内容概要

1．COVID-19流行の現状

2．COVID-19の感染経路

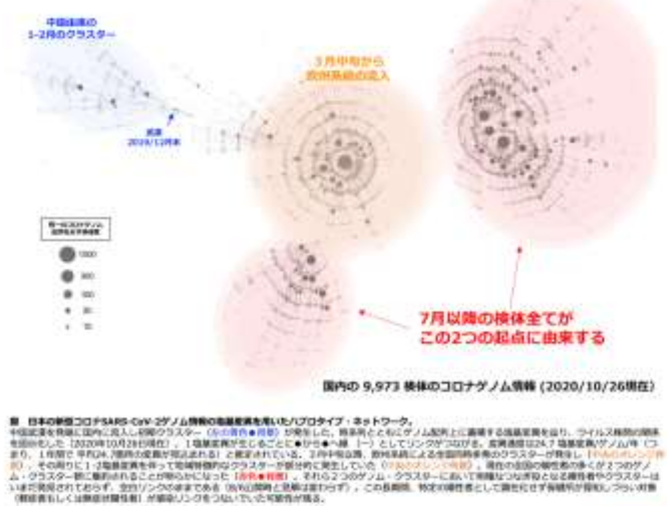
3．室内環境中でのSARS-CoV-2の挙動

4．換気と空気浄化による対策

1． COVID-19流行の現状

2021年1月26日　世界累積感染者数 1億人突破

日本　感染者数：442,385、死亡者数：8412、致死率：1.9％



Science

RESEARCH ARTICLES

Cite as: N. G. Davies *et al.*, *Science*
10.1126/science.abg3055 (2021).

Estimated transmissibility and impact of SARS-CoV-2 lineage B.1.1.7 in England

Nicholas G. Davies[1*], Sam Abbott[1†], Rosanna C. Barnard[1†], Christopher I. Jarvis[1†], Adam J. Kucharski[1†], James D. Munday[1†], Carl A. B. Pearson[1†], Timothy W. Russell[1†], Damien C. Tully[1†], Alex D. Washburne[2†], Tom Wenseleers[3†], Amy Gimma[1], William Waites[1], Kerry L. M. Wong[1], Kevin van Zandvoort[1], Justin D. Silverman[4], CMMID COVID-19 Working Group[1‡], COVID-19 Genomics UK (COG-UK) Consortium‡, Karla Diaz-Ordaz[1], Ruth Keogh[5], Rosalind M. Eggo[1], Sebastian Funk[1], Mark Jit[1], Katherine E. Atkins[1,6], W. John Edmunds[1]

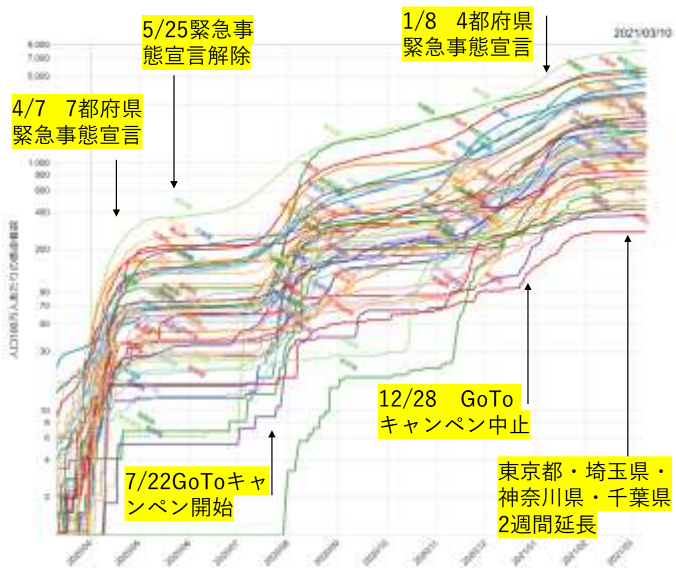
[1]Centre for Mathematical Modelling of Infectious Diseases, London School of Hygiene and Tropical Medicine, London, UK. [2]Selva Analytics LLC, Bozeman, MT, USA. [3]Lab of Socioecology and Social Evolution, KU Leuven, Leuven, Belgium. [4]College of Information Science and Technology, Pennsylvania State University, University Park, PA, USA. [5]Centre for Statistical Methodology and Department of Medical Statistics, London School of Hygiene and Tropical Medicine, London, UK. [6]Centre for Global Health, Usher Institute of Population Health Sciences and Informatics, University of Edinburgh, Edinburgh, UK.

*Corresponding author. Email: nicholas.davies@lshtm.ac.uk

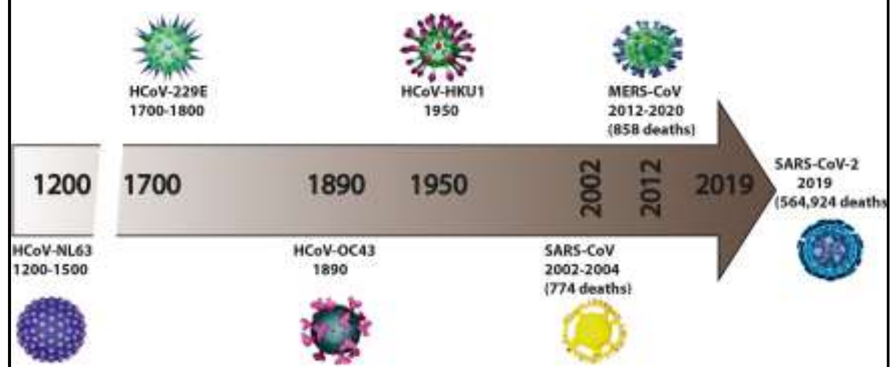
†These authors contributed equally to this work.

‡See supplementary materials for list of consortium members and affiliations.

A novel SARS-CoV-2 variant, VOC 202012/01 (lineage B.1.1.7), emerged in southeast England in November 2020 and is rapidly spreading toward fixation. Using a variety of statistical and dynamic modelling approaches, we estimate that this variant has a 43–90% (range of 95% credible intervals 38–130%) higher reproduction number than preexisting variants. A fitted two-strain dynamic transmission model shows that VOC 202012/01 will lead to large resurgences of COVID-19 cases. Without stringent control measures, including limited closure of educational institutions and a greatly accelerated vaccine roll-out, COVID-19 hospitalisations and deaths across England in 2021 will exceed those in 2020. Concerningly, VOC 202012/01 has spread globally and exhibits a similar transmission increase (59–74%) in Denmark, Switzerland, and the United States.

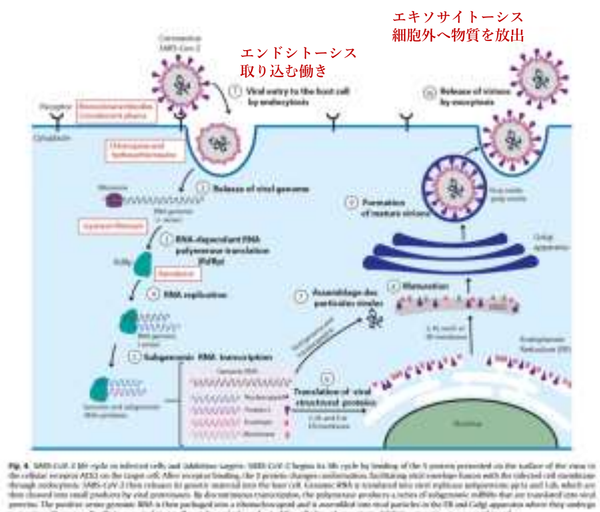


出典札幌医科大学医学部 附属フロンティア医学研究所 ゲノム医科学部門



Bchetnia M, et al. The outbreak of the novel severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2): A review of the current global status. *J Infect Public Health* (2020)

感染：病原体が生体に入り込んで，住み着き，増殖するようになること
伝播：広く伝わること



ウイルス
侵入：～10分
増殖：～10時間

宮坂昌之：新型コロナウイルス感染症の今後：敵を正しく知る、2020年11月16日、工学院大学教育推進機構FDオンライン(ウェビナー)

Bchetnia M, et al. The outbreak of the novel severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2): A review of the current global status. *J Infect Public Health* (2020), https://doi.org/10.1016/j.jiph.2020.07.011

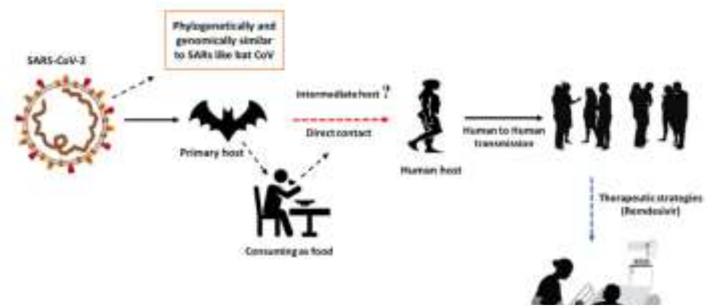
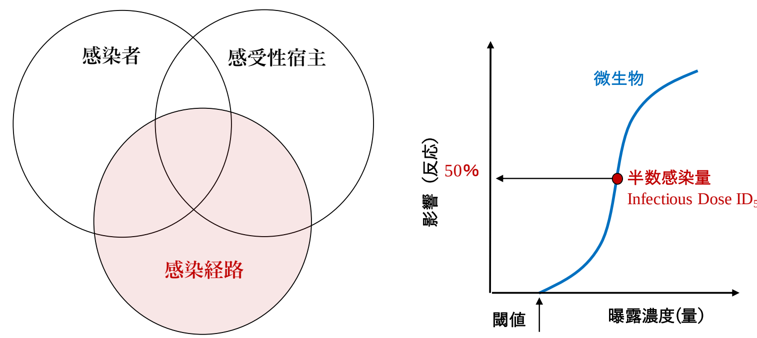


Table 1
Comparative analysis of biological features of SARS-CoV and SARS-CoV-2.

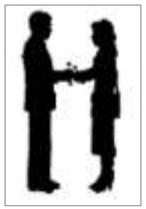
Features	SARS-CoV	SARS-CoV-2	Reference
Emergence date	November 2002	December 2019	[37,79–81]
Area of emergence	Guangdong, China	Wuhan, China	
Date of fully controlled	July 2003	Not controlled yet	
Key hosts	Bat, palm civets and Raccoon dogs	Bat	[22,82,83]
Number of countries infected	26	109	[84]
Entry receptor in humans	ACE2 receptor	ACE2 receptor	[22,53,85]
Sign and symptoms	fever, malaise, myalgia, headache, diarrhoea, shivering, cough and shortness of breath	Cough, fever and shortness of breath	[12,23,85]
Disease caused	SARS, ARDS	SARS, COVID-19	[85,86]
Total infected patients	8098	123882	[84]
Total recovered patients	7322	67051	
Total died patients	776 (9.6% mortality rate)	4473 (3.61% mortality rate)	

Shereen MA, et al. COVID-19 infection: Origin, transmission, and characteristics of human coronaviruse. *Journal of Advanced Research*, 2020. (http://creativecommons.org/licenses/by-nc-nd/4.0)

2． COVID-19の感染経路



感染症の３要素と感染

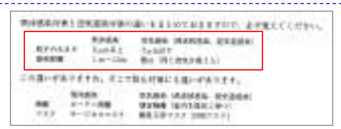


直接

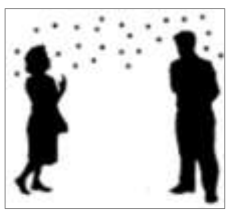
間接（媒介物）

接触感染

出典：
http://www.mhlw.go.jp/english/topics/influenza_a/general_info.html



飛沫感染



エアロゾル感染
（空気感染）

飛沫感染と空気感染を5μmで分類している。

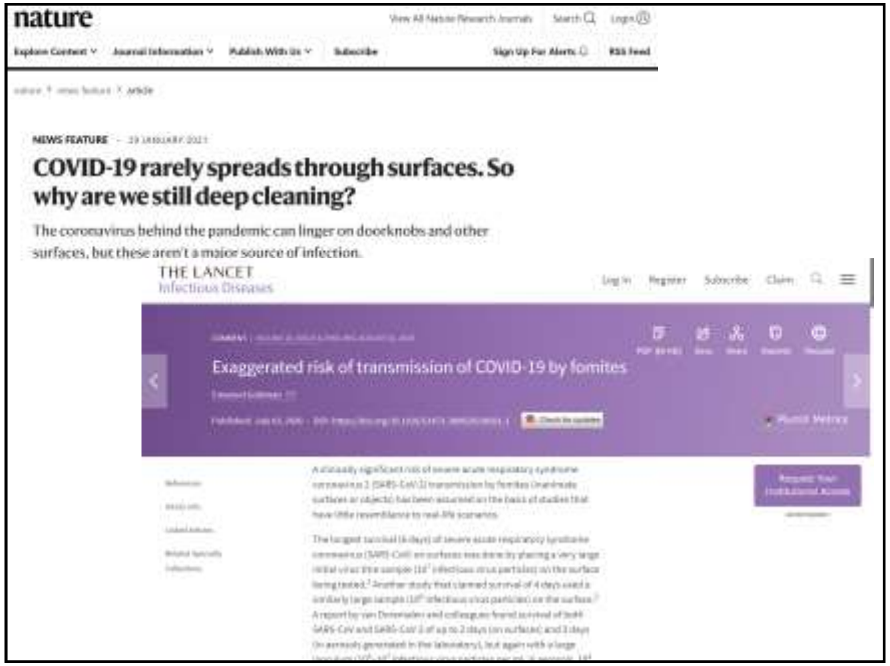
これは妥当なのか？

COVID-19 can sometimes be spread by airborne transmission

- Some infections can be spread by exposure to virus in small droplets and particles that can linger in the air for minutes to hours. These viruses may be able to infect people who are further than 6 feet away from the person who is infected or after that person has left the space.
- This kind of spread is referred to as **airborne transmission** and is an important way that infections like tuberculosis, measles, and chicken pox are spread.
- There is evidence that under certain conditions, people with COVID-19 seem to have infected others who were more than 6 feet away. These transmissions occurred within enclosed spaces that had inadequate ventilation. Sometimes the infected person was breathing heavily, for example while singing or exercising.
  - Under these circumstances, scientists believe that the amount of infectious smaller droplet and particles produced by the people with COVID-19 became concentrated enough to spread the virus to other people. The people who were infected were in the same space during the same time or shortly after the person with COVID-19 had left.
- Available data indicate that it is much more common for the virus that causes COVID-19 to spread through close contact with a person who has COVID-19 than through airborne transmission. [1]

COVID-19 spreads less commonly through contact with contaminated surfaces

- Respiratory droplets can also land on surfaces and objects. It is possible that a person could get COVID-19 by touching a surface or object that has the virus on it and then touching their own mouth, nose, or eyes.
- Spread from touching surfaces is not thought to be a common way that COVID-19 spreads


nature

NEWS FEATURE

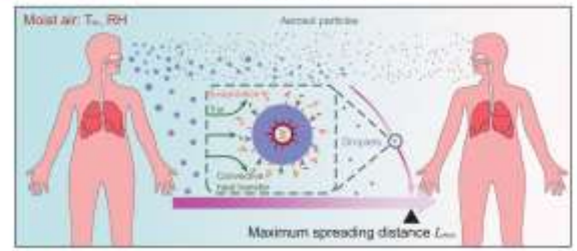
COVID-19 rarely spreads through surfaces. So why are we still deep cleaning?

The coronavirus behind the pandemic can linger on doorknobs and other surfaces, but these aren't a major source of infection.

THE LANCET Infectious Diseases

Exaggerated risk of transmission of COVID-19 by fomites

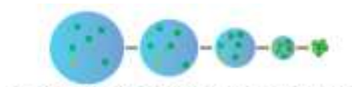
Nano Letters pubs.acs.org/NanoLett Letter



https://pubs.acs.org/doi/10.1021/acs.nanolett.0c03331

Figure 1. Transmission of COVID-19 through droplets and aerosol particles. After being exhaled by a patient, respiratory droplets with various sizes will travel and simultaneously evaporate in the ambient environment. Small-sized droplets dry immediately to form a cloud of aerosol particles. These particles will suspend in the air for a significant amount of time. Large-sized droplets can reach a limited distance and fall to the ground due to gravity. We define L_{max} as the maximum horizontal distance that droplets can travel before they either become dry aerosol particles or descend below the level of another person's hands, i.e., $H/2$ from the ground, where H is the height of another person.

Evaporation



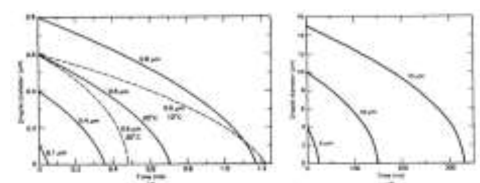


Figure 13.11 Evaporation of pure water droplets at 293 K [20°C] and 50% relative humidity

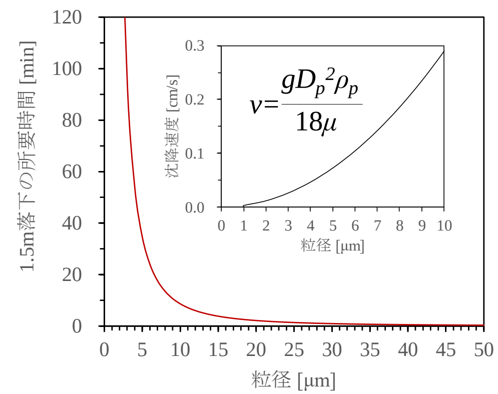
Source: Hinds WC, 1982. Aerosol Technology, p.267, John Wiley & Sons, Inc.

エアロゾル
※ 1920年から作られた用語：固体粒子が分散している安定な懸濁液

※エアロゾルとは，気体中に浮遊する微小な液体または固体の粒子と周囲の気体の混合体をいう。（日本エアロゾル学会）

Source
Turbulent Gas Clouds and Respiratory Pathogen Emissions Potential Implications for Reducing Transmission of COVID-19.
JAMA May 12, 2020 Volume 323, Number 18

浮遊粒子（SARS-CoV-2など）を空気と一緒に吸入するため、エアロゾルの状態となる。



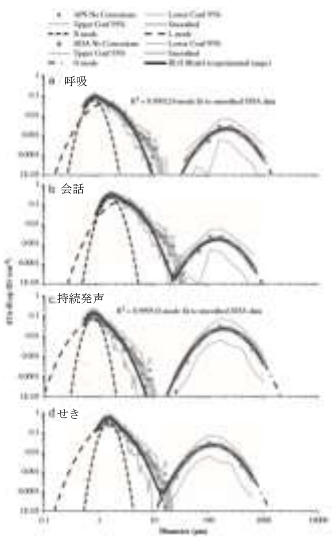
v：終末沈降速度 [cm/s]
g：重力加速度 [cm/s^2]
D_p：粒径 [cm]
ρ_p：粒子の密度 [g/cm^3]
μ：空気の粘度 [g/(cm·s)]

オフィスビル室内の気流速度
0.1～0.4m/s（10～40cm/s）

Source
Motoya Hayashi, U Yanagi, et al., 2020. Measures against COVID - 19 concerning Summer Indoor Environment in Japan. Japan Architectural Review, Volume 3, Issue 4. https://doi.org/10.1002/2475-8876.12183

粒径10μm以下の粒子は無風状態で室内に長時間浮遊することが分かる
（1μm：14.4h；5μm：35min；10μm：9min）。

出典
柳宇：ウイルス感染拡大を抑えるために設備技術者が出来ること感染制とその制御、BE建築設備、pp.14-20、第834号、2020



Johnson GR, et al. Corbett S. Modality of hun expired aerosol size distributions. *Journal of Aerosol Science*, 42, pp.839-851, 2011.

既往の研究では，ヒトの呼吸器系由来の活性飛沫核の粒径は殆ど<5-10μmであることが分かっている。

Chao CYH, Wan MP, Morawska L, et al. Characterization of expiration air jets and droplet size distributions immediately at the mouth opening. *J Aerosol Sci.* 2009; 40: pp.122-133.
Fang M, Lau APS, Chan CK, et al. Aerodynamic properties of biohazardous aerosols in hospitals. Hong Kong *Med J.* 2008; 14: pp.26-28.
Morawska L, Johnson GR, Ristovski ZD, et al. Size distribution and sites of origin of droplets expelled from the human respiratory tract during expiratory activities. *J Aerosol Sci.* 2009; 40: pp.256-269.
Almstrand AC, Bake B, Ljungstrom E, et al. Effect of airway opening on production of exhaled particles. *J Appl Physiol.* 2010; 108: 584-588

Table 2. Size distribution of influenza RNA measured in Lindsley et al. (2010)

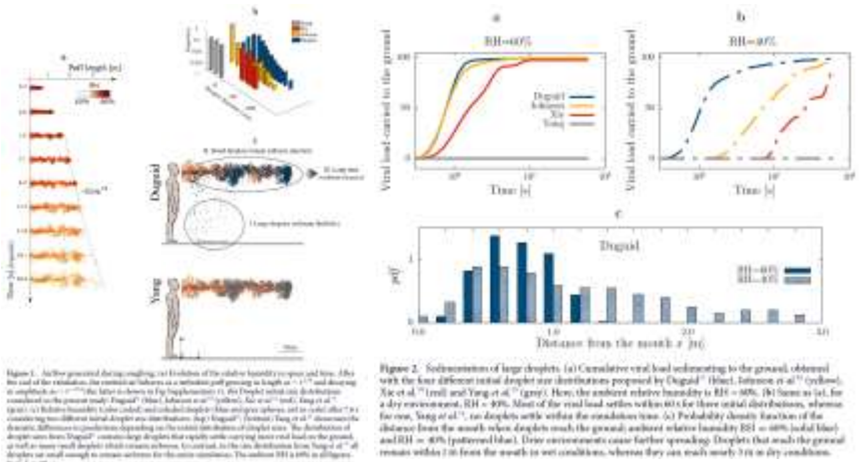
Sampling Location	Distribution of viral RNA		
Personal samplers	< 1.7 μm 32%	1.7-4.9 μm 16%	> 4.9 μm 52%
Lower stationary samplers	< 1 μm 13%	1-4.1 μm 37%	> 4.1 μm 50%
Upper stationary samplers	< 1 μm 9%	1-4.1 μm 27%	> 4.1 μm 64%

nature research scientific reports

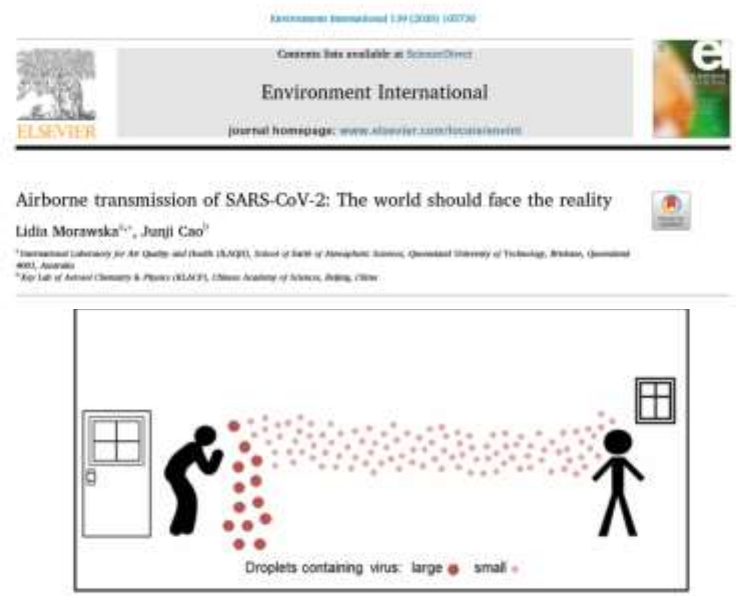
OPEN **Fluid dynamics of COVID-19 airborne infection suggests urgent data for a scientific design of social distancing**

M. E. Rosti, S. Olivieri, M. Cavaiola, A. Seminara & A. Mazzino

COVID-19パンデミックは，その大部分が空気感染伝播によるものであり，この現象は急速に科学界の注目を集めた．科学的な根拠に基づいてソーシャルディスタンスのルールを設定するためには，ウイルスを含む呼吸器飛沫の飛散過程を理解しなければならない．
文献から得られた飛沫の初期サイズ分布の違いと周囲の相対湿度の違いによって，反対の結論が得られることがわかった: (i) ほとんどのウイルス量は数秒で最初の1-2mで沈降する vs しない; (ii) すべてのウイルス量は乾燥した（飛沫）核 vs 液体飛沫で運ばれる; (iii) 空気中の小さな粒子は2.5m未満 vs 7.5mを超えて移動する．我々の研究の知見を考慮すると，科学的な基礎に基づくソーシャルディスタンスを決定するために，予測が不確実である原因となっている2つの重要な課題，すなわち放出される時の飛沫サイズ分布の決定(I1)，乾燥した（飛沫）核 vs 湿潤した（飛沫）核で運ばれるウイルス量の感染可能性(I2)に取り組むための新たな実験が必要である．



www.nature.com/scientificreports
https://doi.org/10.1038/s41598-020-80078-7


Environment International

Airborne transmission of SARS-CoV-2: The world should face the reality

Lidia Morawska, Junji Cao

Transmission of SARS-CoV-2: implications for infection prevention precautions

Scientific brief

9 July 2020

World Health Organization

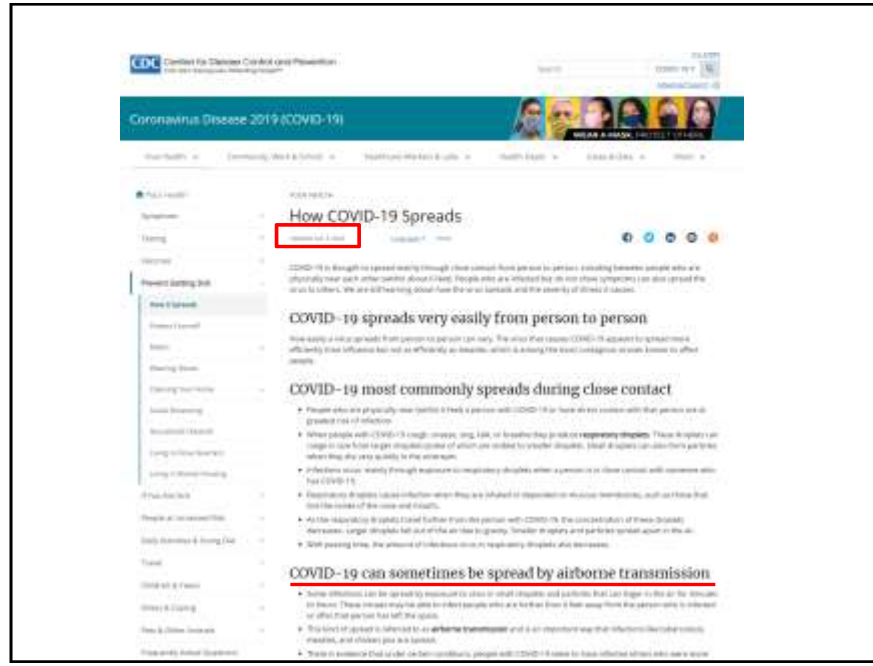
This document is an update to the scientific brief published on 29 March 2020 entitled "Modes of transmission of virus causing COVID-19: implications for infection prevention and control (IPC) precaution recommendations" and includes new scientific evidence available on transmission of SARS-CoV-2, the virus that causes COVID-19.

Overview

Outside of medical facilities, some outbreak reports related to indoor crowded spaces (40) have suggested the possibility of aerosol transmission, combined with droplet transmission, for example, during choir practice (7), in restaurants (41) or in fitness classes (42). In these events, short-range aerosol transmission, particularly in specific indoor locations, such as crowded and inadequately ventilated spaces over a prolonged period of time with infected persons cannot be ruled out. However, the detailed investigations of these clusters suggest that droplet and fomite transmission could also explain human-to-human transmission within these clusters. Further, the close contact environments of these clusters may have facilitated transmission from a small number of cases to many other people (e.g., superspreading event), especially if hand hygiene was not performed and masks were not used when physical distancing was not maintained. (43)

Fomite transmission

Respiratory secretions or droplets expelled by infected individuals can contaminate surfaces and objects, creating fomites



3．室内環境中でのSARS-CoV-2の挙動

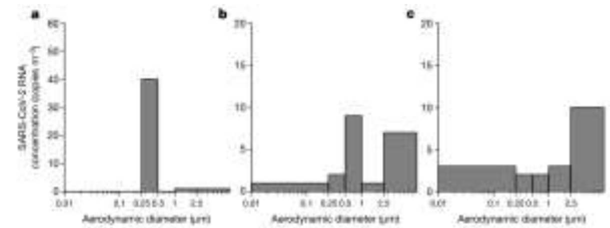


Fig. 1 | Concentration of airborne SARS-CoV-2 RNA in different aerosol size bins. a, Concentration of SARS-CoV-2 in a protective-apparel removal room in zone B of Fangcang Hospital. **b**, Concentration of SARS-CoV-2 in a protective apparel removal room in zone C of Fangcang Hospital. **c**, Concentration of SARS-CoV-2 in the medical staff's office of Fangcang Hospital. The *x* axis represents the aerodynamic diameter on a logarithmic scale to cover the multiple magnitudes of measured aerosol diameters.

Yuan Liu,et al. Dane Westerdahl, Xinjin Liu, Ke Xu, Kin-fai Ho, Haidong Kan, Qingyan Fu & Ke Lan. Aerodynamic analysis of SARS-CoV-2 in two Wuhan hospitals. *Nature*, Vol 582, 25, pp.557-560, June 2020.
https://www.nature.com/articles/s41586-020-2271-3

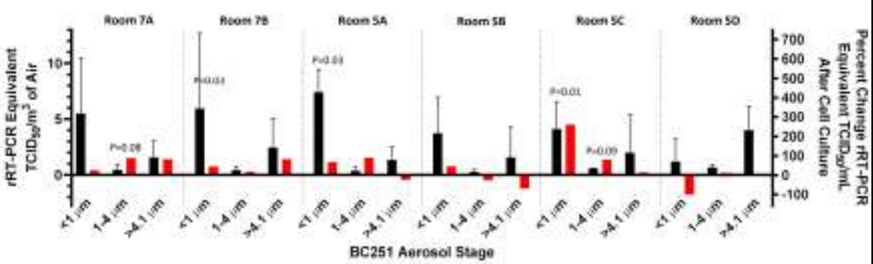
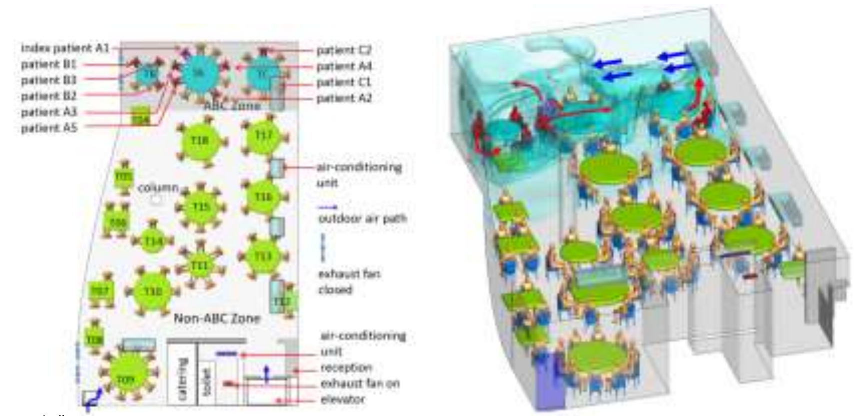


Figure 1. Measured Airborne RNA Concentrations and Associated Percent Change in Viral Copies in Cell Culture. Measured RT-PCR equivalent TCID50/m³ (black) indicate in initial viral RNA concentrations while the percent change viral copies (red) indicates viral replication in cell culture (or lack thereof). Error bars indicate the standard deviation of the RT-PCR-derived concentrations (for air concentration) and calculated measurement uncertainty (for percent change in cell culture). The P-value comparing the initial and final PFU/mL measurements is shown if the change is positive and the P-value is less than 0.1. Three of the six submicron filter samples indicated an increase in cell culture that was significant (p<0.05) based on the Students T-Test (7B, 5A and 5C. Two of the 1-4 um samples had P-values less than 0.1, but not less than 0.05 (7A and 5C). None of >4.1 um samples demonstrated statistically significant replication.

注：$TCID_{50}$：Tissue Culture Infectious Dose 50，50%の組織培養細胞感染量（半数感染量）

Santarpia JL, et al. The Infectious Nature of Patient-Generated SARS-CoV-2 Aerosol. *medRxiv preprint*.
https://doi.org/10.1101/2020.07.13.20041632



出典 Yuguo Li, et al. Evidence for probable aerosol transmission of SARS-CoV-2 in a poorly ventilated restaurant. 2020. *medRxiv preprint*. https://doi.org/10.1101/2020.04.16.20067728

Yuguo Liらによる当日の状況を再現した詳細な調査の結果，当日換気のための排気ファンは入り口付近のトイレを除いてすべて止められており，換気量は2.7~3.7m³/h・人（換気回数0.56~0.77回/h）しかなかったことが明らかになった。

空気調和・衛生工学会 新型コロナウイルス対策特別委員会：空調・換気によるCOVID-19の拡散はあるのか？空気調和・衛生工学分野の専門家からの見解。http://www.shasej.org/oshirase/2006/covid19v2.pdf

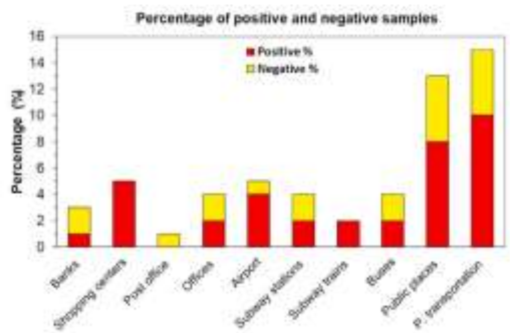


Fig. 1. Percentage of positive and negative samples based on the group of sampling sites.

Hadei M, et al. Presence of SARS-CoV-2 in the air of public places and transportation. Atmospheric Pollution Research,
https://doi.org/10.1016/j.apr.2020.12.016

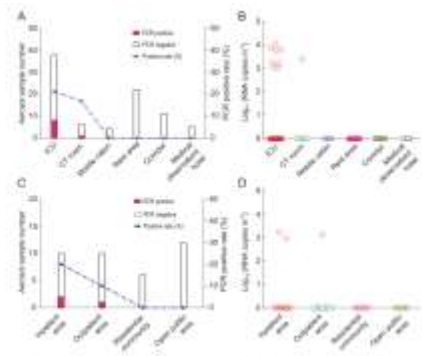
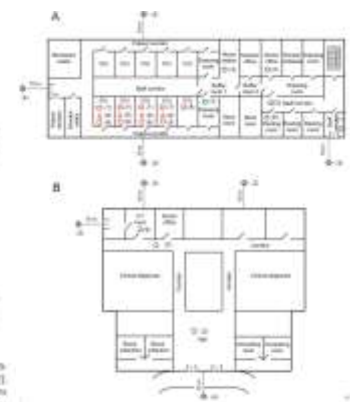


Figure 1. Detection of SARS-CoV-2 in the aerosol samples in Wuhan hospitals, China. Aerosol samples from various locations were collected over 30 min with centrifugal bioaerosol samplers. qRT-PCR targeting the ORF1ab gene of the SARS-CoV-2 was performed using One Step PrimeScript™ RT-PCR kits. (A and C): the numbers of qRT-PCR positive and negative aerosol samples from (A) indoors or (C) outdoors are shown as filled and open bars, respectively; the dashed line represents the qRT-PCR positive rates of the aerosol samples; (B and D): copy numbers of SARS-CoV-2 RNA in aerosols from (B) indoors or (D) outdoors. A standard curve (Y = 47.951 − 3.44 × log (copy numbers)) generated from the *in vitro* transcribed RNA was used to calculate the copy numbers of SARS-CoV-2 RNA.



サンプル数：123（室内・屋外）2020.2.16-2020.3.14

Hu J, et al. 2020. Distribution of airborne SARS-CoV-2 and possible aerosol transmission in Wuhan hospitals, China. National Science Review, 7: 1865–1867, 2020.
https://doi.org/10.1093/nsr/nwaa250

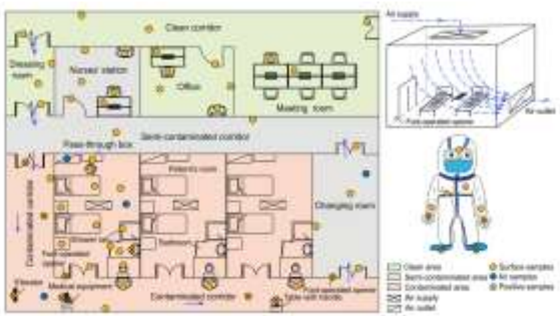


Fig. 1 Schematic diagram showing environmental sampling sites in the inpatient area of the Shanghai Public Health Clinic Center hospital. Arrows in blue show the direction of people's movement.

Identifying the Risk of SARS-CoV-2 Infection and Environmental Monitoring in Airborne Infectious Isolation Rooms (AIIRs)
https://link.springer.com/content/pdf/10.1007/s12250-020-00301-7.pdf

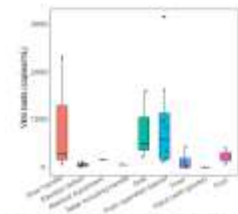
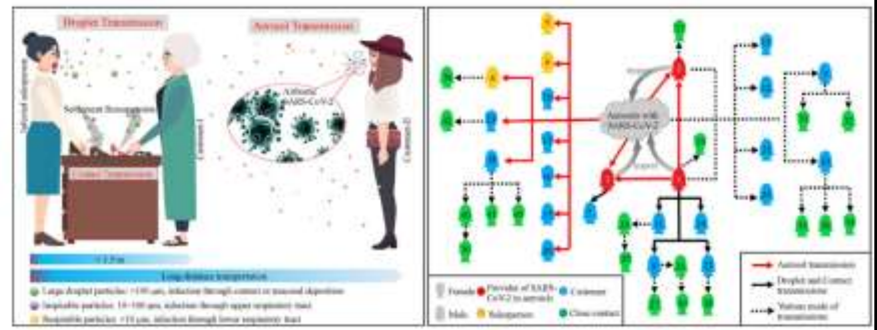


Fig. 2 Viral loads in all the positive samples. The horizontal box lines represent the first quartile, the median, and the third quartile of viral loads. Each dot represents a positive sample and circles represent outliers.

Abstract
Healthcare workers (HCWs) are at high risk of occupational exposure to the new pandemic human coronavirus, SARSCoV-2, and are a source of nosocomial transmission in airborne infectious isolation rooms (AIIRs). Here, we performed comprehensive environmental contamination surveillance to evaluate the risk of viral transmission in AIIRs with 115 rooms in three buildings at the Shanghai Public Health Clinical Center, Shanghai, during the treatment of 334 patients infected with SARS-CoV-2. The results showed that the risk of airborne transmission of SARS-CoV-2 in AIIRs was low (1.62%, 25/1544) due to the directional airflow and strong environmental hygiene procedures. However, we detected viral RNA on the surface of foot-operated openers and bathroom sinks in AIIRs (viral load: 55.00–3154.50 copies/mL). This might be a source of contamination to connecting corridors and object surfaces through the footwear and gloves used by HCWs. The risk of infection was eliminated by the use of disposable footwear covers and the application of more effective environmental and personal hygiene measures. With the help of effective infection control procedures, none of 290 HCWs was infected when working in the AIIRs at this hospital. This study has provided information pertinent for infection control in AIIRs during the treatment of COVID-19 patients.



SARS-CoV-2 transportation in aerosol was dependent on temperature, air humidity, ventilation rate and inactivating chemicals (ozone) content. As for the infection route of case numbers 2 to 6, 10, 13, 16, 17, 18, 20 and 23, we believe that aerosol transmission played a significant role in analyzing their exposure history and environmental conditions in Baodi Department Store. Aerosol transmission could occur in some cluster cases when the environmental factors are suitable, and it is an indispensable route of COVID-19 spread.

Jiang G., et al., Aerosol transmission, an indispensable route of COVID-19 spread: case study of a department-store cluster. Front. Environ. Sci. Eng. 2021, 15(3): 46. https://doi.org/10.1007/s11783-021-1386-6

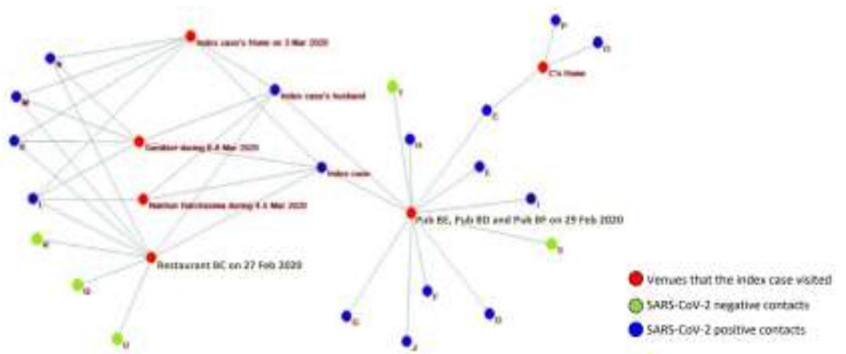
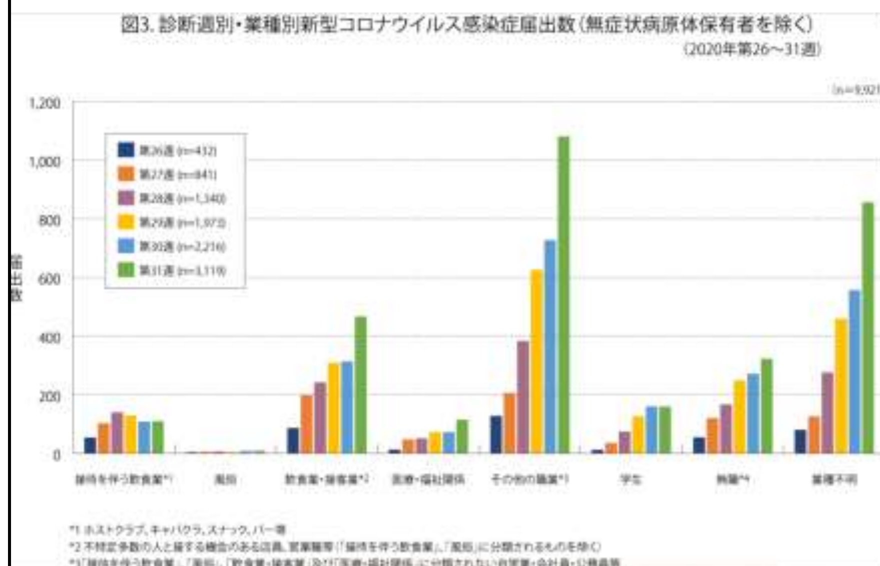


Figure 2. Sociogram illustrating the connection of cases, contacts, and venues that the index case visited in cluster#1 (N=21)

Kripattanapong S., et al, 2020. Clusters of Coronavirus Disease (COVID-19) in Pubs, Bars and Nightclubs in Bangkok, 2020. OSIR, December 2020, Volume 13, Issue 4, p.146-153. http://www.osirjournal.net/index.php/osir/article/download/218/204



出典：感染症研究所疫学情報、20210114

事例	場面	推定感染経路	発生状況	推定感染原因
A	スポーツ関連施設	利用者→利用者	スポーツ関連施設において6名の症例が発生 6名の共通利用日、時間、場所は更衣室だった	・マスク着用なし、換気不良、人が密な空間での会話
B	スポーツ関連施設	利用者→利用者	スポーツ関連施設において3名の症例が発生 3名は更衣室や休憩ラウンジで会話していた。3名のうち1名は利用時に発症していた	・発症後の施設利用 ・マスク着用なしでの会話
C	バーベキュー	参加者→参加者	10名程度が参加し半数以上の症例が発生 調理した料理を大皿から各自取り分けて食事していた	・大皿周囲の人の密集、マスク着用なしでの会話 ・自由に移動することによる複数の人との会話
D	合唱練習	団員→団員	20名程度の合唱団の練習で症例が発生 発症した団員が練習に参加し、近くで練習した団員が感染	・発症後の練習参加 ・換気不良、大人数かつ人が密な空間におけるマスクなしでの発声
E	カラオケ設備のある飲食店	客→従業員 従業員→客	複数の客の症例が発生 別の日に客から感染した従業員が勤務していた 客は席で密集した状態でマスクを着用せず歌っていた 従業員もマスクを着用せず歌う事があった	・換気が悪く人が密集した場所における、マスク着用なしでの発声
F	カラオケ設備のある飲食店	客→客	複数の客の症例が発生 ステージの近くやステージ側を向いた席に着席した客が感染 症状のある客がステージで歌っていた	・人が密集した空間での飲食や会話 ・歌う事で発生した飛沫への曝露

出典：感染症研究所疫学情報、20201212

４．換気と空気浄化による対策

Table 1 Airborne Infectious Disease Engineering Control Strategies: Occupancy Interventions and Their Priority for Application and Research

Strategy	Occupancy Categories Applicable for Consideration*	Application Priority	Research Priority
Dilution ventilation	All	High	Medium
Temperature and humidity	All except 7 and 11	Medium	High
Personalized ventilation	1, 4, 6, 9, 10, 14	Medium	High
Local exhaust	1, 2, 8, 14	Medium	Medium
Central system filtration	All	High	High
Local air filtration	1, 4, 6, 7, 8 10	Medium	High
Upper-room UVGI	1, 2, 3, 5, 6, 8, 9, 14	High	Highest
Duct and air-handler UVGI	1, 2, 3, 4, 5, 6, 8, 9, 14	Medium	Highest
In-room flow regimes	1, 6, 8, 9, 10, 14	High	High
Differential pressurization	1, 2, 7, 8 11, 14	High	High

Note: In practical application, a combination of the individual interventions will be more effective than any single one in isolation.
*Occupancy Categories:
1. Health care (residential and outpatient)
2. Correctional facilities
3. Educational < age 8
4. Educational > age 8
5. Food and beverage
6. Internet café/game rooms
7. Hotel, motel, dormitory
8. Residential shelters
9. Public assembly and waiting
10. Transportation conveyances
11. Residential multifamily
12. Retail
13. Sports
14. Laboratories where infectious diseases vectors are handled

出典
ASHRAE Position Document on Airborne Infectious Diseases_2020

Table A.1 comparison of the main strategies

	ASHRAE	REHVA	SHASE	[illegible]
Outdoor air	[illegible]	[illegible]	[illegible]	[illegible]
Operation of HVAC systems	[illegible]	[illegible]	[illegible]	[illegible]
Temperature and humidity setpoint	[illegible]	[illegible]	[illegible]	[illegible]
Pressure differential	[illegible]	[illegible]	[illegible]	[illegible]
Filters equipped in the HVAC system	[illegible]	[illegible]	[illegible]	[illegible]
Air cleaning	[illegible]	[illegible]	[illegible]	[illegible]
Heat recovery equipment	[illegible]	[illegible]	[illegible]	[illegible]
Others	[illegible]	[illegible]	[illegible]	[illegible]

Guo M., et al. Review and comparison of HVAC operation guidelines in different countries during the COVID-19 pandemic. *Building and Environment.* 2020. https://doi.org/10.1016/j.buildenv.2020.107368


～ 商業施設等の管理権原者の皆さまへ ～

「換気の悪い密閉空間」を改善するための換気の方法

専門家検討会の見解（抄）

推奨される換気の方法

① 機械換気(空気調和設備、機械換気設備)による方法

空気清浄機を使用する際の留意点

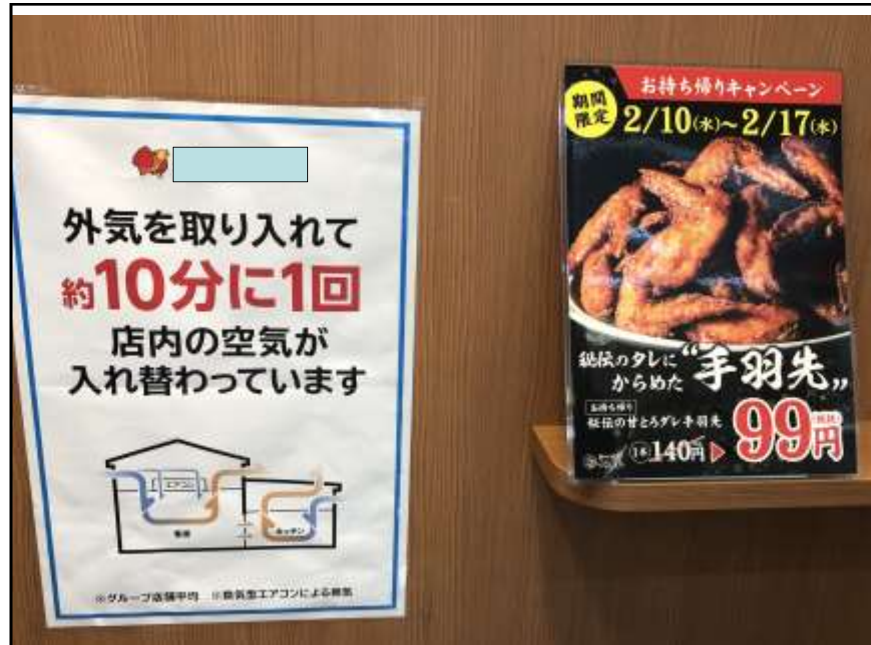
② 機械換気(空気調和設備、機械換気設備)による方法

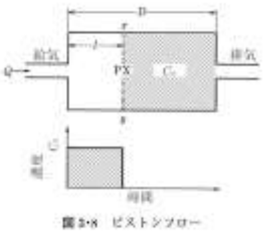
（一人あたり毎時30m³）

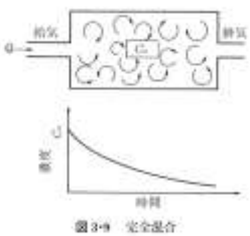
参考

厚生労働省：2020年4月3日

厚生労働省：2020年11月27日







(1)ピストンフロー

気流はピストンのように動き、混合せずに、その前にある古い空気を押し出すので、もっとも換気の効率がよい。

出典：空気調和・衛生工学会：空気調和・衛生工学便覧第14 版，3 空気調和設備設計，2010

（２)完全混合

完全混合では、濃度は時間的に上図のように減衰するするが、室内全ての点の値が等しい。
この方式はもっとも一般的な換気方式である。実際の場合、気流の滞留域が生じ、完全混合にはならないケースは殆どである。

換気回数＝換気量÷室容積

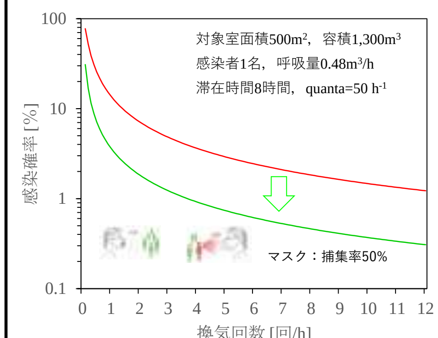
混合型換気の環境（一般環境）であれば、指数関数で減衰するので、理論的に室内に永久的に古い空気が残る。

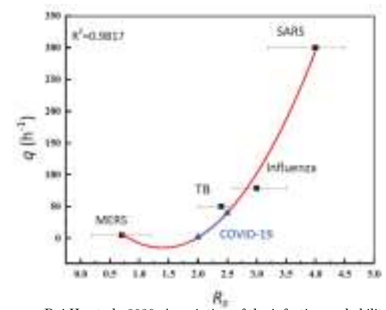
Wells-Rileyモデル

$$P_I = \frac{C}{S} = 1 - e^{-\frac{Iqpt}{Q}}$$

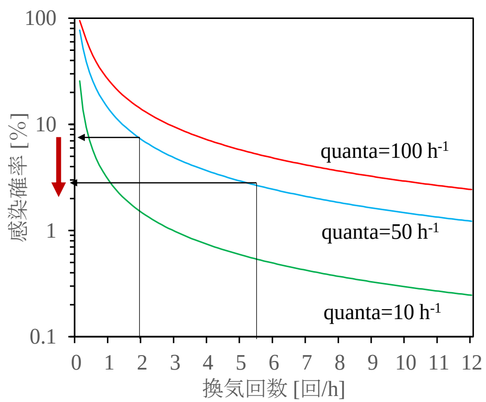
P_I：感染確率 [-]
C：新たな感染者数 [人]
S：感受者宿主数 [人]
I：感染者数 [人]
Q：室換気量 [m3/s]
q：発生量 [quanta/s]
p：一人当たり呼吸量 [m^3/(人・s)]
t：曝露時間 [s]

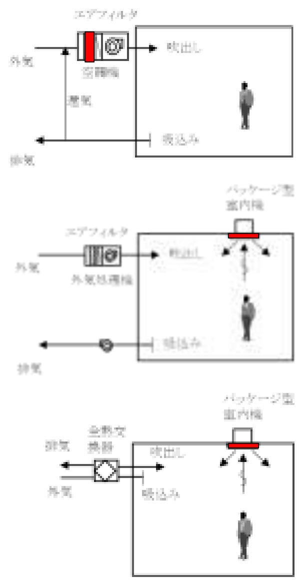
換気が一定で室内の空気が完全混合の状態の場合，肺結核の空気感染の確率がポアソン分布に従う。閉鎖空間では1 quantaの感染核を各被感染者が吸入した場合に平均的63.2%（$1-e^{-1}$）が感染し，上記により感染リスク（確率）が推定可能であるとしている。



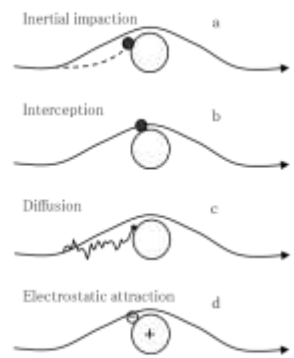


Dai H., et al., 2020. Association of the infection probability of COVID-19 with ventilation rates in confined spaces. *BUILD SIMUL* https://doi.org/10.1007/s12273-020-0703-5





Source
Kenichi A, Yanagi U, et al., 2020. Environmental factors involving in SARS-CoV-2 transmission: Effect and role of indoor environmental quality control in strategy for COVID-19 infection control. Health and Preventive Medicine (Accepted, October 24, 2020)



エアフィルタの捕集原理
a 慣性衝突 b さえぎり c 拡散 b 静電気

粗塵用

中高性能

高性能

引用：日本無機の医薬品製造施設用カタログ,（2018）

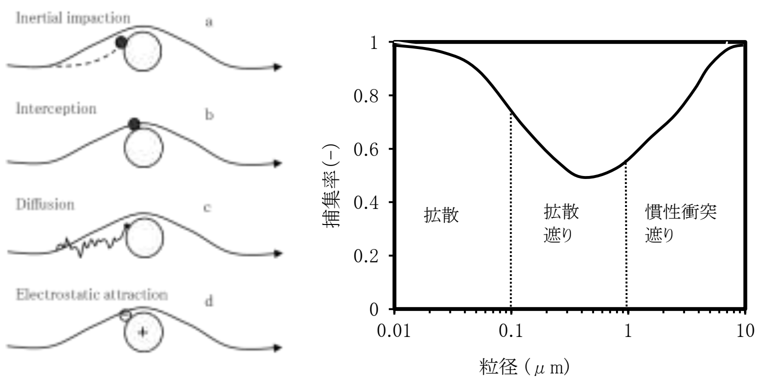


表１　海外規格の捕集率の比較表（表中の数値はクラスにおける捕集率下限を表す、単位%）

ASHRAE52.2：2012, 2017					EN779：2012				ISO16890：2016			
MERV	E1(0.3-1.0)	E2(1.0-3.0)	E3(3.0-10)	E(質量)	クラス	E(0.4)		E(質量)	ePM_1, min	$ePM_{2.5}$, min	ePM_{10}	グループ
	0.55μm	1.73μm	5.48μm	平均		平均	最小	平均	除電後		[illegible]	
1				<65	G1			50				ISO Coarse
2				65	G2			65				ISO Coarse
3				70	G2			65				ISO Coarse
4				75	G2			65				ISO Coarse
5			20		G3			80				ISO Coarse
6			35		G3			80				ISO Coarse
7			50		G4			90				ISO Coarse
8		20	70		G4			90				ISO Coarse
9		35	75		M5	40					46	ISOePM10
10		50	80		M5	40				20	53	ISOePM10
11	20	65	85		M6	60				33	63	ISOePM10
12	35	80	90		M6	60				46	73	ISOePM2.5
13	50	85	90		F7	80	35		47	58	78	ISOePM1
14	75	90	95		F8	90	55		71	77	88	ISOePM1
15	85	90	95		F9	95	70		80	83	90	ISOePM1
16	95	95	95		−	−			92	93	94	ISOePM1

出典：大垣豊. 各国の一般換気用エアフィルタの規格にける捕集率の比較に関する指針（JACA No.53）, 空気清浄. 2018;56(1):36-40

表２　ASHRAEとJIS規格の捕集率の比較（表中の数値はクラスにおける捕集率下限を表す、単位%）

ASHRAE52.2	JISB9908：2018				JISB9908：2011（非エレクトレット）					同：2001
MERV	ePM₁ min	ePM₂.₅ min	ePM10	グループ	E(0.4)	E(0.7)	E(2.5)	E(4.0)	E(質量)	E(比色)
	除電後		初期除電後平均		初期				平均	平均
1				初期質量捕集率					＜65	
2									65	
3									70	
4									75	
5								10	80	
6								25	80	
7								40	90	40
8							20	60	90	40
9							35	65		50
10			45				60	75		50
11		36	55	PM10捕集率		30	70	80		60
12		49	65	PM2.5捕集率	20	50	85	90		75
13	49	61	73		40	60	88	90		90
14	72	78	85	PM1捕集率	65	80	92	95		95
15	81	84	88		80	85	92	95		98
16	92	93	94		90	95	95	95		－

出典：大垣豊. 各国の一般換気用エアフィルタの規格にける捕集率の比較に関する指針（JACA No.53）， 空気清浄. 2018;56(1):36-40

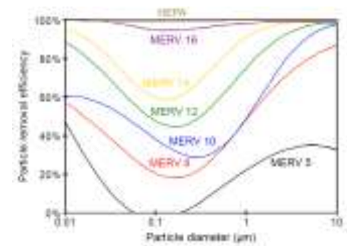


Table 6. Droplet nuclei particle removal rates [illegible] for a range of MERV filters for use in modelling risk inside the school classroom with a recirculation rate of [illegible] per hour

MERV	Droplet nuclei removal efficiency [illegible]	Assumed filter removal rate [illegible]
4	[illegible]	[illegible]
7	[illegible]	[illegible]
11	[illegible]	5.84
13	87%	7.08
14	[illegible]	7.20
15	[illegible]	7.33
16	95%	7.55
HEPA	[illegible]	[illegible]

MERV	0.3-1.0 μm	1.0-3.0 μm	3.0-10 μm
1	n/a	n/a	$E_3<20$
2	n/a	n/a	$E_3<20$
3	n/a	n/a	$E_3<20$
4	n/a	n/a	$E_3<20$
5	n/a	n/a	$20\leqq E_3$
6	n/a	n/a	$35\leqq E_3$
7	n/a	n/a	$50\leqq E_3$
8	n/a	$20\leqq E_2$	$70\leqq E_3$
9	n/a	$35\leqq E_2$	$75\leqq E_3$
10	n/a	$50\leqq E_2$	$80\leqq E_3$
11	$20\leqq E_1$	$65\leqq E_2$	$85\leqq E_3$
12	$35\leqq E_1$	$80\leqq E_2$	$90\leqq E_3$
13	$50\leqq E_1$	$85\leqq E_2$	$90\leqq E_3$
14	$75\leqq E_1$	$90\leqq E_2$	$95\leqq E_3$
15	$85\leqq E_1$	$90\leqq E_2$	$95\leqq E_3$
16	$95\leqq E_1$	$95\leqq E_2$	$95\leqq E_3$

n/a: not available

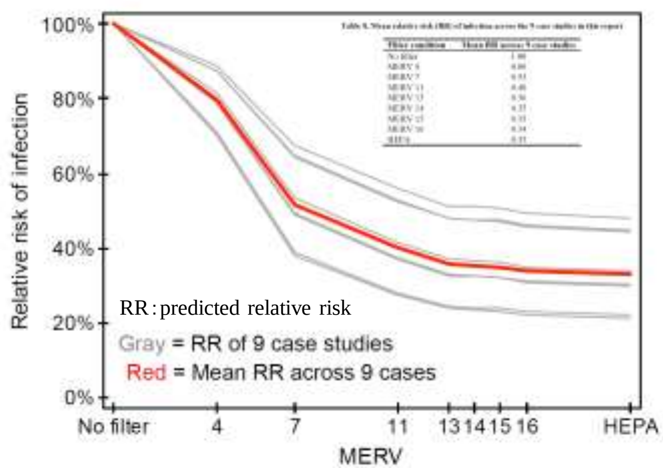


Figure 15. Relative risk of infection across the 9 case studies and 9 levels of HVAC filtration

Source:
The National Air Filtration Association (NAFA) Foundation, 2012. HVAC filtration and the Wells-Riley approach to assessing risks of infectious airborne diseases - Final Report.

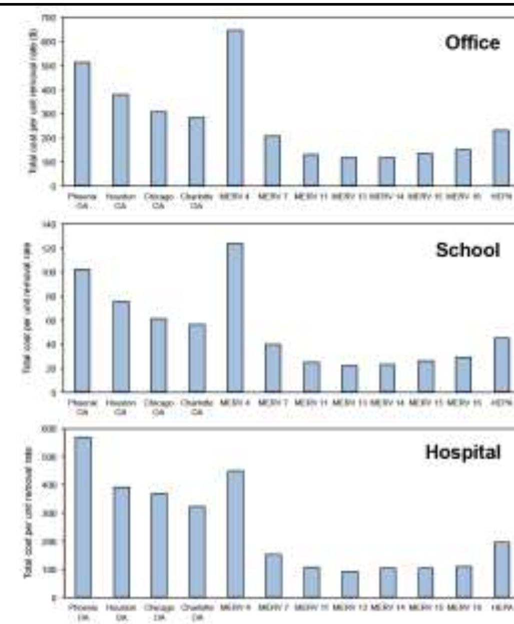


Figure 20. Total annual cost per unit removal rate ($ per 1/hr) of outdoor air ventilation and HVAC filtration products in each of the three hypothetical case study environments

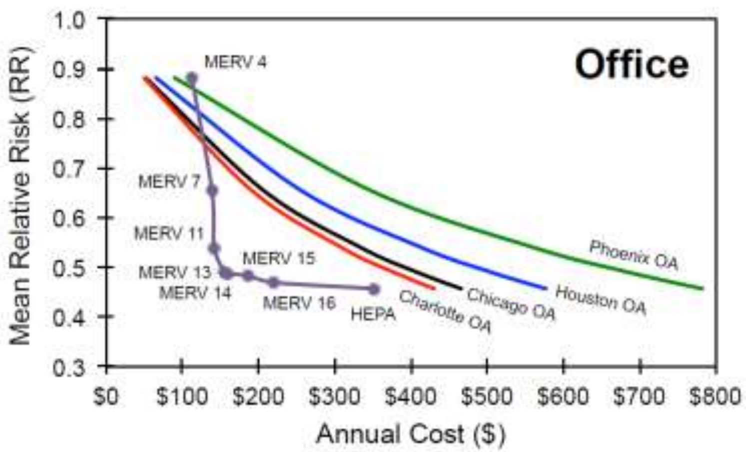
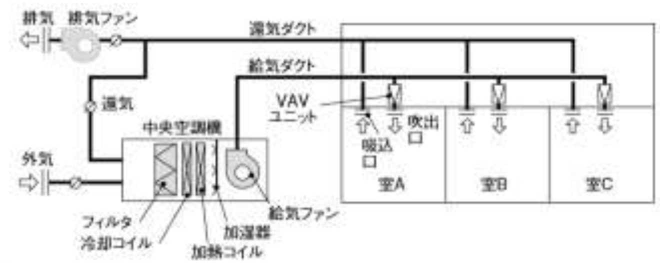


Figure 21. Relative risk (RR) of infectious disease transmission across the three diseases in the office environment with both HVAC filtration and "equivalent" outdoor air ventilation rates. Note that lower costs and lower risks (both beneficial) lie in the bottom left corner of the graph.



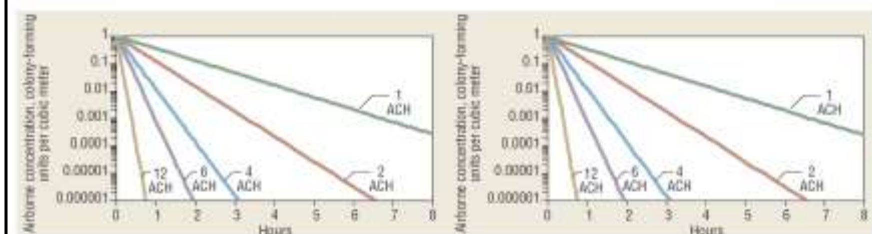


FIGURE 2. The effect of filtered-OA ACH on an initial level of airborne microbial contamination over an 8-hr period (left) and the effect of HEPA 99.97-percent filtration on recirculated air (right).

Source
Kowalski, 2007. Hospital-Acquired Infections. January 2007 • HPAC Engineering

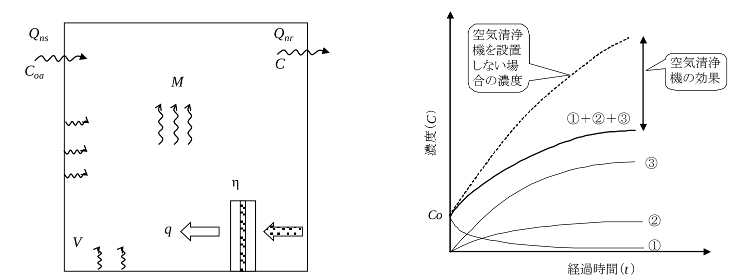
方　　式	構　成　例	備　　考
機　械　式	①　②　③	① プレフィルタ ② 主フィルタ ③ ファン ④ イオン荷電部 ⑤ 静電フィルタ ⑥ 活性炭または多孔質無機物質吸着剤 ⑦ ケミカルフィルタ ⑧ 光触媒フィルタ ⑨ バイオフィルタ
電　気　式	①　④　⑤　③	
物理吸着式	①　⑥　③	
化学吸着式	①　⑦　③	
複　合　式	①　④　⑤　⑧　⑨　③	

出典
柳　宇：小型空気清浄機，空気清浄協会編「室内空気清浄便覧」，pp.239-245，オーム社出版，2000

感染性エアロゾルの対策において、補助設備として空気清浄機の利用がアメリカCDC，REHVA，ASHRAE、厚生労働省、空気調和衛生工学会などより推奨されている。

消費者庁は2020年3月10日「新型コロナウイルスに対する予防効果を標ぼうする商品の表示に関する改善要請等及び一般消費者への注意喚起」においてマイナスイオン発生器，イオン空気清浄機に対して，当該表示を行っている事業者等に対し，緊急的に改善要請等を行っている。

空気清浄機の浄化性能 ー$q\eta$

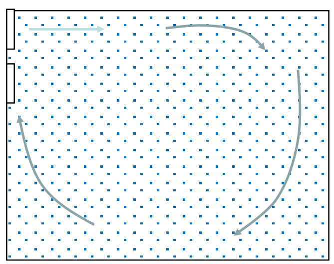


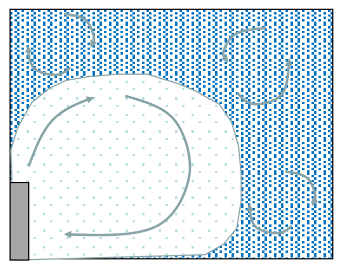
$$C = Coe^{-\left(\frac{q\eta}{V}+\frac{Qnr}{V}\right)t} + \frac{QnsCoa}{q\eta+Qnr}\left[1-e^{-\left(\frac{q\eta}{V}+\frac{Qnr}{V}\right)t}\right] + \frac{M}{q\eta+Qnr}\left[1-e^{-\left(\frac{q\eta}{V}+\frac{Qnr}{V}\right)t}\right]$$

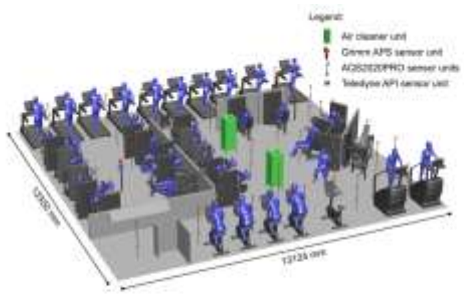
①　②　③

M：室内汚染発生量 [mg/h]
V：室容積 [m^3]
Q_{oa}：自然給気量 [m^3/h]
Q_{nr}：自然排気量 [m^3/h]
C：室内汚染物質濃度 [mg/m^3]
C_{ns}：外気中汚染物質濃度
C_o：室内初期汚染物質濃度 [mg/m^3]
η：空気清浄機捕集率 [–]
t：経過時間 [h]

出典
日本空気清浄協会編：室内空気清浄便覧、p.242、オーム社、2000







床面積175m^2、容積886m^3
換気回数は2.2回/h
1台の空気清浄機の相当換気回数は1.39回/hで単独使用：30分間のAerosol濃度上昇抑制できない。
換気と空気清浄機を併用：80～90%↓

Source:
Blocken B, et al, 2021. Ventilation and air cleaning to limit aerosol particle concentrations in a gym during the COVID-19 pandemic. *Building and Environment*, Volume 193, 15 April 2021, 107659.

空気清浄機の適用床面積

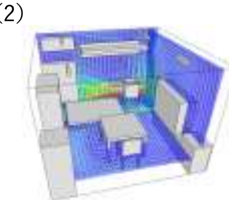
ここでは、空気清浄機を作動させてから１時間後、室内濃度は定常状態（ここでは、理論的な定常濃度の95%になる濃度とし、その時点での室内状態を定常状態と見なす）になることを目標とする。仮に、自然換気量$Q_{ns}=Q_{nr}=0$、室内初期濃度$C_o=0$とすると、式（1）より式(2)と式（3）が得られる。qの単位はm^3/minである。仮に天井高が2.6mとすると、式（3）は式（4）になる(図)。

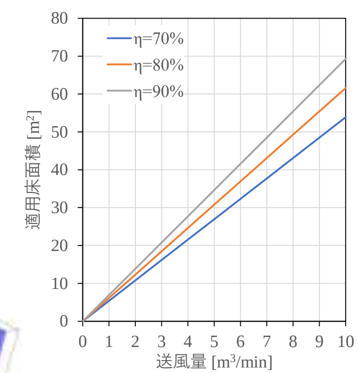
$$C=Coe^{-(\frac{q\eta}{V}+\frac{Qnr}{V})t}+\frac{QnsCoa}{q\eta+Qnr}\left[1-e^{-(\frac{q\eta}{V}+\frac{Qnr}{V})t}\right]+\frac{M}{q\eta+Qnr}\left[1-e^{-(\frac{q\eta}{V}+\frac{Qnr}{V})t}\right] \quad (1)$$

$$1-e^{-\frac{q\eta}{V}\times 60}=0.95 \quad (2)$$

$$V=20q\eta \quad (3)$$

$$A=7.7q\eta \quad (4)$$

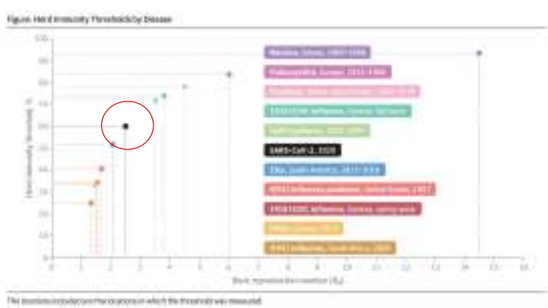




出典：柳宇、小型空気清浄機、空気清浄便覧、オーム社、2000

まとめ

1. COVID-19の主な感染経路は大きな飛沫感染であるとされているが、最近ではLong-rangeのエアロゾル感染の事例報告が増えている。
2. 換気は有効な手段である。
3. フィルタによるウイルスを含めた粒子状物質のろ過は有効である。
4. 換気とフィルタのろ過によるバランスの取れた総合的な対策が有効である



SARS-CoV-2のR_0値は2～3
集団免疫閾値は50～67%
（集団免疫閾値＝100×(1-1/R_0)）

現在日本人の感染者数は約37万人で、人口の1.26億人
感染率0.3%

ワクチンが普及するまで、ウイズコロナ時代はしばらく続く

Source
Herd Immunity and Implications for SARS-CoV-2 Control. JAMA Published online October 19, 2020.