where infection control measures are taken, or commuting on well-ventilated trains, the possibility of “micro-droplet infection” is assumed to be weak.

⑥ Infection Routes of SARS-CoV-2 (National Institute of Infectious Diseases (NID), 28 March 2022)

A person becomes infected with SARS-CoV-2 through the exposure of an aerosol containing infectious virus emitted from the nose or mouth of an infected person.

The main three infection routes are:

i. breathing in an aerosol containing virus floating in the air (**aerosol infection**)
ii. the attachment of droplets containing the virus on bare mucous membranes such as mouths, noses, or eyes (**droplet infection**)
iii. fingers touching bare mucous membranes after touching droplets containing virus or touching the surface of things with virus (**contact infection**)

⑧ Effective Ventilation Methods in an Emergent Proposal (Subcommittee on Novel Coronavirus Disease Control,14 July 2022)

① To prevent **Aerosol Infection** + ② **Droplet Infection** in necessary

① Measures to prevent Aerosol Infection

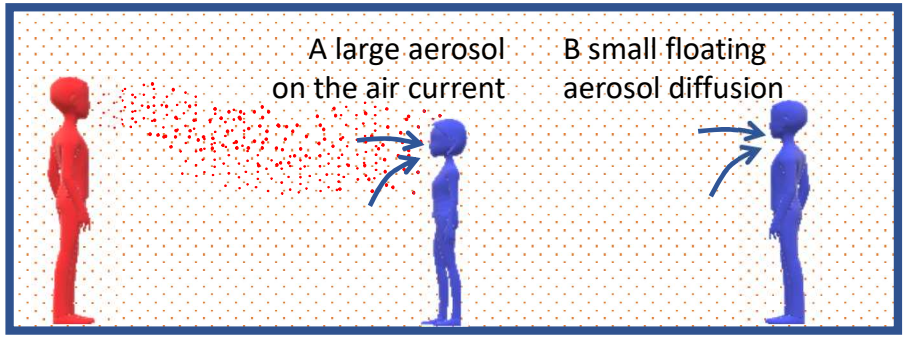
The relationship between infectiousness and the particle size of aerosol has not been clear, so the following **A and B** is desirable

A. Prevent infection caused by large aerosol on air current

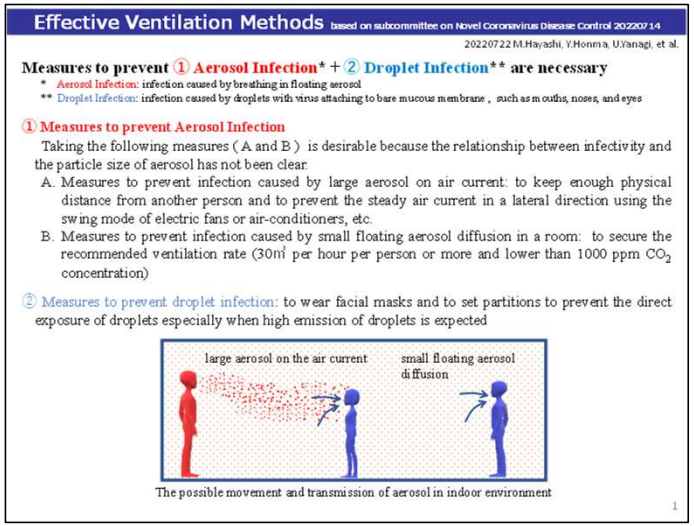
⇒ Physical distance, Prevent the steady air current.

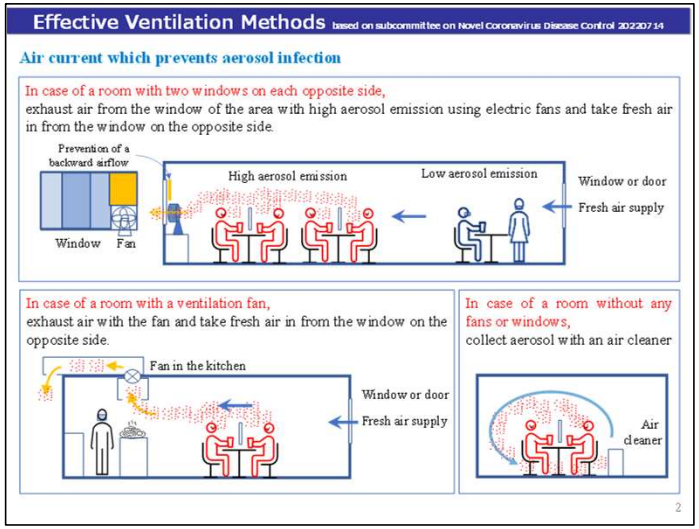
B. Prevent infection caused by small floating aerosol diffusion

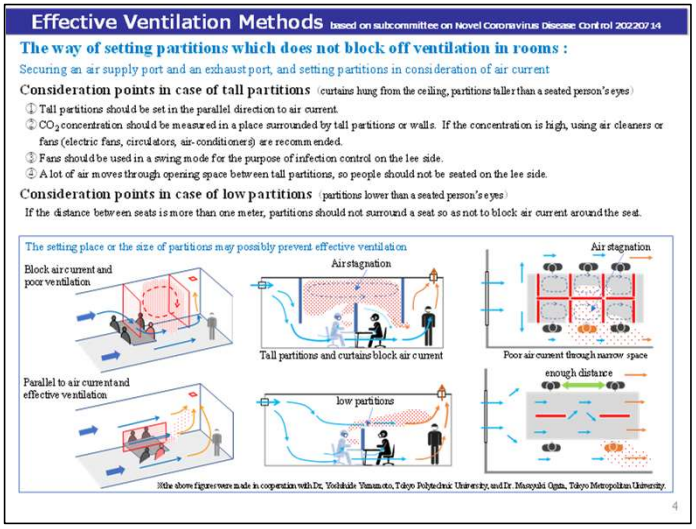
⇒ Ventilation rate 30 m^3/h person, CO_2 under 1000ppm.



The possible movement and transmission of aerosol in indoor environment

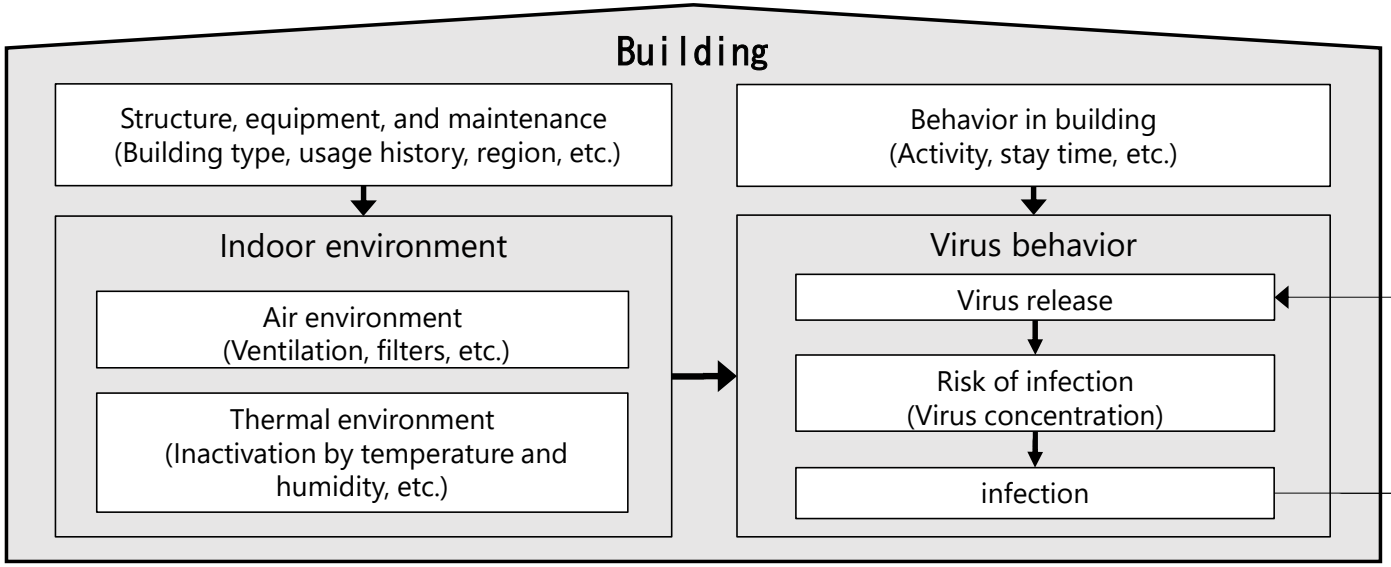




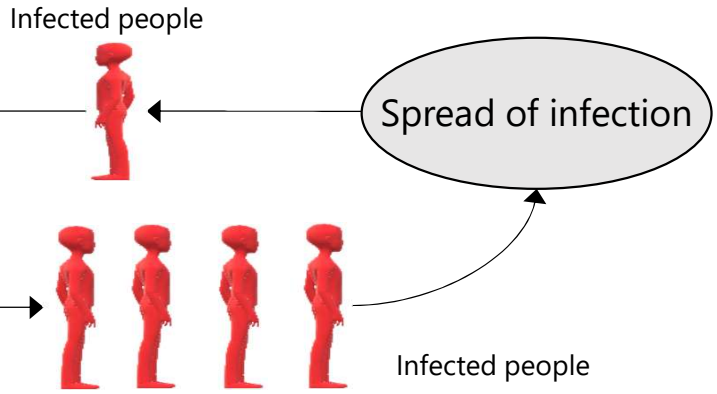


Atmosphere **2023**, *14*, 150. https://doi.org/10.3390/atmos14010150

3.Investigations on the building environment of COVID-19 outbreak cases



Building and spread of infection



Infection mechanisms in buildings

1. Infectious and medical effects of viruses
2. Effects of Indoor Environment and Effects of Infection Control
3. Virus infectiousness, countermeasure effect, and scale of damage

"Research on risk assessment of emerging and re-emerging infectious diseases and implementing crisis management functions"

Health and Labor Sciences Research Grant.

I. Infection mechanism and countermeasure effect in the indoor environment

II. Investigations on building environments of COVID-19 outbreak cases

Exhibition halls, restaurants with music and entertainment, offices, call centers, hospitals, facilities for the elderly, ice arenas, etc.

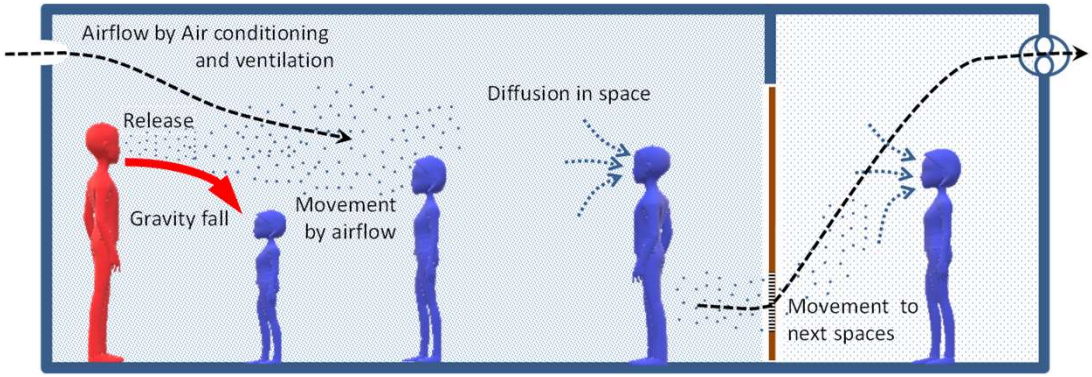
Ⅱ. Investigations on building environments of COVID-19 outbreak cases

Motoya Hayashi, Hirofumi Hayama, Mori taro ,Koki Kikuta, Yoshinori Honma, Naoki Kagi, U Yanagi, Asako Hasegawa, Sayaka Murata, Kenichi Kobayashi, Michiko Bando Hoon Kim Isao, Noriko Kaihara, Novel Coronavirus Infection Control Headquarters, Cluster Control Team, National Institute of Infectious Diseases, Local governments, public health centers, facility officials, related organizations, companies

Basics of ventilation measures to prevent

A. Infection caused by large aerosol on air current

B. Infection caused by small floating aerosol diffusion



Movement of floating droplet (aerosol) in building

Consideration of countermeasures

- Investigation on the influences of ventilation properties upon the cluster infection.
- Improvement proposals (usage restriction, emergency response, repair, etc.)

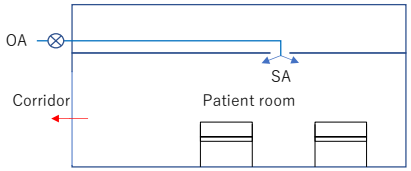
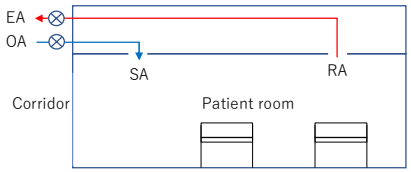
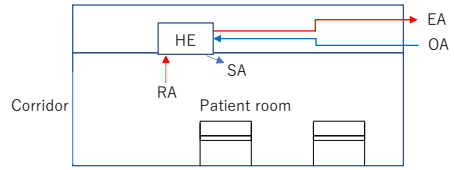
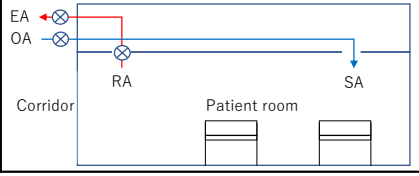
Measurement of indoor air environment

- Air conditioning and ventilation system
- Operation and maintenance
- Airflow rates and pressure difference between rooms
- CO_2 concentrations monitoring data
- Experiments on aerosol movement
  using tracers(aerosol, smoke, CO_2)

① Wards for uninfected patients in hospitals

- 8 hospitals were investigated, from Hokkaido to Kyushu .
- The age after construction was form 10 to over 30 years.
- Poor ventilation was recognized in 4 hospitals, caused by the aging of the equipment, energy and cost saving.

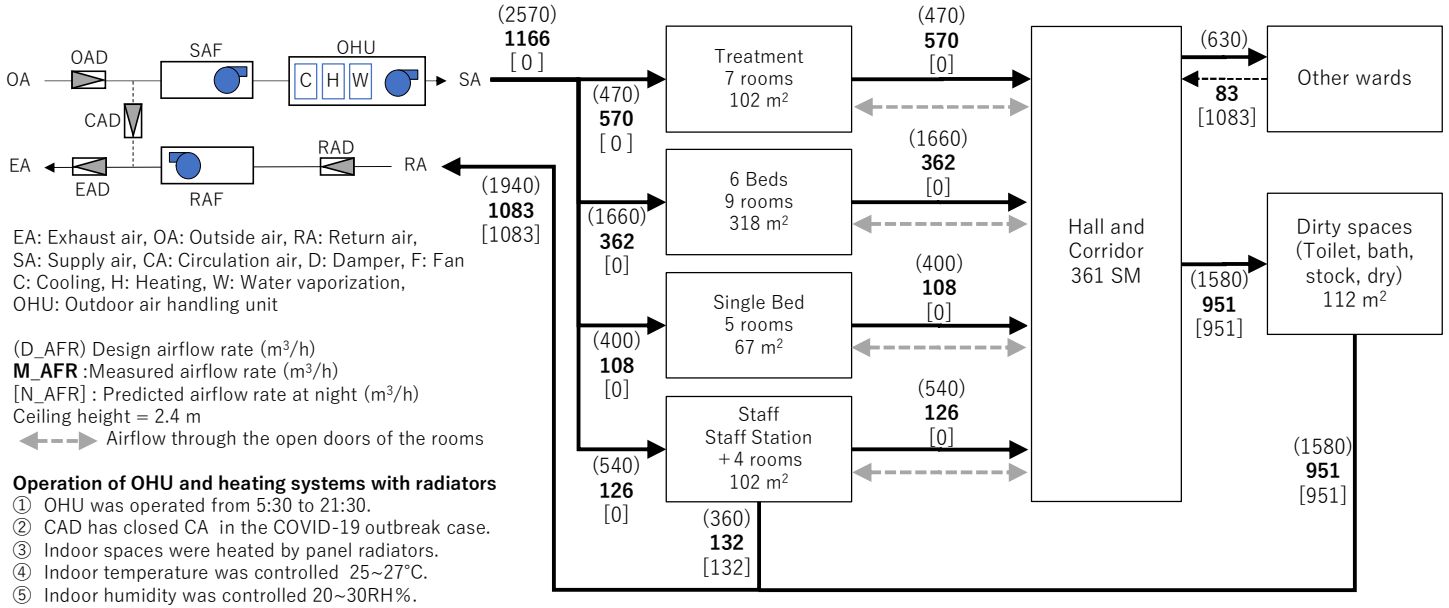
CO_2 generation by dry ice | CO_2 concentration meter | Pressure gauge

Hospital	Number of infected people	Ventilation of patient room	Ventilation properties and the operation of air conditioning and ventilation system
A	Approx.300 in heating season		i. NHF* was used for a week in a treatment room where ventilation rate was 10% of the design value. ii. The ventilation rate of the ward reduced to 30% of the design value. iii. Outside air supply stopped at night to keep indoor temperature. iv. Air supply rates were 4-31% of the design value in patient rooms. v. Aerosol flowed from patient rooms to corridors, especially when the door was opened.
B	Approx.50 in cooling season		i. NHF* was used in patient rooms. ii. Air supply rates were close to the design value, but exhaust rates were about 50% of design value. iii. Air supply stopped for about 3 minutes every 30 minutes to save electricity cost. iv. Aerosol flowed from patient rooms to corridors especially when air supply stopped.
C	Approx.150 in heating season		i. NHF* was used in patient rooms. ii. Supply rates and exhaust rates were about 50% of the capacity of heat exchange unites, in patient rooms.
D	Approx.10		i. NHF* weas used in patient rooms. ii. Supply rates and exhaust rates were about 50% of the design values, in patient rooms.

＊ NHF(nasal high flow): high oxygen concentration and humidity is sent continuously from a tube attached to the nose

Hospital A

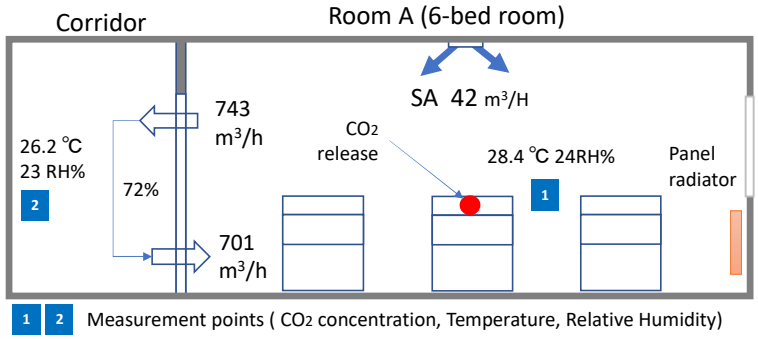
- Ventilation and airflow in the ward where a cluster occurred in winter.

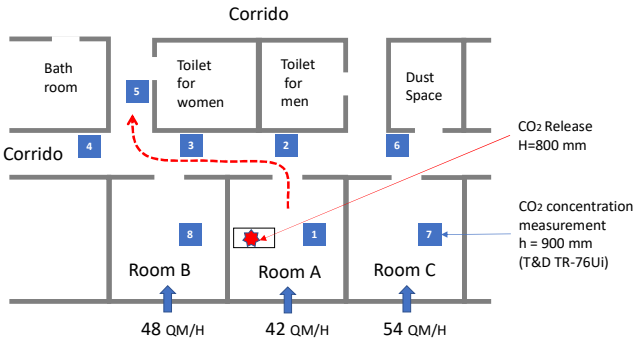


EA: Exhaust air, OA: Outside air, RA: Return air,
SA: Supply air, CA: Circulation air, D: Damper, F: Fan
C: Cooling, H: Heating, W: Water vaporization,
OHU: Outdoor air handling unit

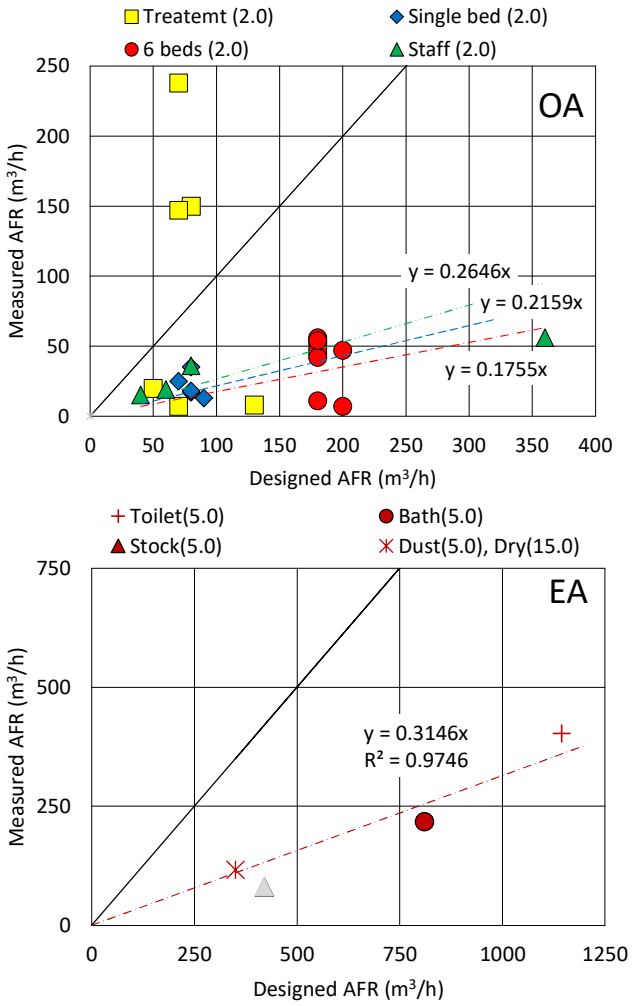
(D_AFR) Design airflow rate (m³/h)
M_AFR :Measured airflow rate (m³/h)
[N_AFR] : Predicted airflow rate at night (m³/h)
Ceiling height = 2.4 m
Airflow through the open doors of the rooms

Operation of OHU and heating systems with radiators
① OHU was operated from 5:30 to 21:30.
② CAD has closed CA in the COVID-19 outbreak case.
③ Indoor spaces were heated by panel radiators.
④ Indoor temperature was controlled 25~27℃.
⑤ Indoor humidity was controlled 20~30RH%.





Ventilation rates and airflow by tracer gas, etc.

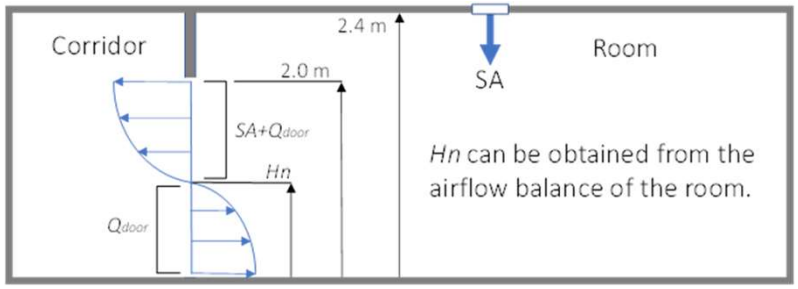


Measured airflow rates and the design value

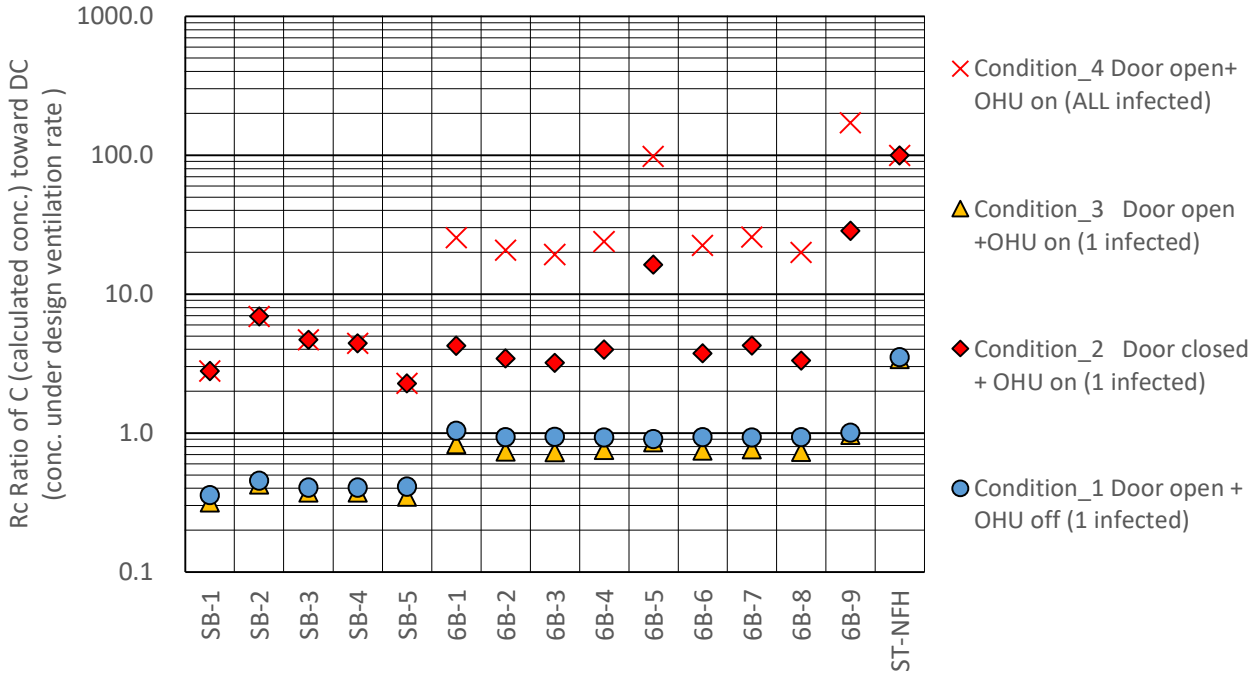
Hospital A

- The ventilation rates were calculated in rooms of the ward using measured data on ventilation and indoor environment.
- The expiratory concentrations from the infected were calculated and compared with the concentrations when the ventilation rates meet to the design values.
- The ratio of the expiratory concentrations toward those under the design ventilation rates, were 0.3 – 7 in Single bedroom (SB-1~6), 0.3 – 170 in 6 bed-room (6b-1~9) and 3.4-100 in treatment room (ST-NFH).

- NHF was initially used in poorly ventilated (10% of the design value) treatment room.
- During the outbreak, large numbers of patients used 6 bed-rooms.
- **The possibility of Aerosol infection** could not be denied in poor ventilated rooms in the ward.



Calculation of ventilation rates in heated patient rooms using measured data on ventilation, etc.



Predicted ratios of the expiratory concentrations from the infected, toward those when the ventilation rates meet to the design values

MHLW Notice “About ventilation equipment when treating new coronavirus infection” 7 April 2021

Health Crisis Report

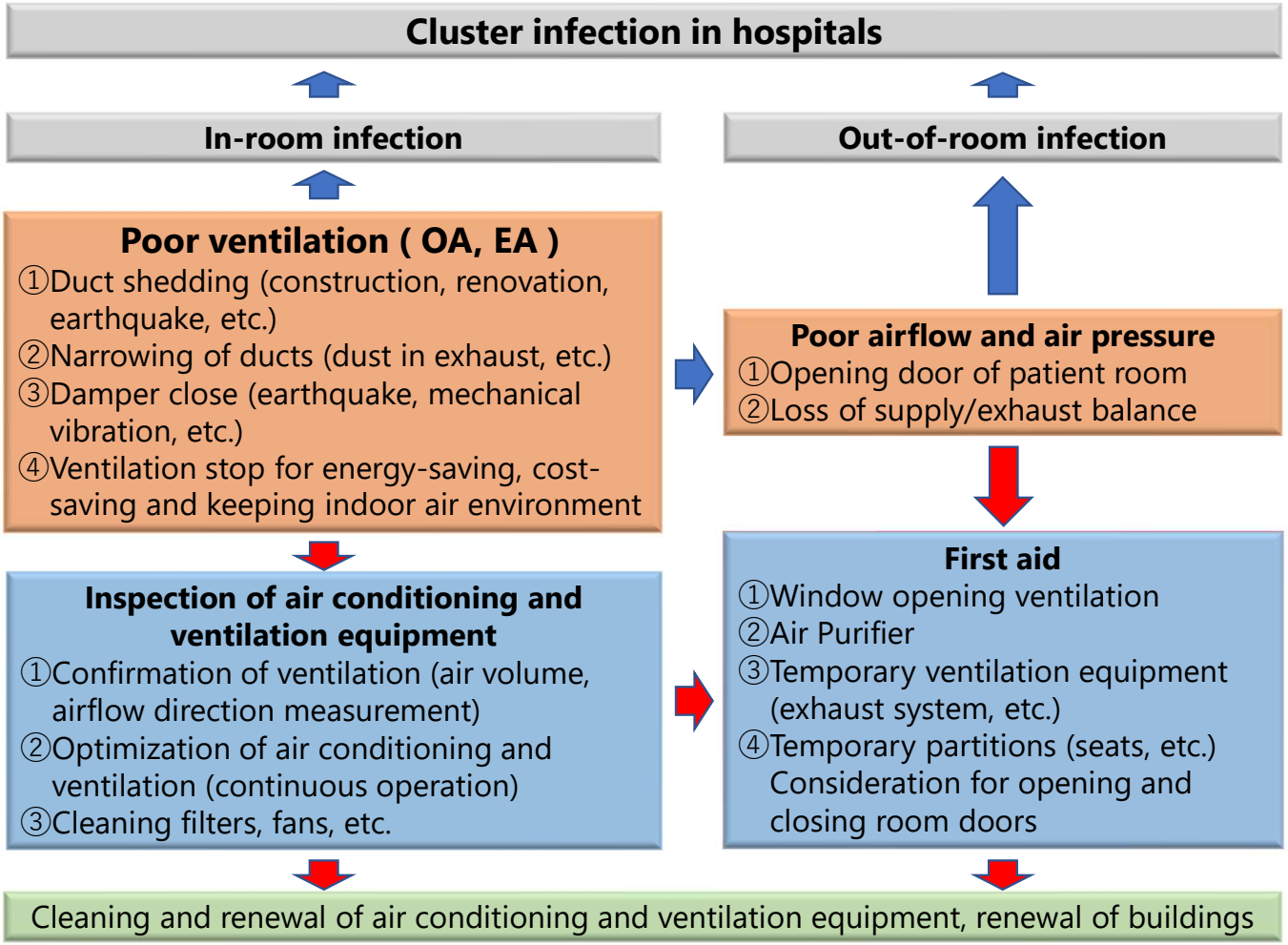
according to the investigation results
(30 March 2021)

Administrative liaison by MHLW

“About ventilation equipment when treating new coronavirus infection” (7 April 2021)

- The Japanese government has already noticed that adequate ventilation should be provided in the treatment of patients infected or possibly infected with COVID-19.
- The recent investigation showed the influence of the poor ventilation upon the outbreaks in hospitals.
- The following ventilation measures are proposed here.

① Inspection (the measurement of ventilation rate, etc.)
② Cleaning and repair of ventilation equipment, etc.
③ Temporary measures until the improvement of ventilation system (opening windows ,etc.)



Cluster infection due to poor ventilation and countermeasures

② Ice arenas for ice hockey

- Large infection-clusters occurred in two ice arenas in Hokkaido.

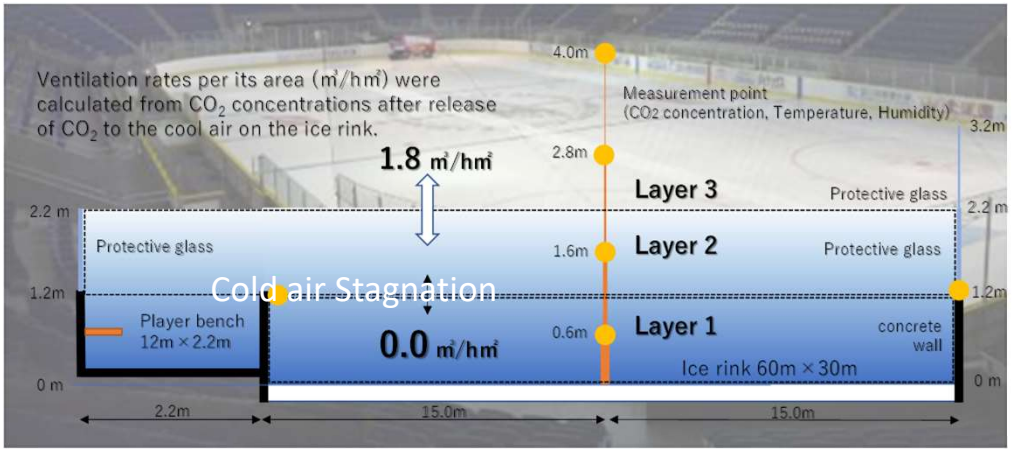
National High School Selection Ice Hockey Tournament

Investigation

- ➢ Contact and droplet infection in practices and tournaments.
- ➢ Possibility of aerosol infection due to
  ice arena-specific behavior (heavy physical exertion) and
  ventilation properties (stagnation of cold air) .

Measures to prevent aerosol infection among players

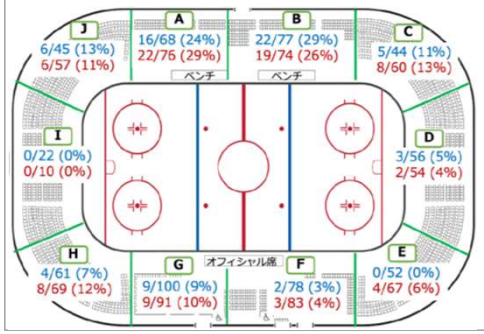
- ✓ Remove perimeter panel to improve ventilation on ice rink
- ✓ Set fans to reduce aerosol concentration around players' benches
- ✓ Set CO_2 concentration monitor to check ventilation efficiency



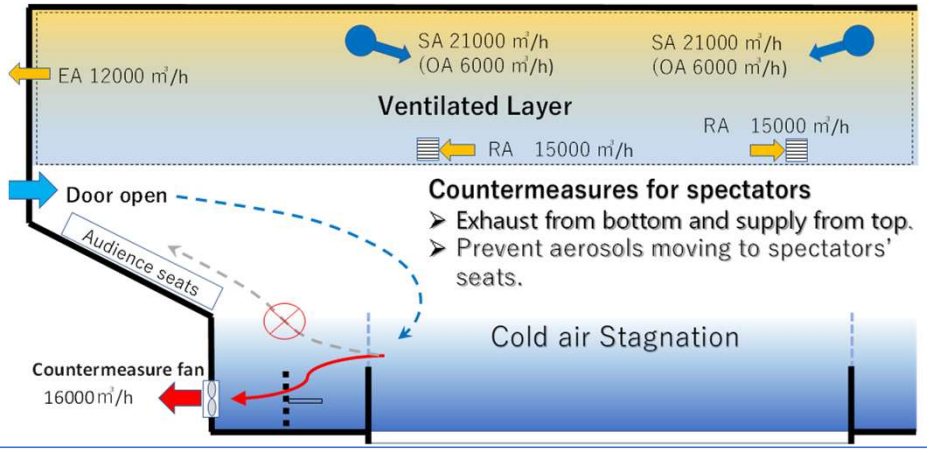
Asia League Ice Hockey Tournament

Investigation

- ➢ Many players released virus with heavy physical exertion on ice rink.
- ➢ Aerosol moved to spectators with air conditioning airflow.
- ➢ Airflow direction met to infection ratios at each seat area.



Measures to protect spectators from aerosol infection

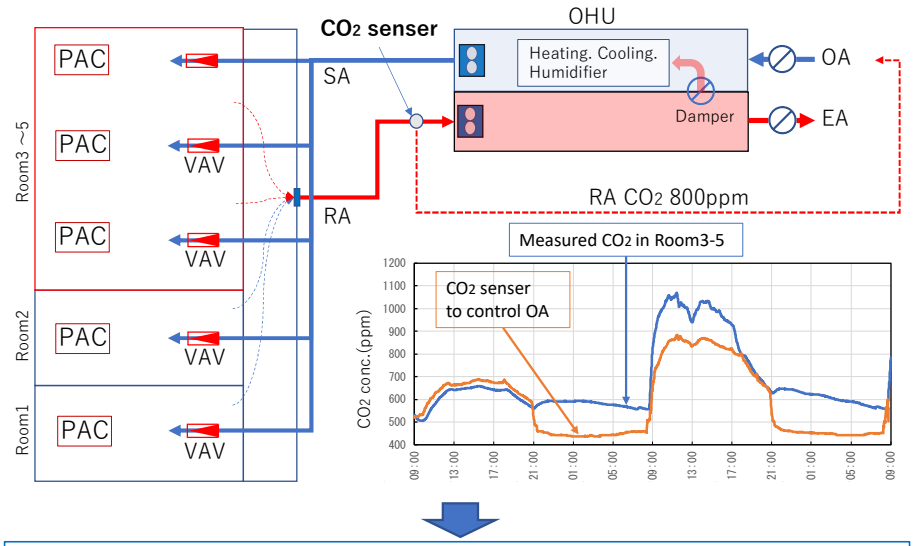


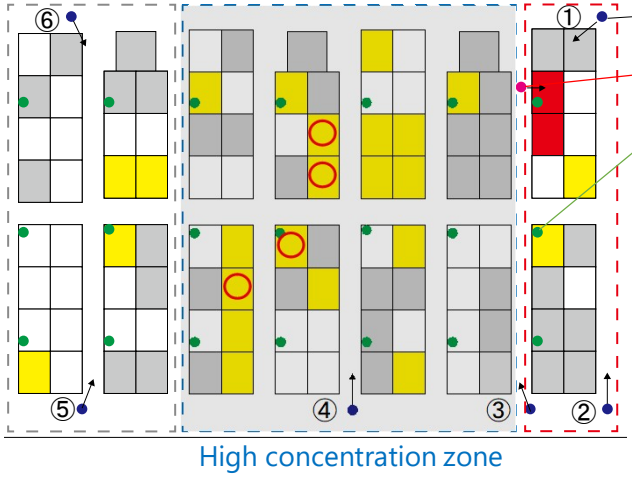
③ Office spaces used as call centers

- Infection-clusters occurred in many office spaces used as call centers.

Investigation

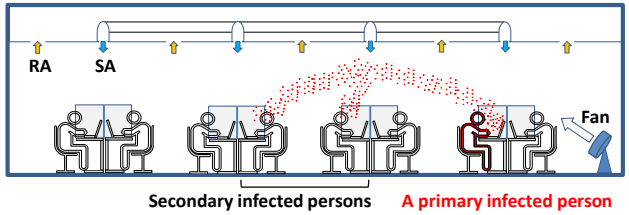
➢ Possibility of aerosol infection due to
telephone call staff's continuous talking at desk with 3 side partition to prevent droplet infection,
guidance stuff's access to desks and talking with telephone staff in high concentration space,
poor ventilation caused by malfunction of ventilation system with a CO_2 sensor,
high concentration zone by steady air current of a circulator behind infected staff.

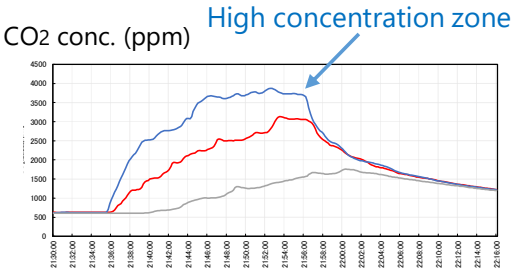




Measures to prevent aerosol infection

- ✓ Repair CO_2 sensors and ventilation control
- ✓ Removal of circulators and Installation of air purifiers
- ✓ Reduction of staff density



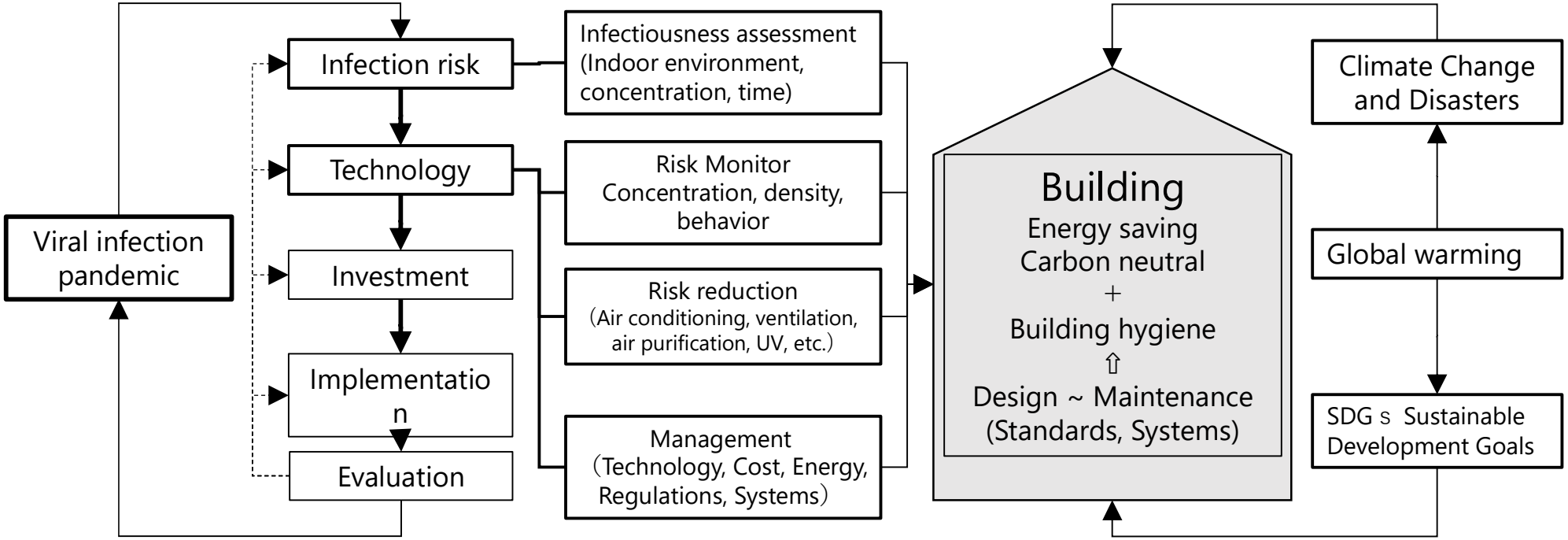


4. Infection control and Energy Conservation in Buildings for Post-COVID-19

"Committee on Air Conditioning, Ventilation in the Post-COVID-19" by Institute for Built Environment and Carbon Neutral for SDGs

Global warming influences upon public health now and in future.

- Global warming increases the risk of emerging and re-emerging infectious diseases by the change of ecosystem and the thaw of permafrost.
- Effective solution sets for both infection control and warming control is an emergent task in architecture as well as other fields.



Research and developments for energy saving and health in building under the age of viral infection pandemic and global warming

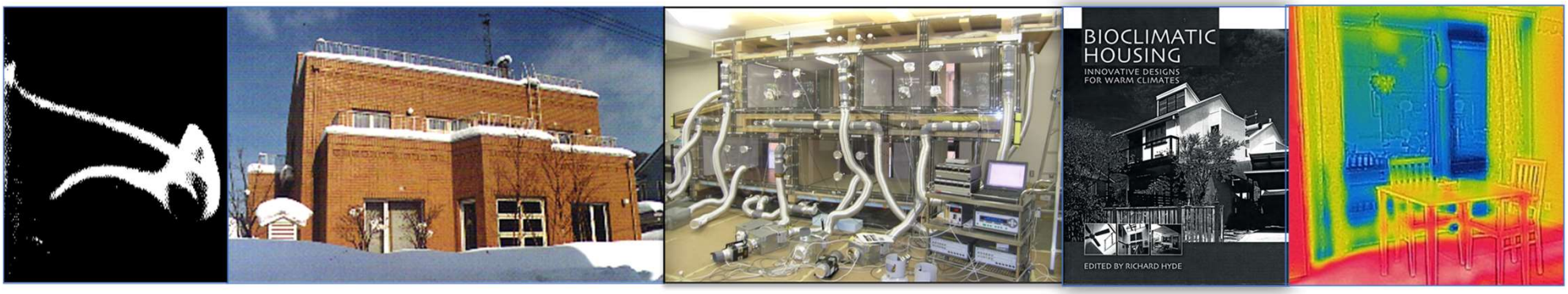
Conclusion

- In large buildings, poor air environment has increased since the 1990s.
- In houses, poor air environment influenced upon the health of the residents before.

- Under COVID-19 pandemic, ventilation measures were carried out immediately (March 2020).
- Soon, the influences of ventilation measures upon indoor environment were considered (May 2020, February 2020).
- Investigations on the air environment of cluster cases showed the influence of poor ventilation upon aerosol infection (2020-2022).
- Effective ventilation methods to prevent two types of aerosol infection were recommended (July 2022).

- For “Post COVID-19”, the balance of infection control and energy saving must be studied.

Thank you very much.

Motoya Hayashi

- 1979-1988 Hokkaido University Faculty of Engineering, graduate school of Engineering (Sapporo)
  "Natural ventilation of buildings considering wind pressure fluctuation "
- 1988-1999 Sekisuihouse ltd. (Tokyo, Osaka, Shizuoka) Tokyo planning office and Research institute
  "Adaptation of light steal structure to cold climate", "Hybrid ventilation system "
- 1999-2014 Miyagi Gakuin Women's University Department of Lifestyle and Space Design (Sendai)
  "Countermeasures against Sick house problems (Building Standard Law on Sick House Issues, 2003)
  "Annex38 "Sustainable Solar Housing (IEA 2000-2005)"
- 2014- National Institute of Public Health (Wako) Research managing director
  "Environmental health in buildings(LEHB1970)", "Planning of welfare facility for infection control"
- 2020 Hokkaido University Faculty of Engineering (Sapporo)
  "Countermeasures against COVID-19 in buildings