

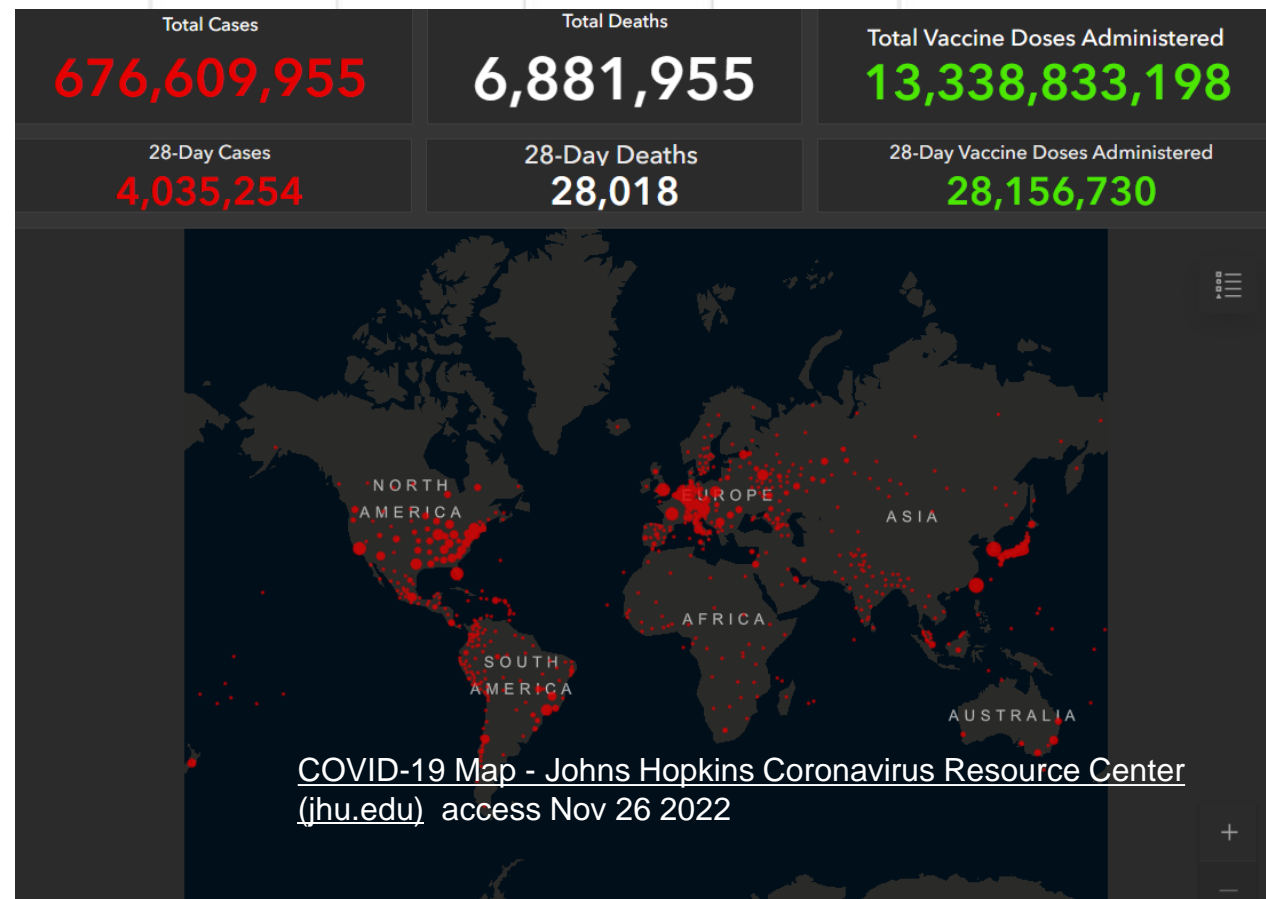
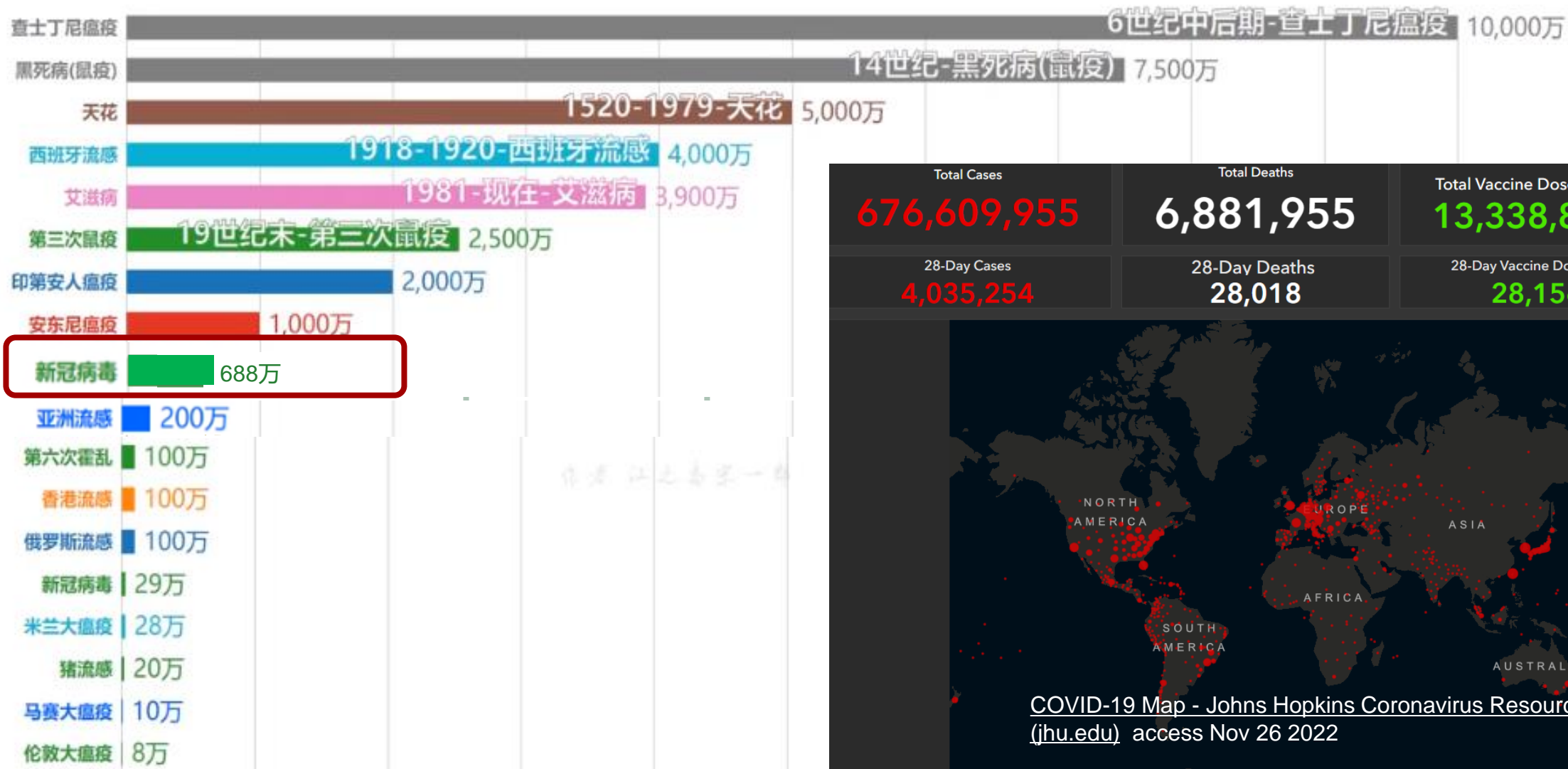
室内环境控制呼吸道传染病进展及 展望

钱华
东南大学



Indoor Environment &
Thermal science Lab

呼吸道传染病的爆发给人类造成了巨大的灾难



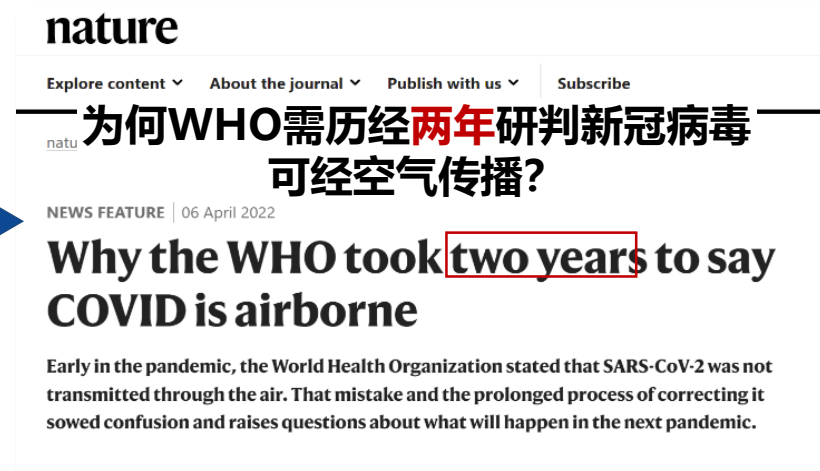
面临挑战

(1) 呼吸道传染病传播机制不清

生物气溶胶在非定常非均匀流场中相变、迁移和凋亡过程复杂，加上伦理要求等问题导致传播过程**无法实验复现**，从而传播途径确定困难，传播机制不清。



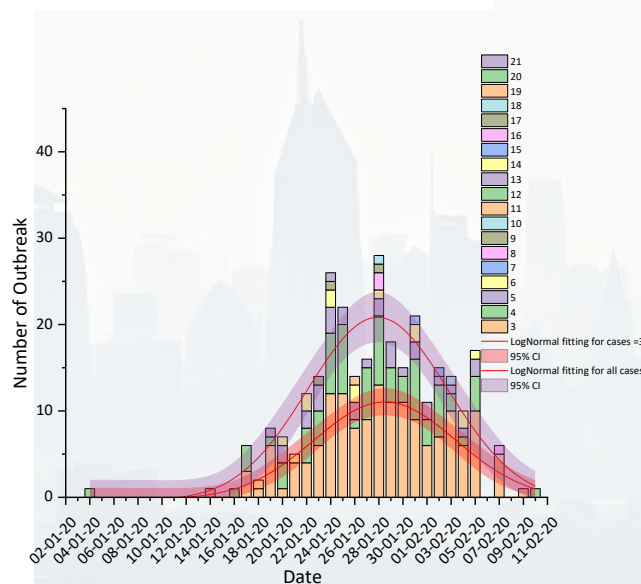
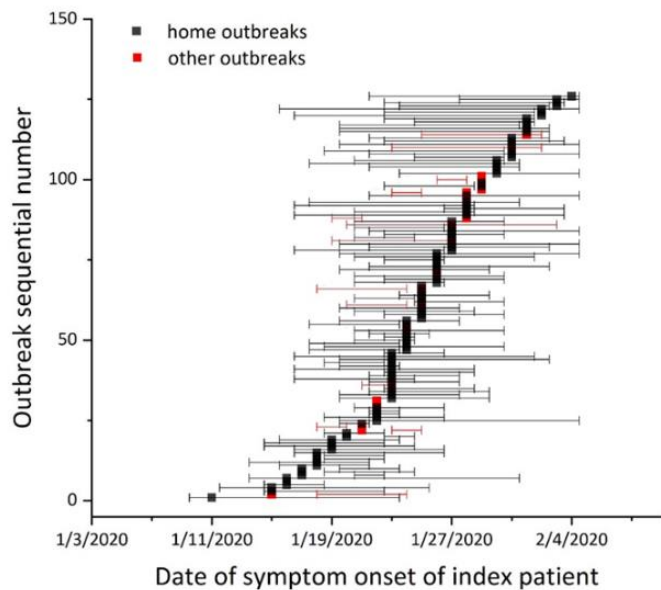
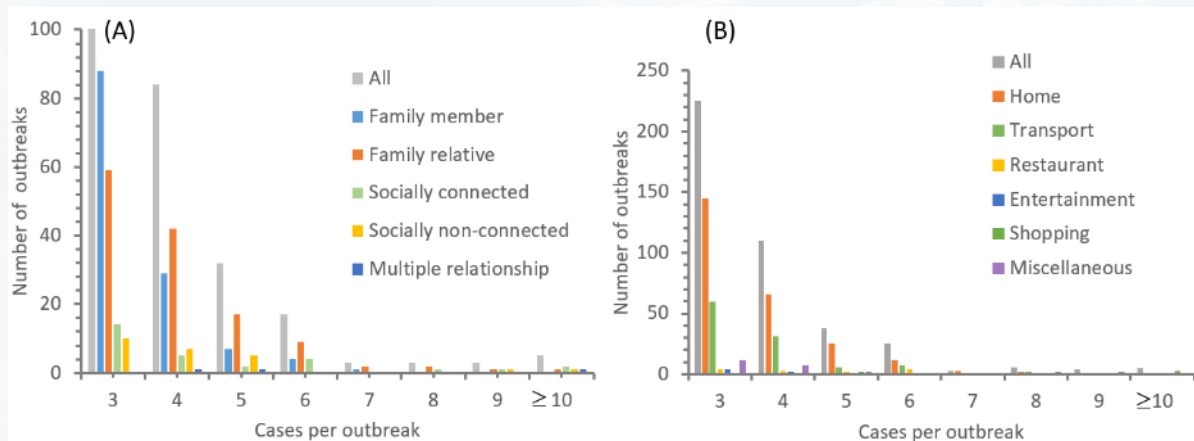
2020年3月WHO发文否定新冠病毒空气传播



2022年4月WHO研判认为病毒空气传播

呼吸道传染病是如何传播的？

室内新冠传播规律



通过网络抓取了2020年2月11日之前，7324个非湖北数据传播数据，分析了其中涉及3人以上的爆发318例，涉及到120个城市1245起感染。

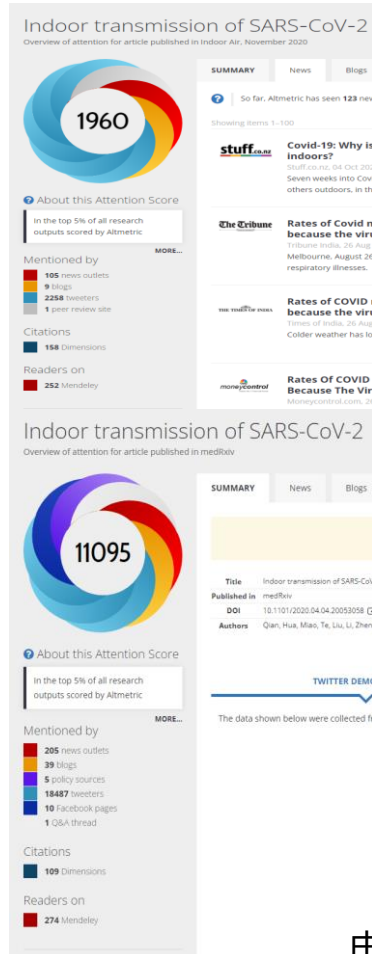
发现：

7324例里面仅1例 发生在室外，室内环境占主导因素

家庭为主要因素

大的爆发都发生在通风不良的拥挤室内环境

国际媒体报道



The New York Times **A Misleading C.D.C. Number**
New York Times, 11 May 2021
The Morning Newsletter We have a special edition of the newsletter on a misleading C.D.C.

FOX NEWS **More liberal voices criticize media's 'panic porn' coronavirus coverage, shaming about outdoor gatherings**
FOX News, 19 Apr 2021
Some of the most blaring examples of the press scolding on outdoor gathering and mask-wearing during the coronavirus pandemic...

Yet, as Maher said in his monologue on Friday, "it's increasingly looking like the beach is the best place to avoid" coronavirus. One study in China found that out of 7324 identified cases in China with sufficient descriptions, only one outdoor outbreak involving two cases occurred in a village in Shaogou, Henan. Throughout the pandemic, the Centers for Disease Control and Prevention have noted it's far safer to interact with people outdoors than indoors.

福克斯新闻和科学美国人均以申请人研究结果举证了新冠主要在室内传播

SCIENTIFIC AMERICAN **So. What Can People Actually Do after Being Vaccinated?**
Scientific American, 11 Mar 2021
The first raft of stories in the wake of the Biden administrations dramatic acceleration of the COVID-19 vaccine rollout in the... distancing and ventilation needs duly observed. That, for some experts, is a threshold they're reluctant to cross because of viral spread issues indoors. Paul Griffin, an infectious disease specialist at the University of

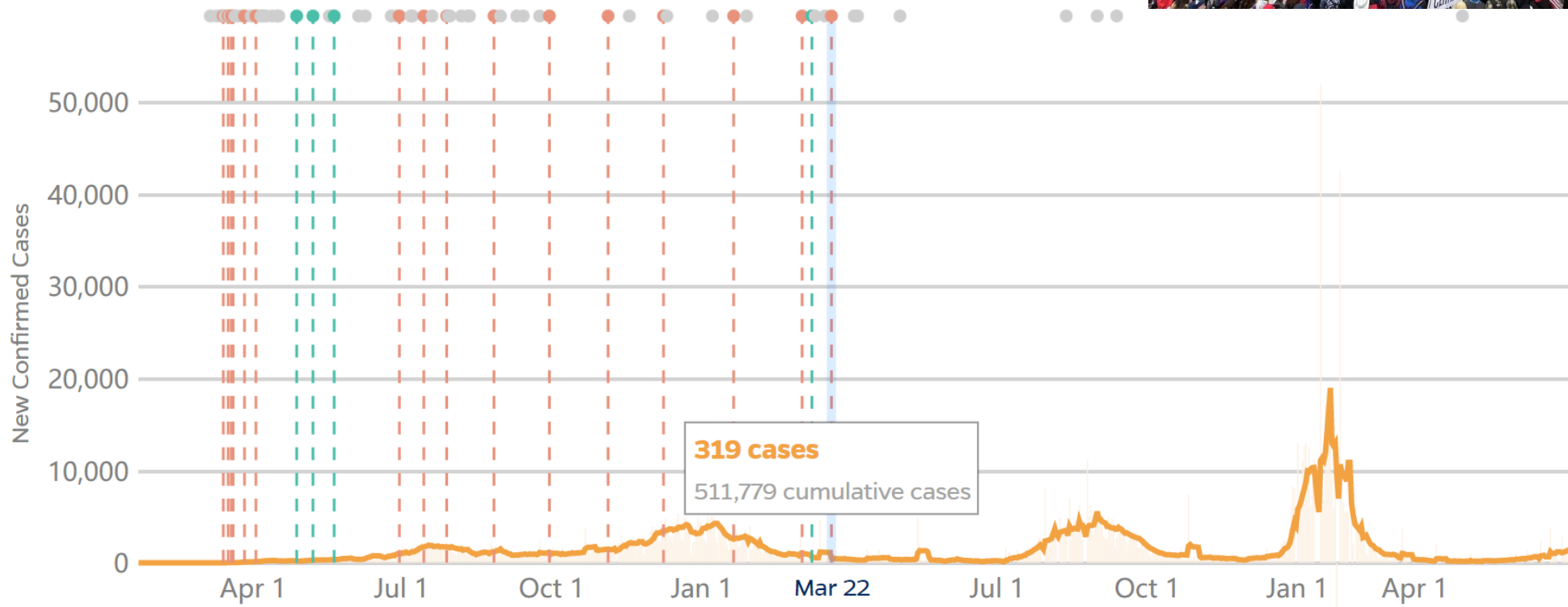
CNN **El covid-19 se contagia por el contacto de aerosoles con los ojos, boca y nariz, según OMS**
CNN News, 04 May 2021
Científicos ya han establecido que el covid-19 se transmite a través de los aerosoles.

Los brotes y los espacios cerrados
En otro estudio, esta vez publicado en la revista *Indoor Air* de mayo del 2021, un grupo de investigadores chinos estudió 318 brotes que produjeron 1.245 casos confirmados de covid-19 en 120 ciudades de China.

- La ubicación de los brotes fue clasificada en seis categorías:
- hogares,
 - transporte,
 - restaurantes,
 - entretenimiento,
 - compras y otros.

西班牙版CNN具体介绍了申请人研究的结论

申请人研究成果Indoor transmission of SARS-CoV-2 被全球包括纽约时报、福克斯新闻、科学美国人、CNN等超过**300家**媒体报道，预印本及发表后论文累积Altmetric影响系数接近**13000**



OSHA recognizes that outdoor transmission has been identified in a few specific incidents (*e.g.* , 2 of 7,324 cases, Qian et al., October 27, 2020). However, general reviews of transmission studies that include large-scale and high-density outdoor gatherings indicate that indoor transmission overwhelmingly is responsible for SARS-CoV-2 transmission. Additionally, the lack of evidence tied to specific case studies illustrating outdoor transmission in comparison to the bevy of case studies on indoor transmission makes it difficult to support a conclusion that outdoor transmission rises to the level of a grave danger.



FEDERAL REGISTER

The Daily Journal of the United States Government



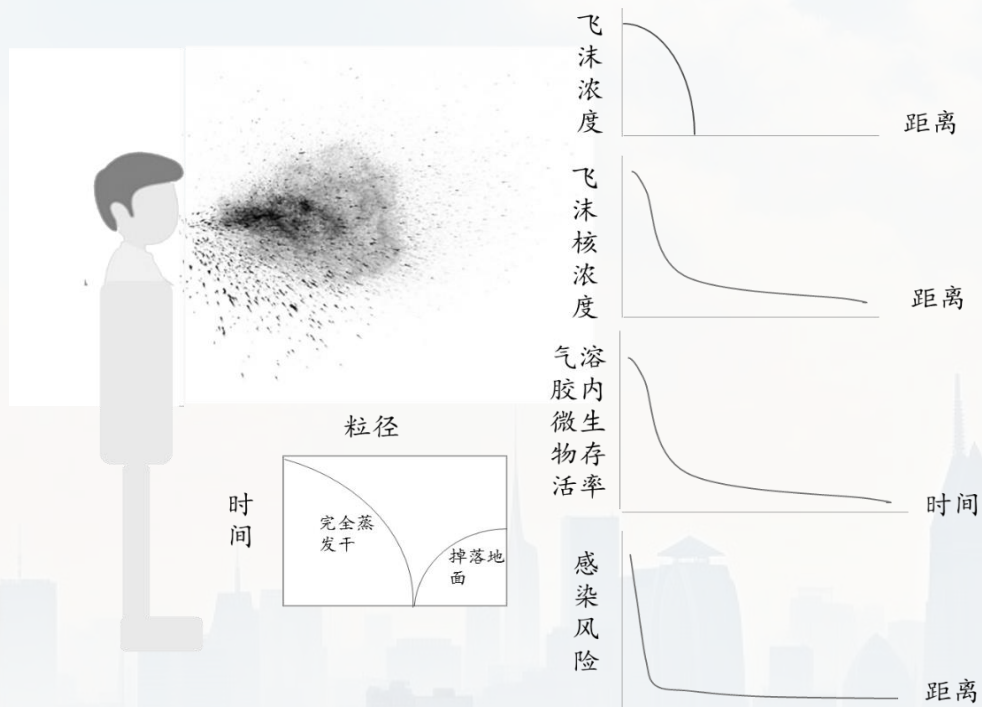
Ⓜ Rule

COVID-19 Vaccination and Testing; Emergency Temporary Standard

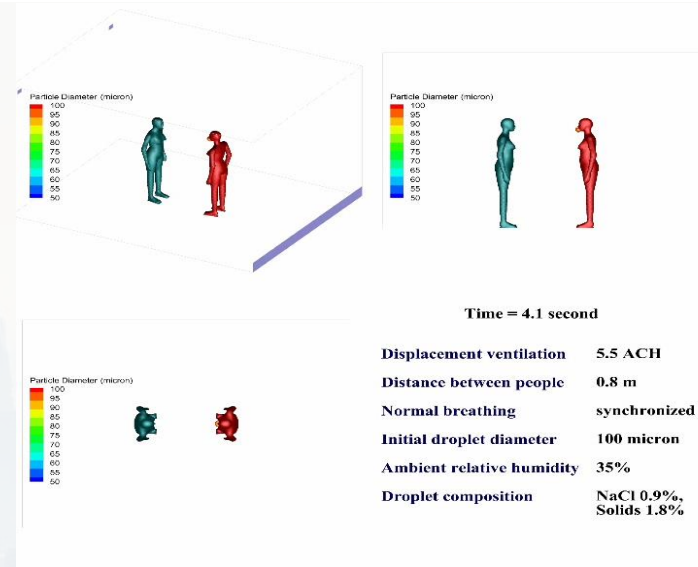
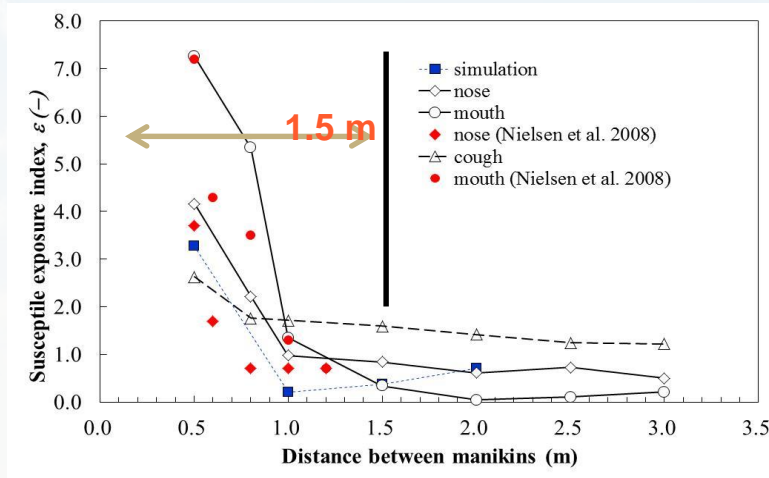


- 为什么室外爆发例子低?

风险和距离关系



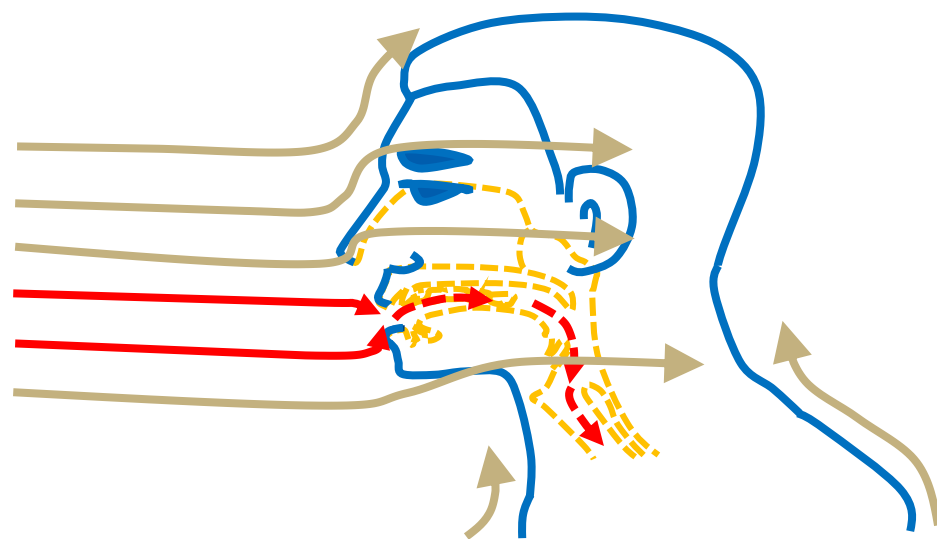
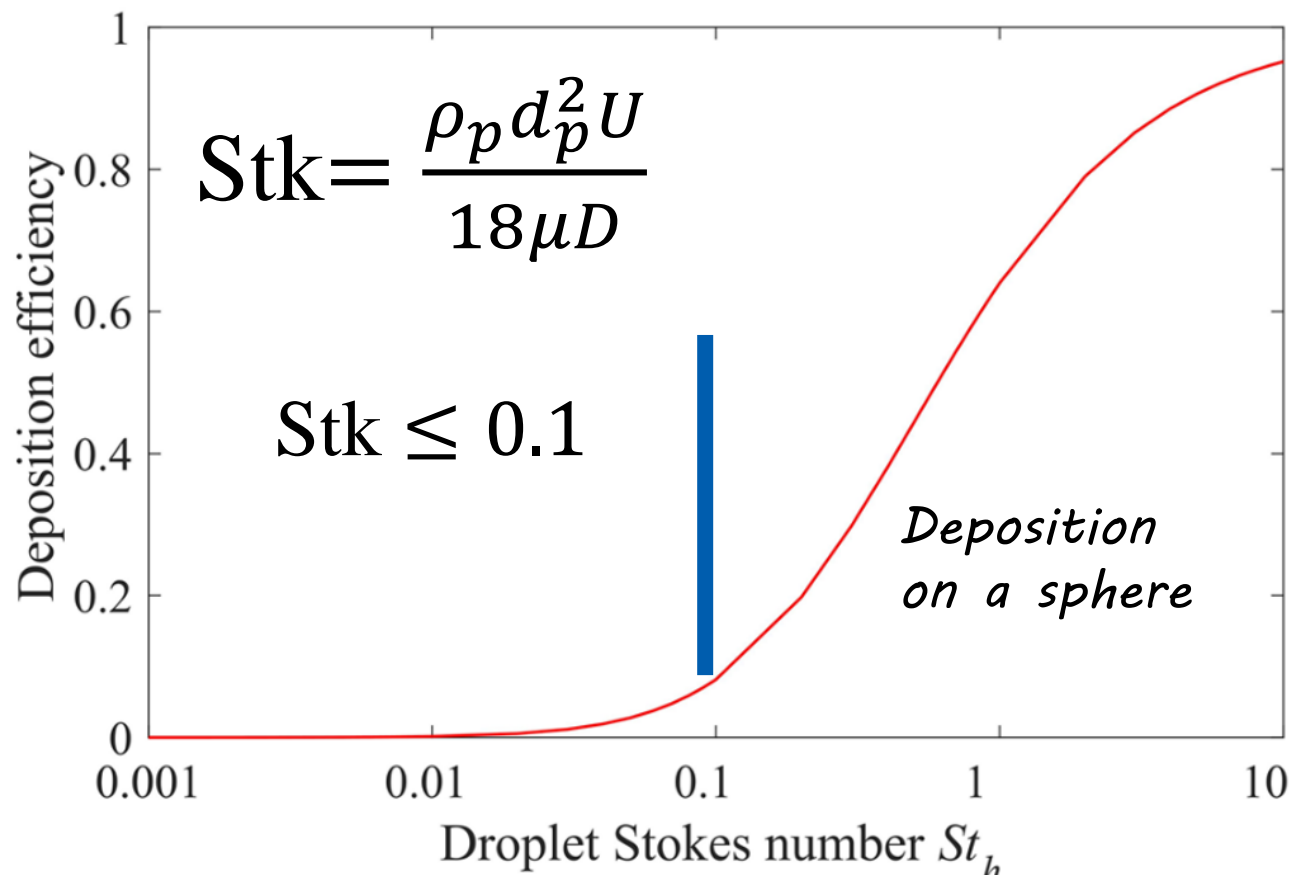
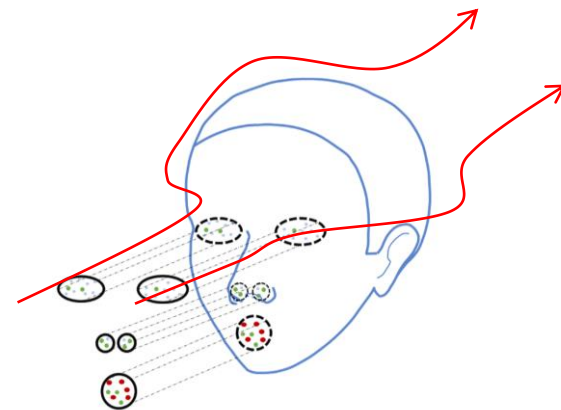
钱华等, 科学通报 (2017)

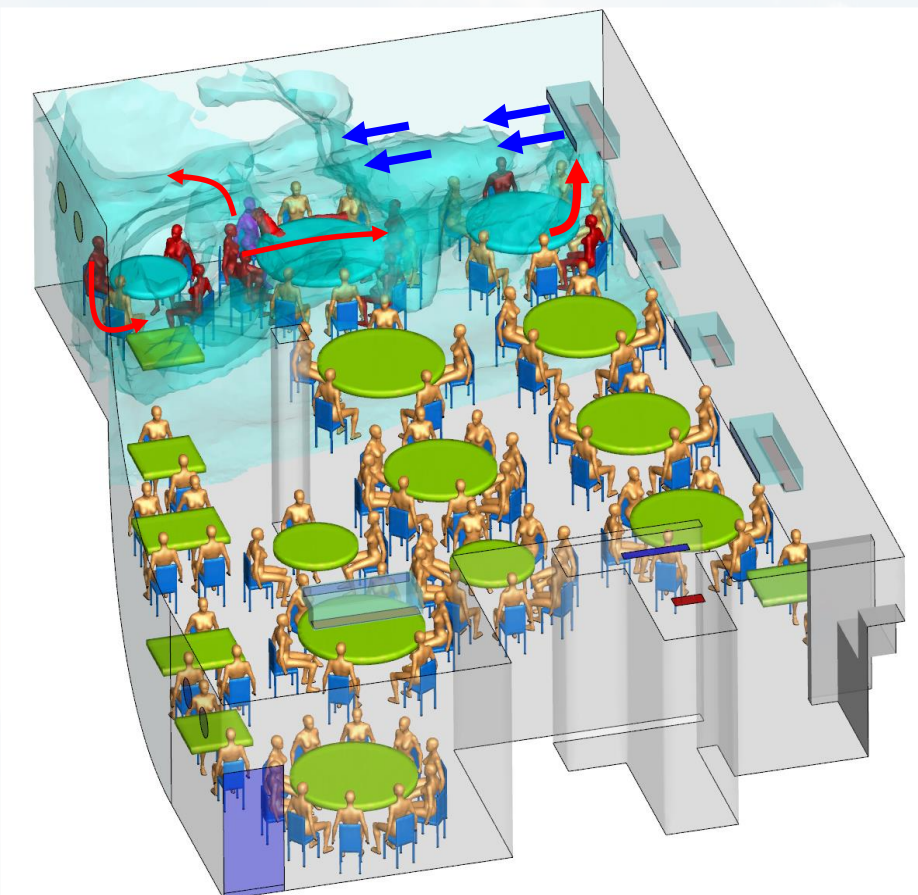


Liu L. et al (2017). *Indoor air*, 27:452-462.

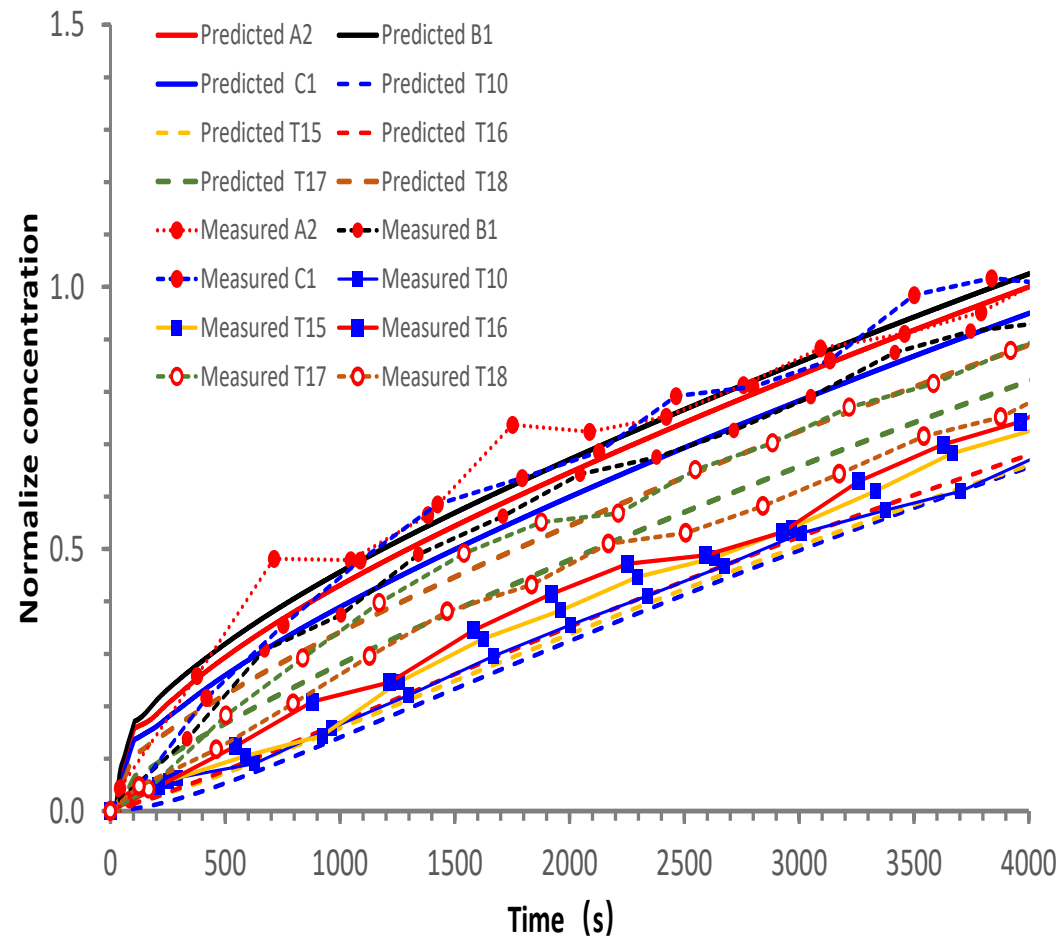
飞沫暴露很小，近距离吸入为主

Only >50-100 microns can deposit on face (1m), and much less on noses, mouth and eyes. Small ones follow airflow.

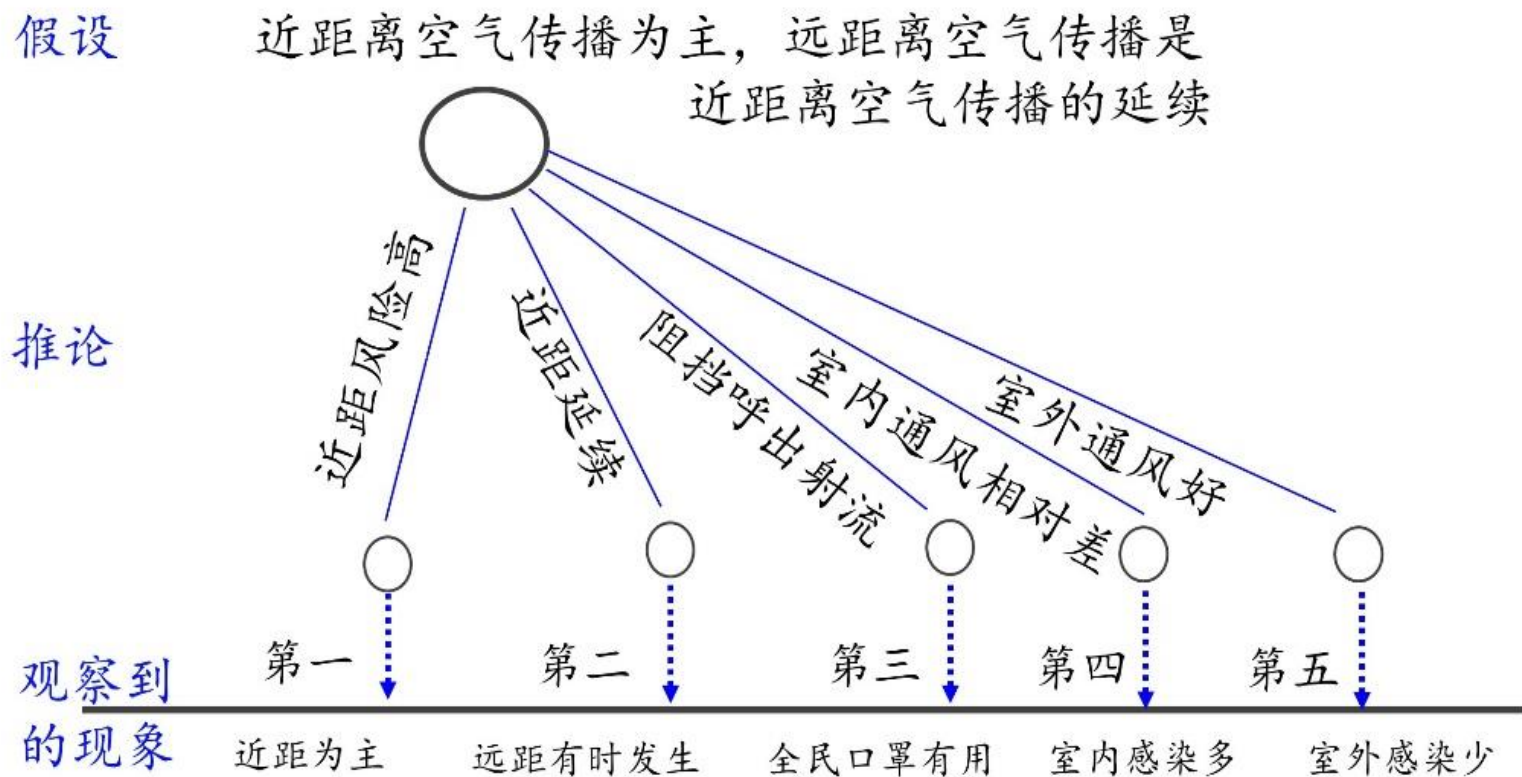




现场测量+CFD模拟揭示了新冠在通风不良环境的传播途径



Y Li, H Qian, J Hang, X Chen, L Hong, P Liang, J Li... - Building and environment 2020



李玉国，程盼，钱华：新型冠状病毒的主要传播途径及其对室内环境设计的影响，科学通报 2021



Bobby and his dad are protected when they stay home.

They keep protecting themselves when they are outside of their house.

Be like Bobby and his dad

-  **stay 6 feet apart**
-  **wash your hands**
-  **wear a mask**
-  **avoid crowds**

cdc.gov/coronavirus



321769 1/13/2020

Inhalation of air carrying very small fine droplets and aerosol particles that contain infectious virus. Risk of transmission is greatest within three to six feet of an infectious source where the concentration of these very fine droplets and particles is greatest.

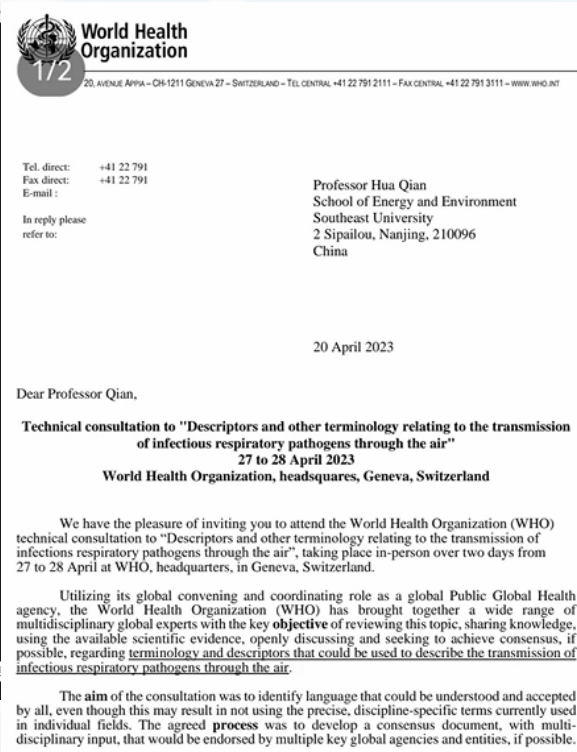
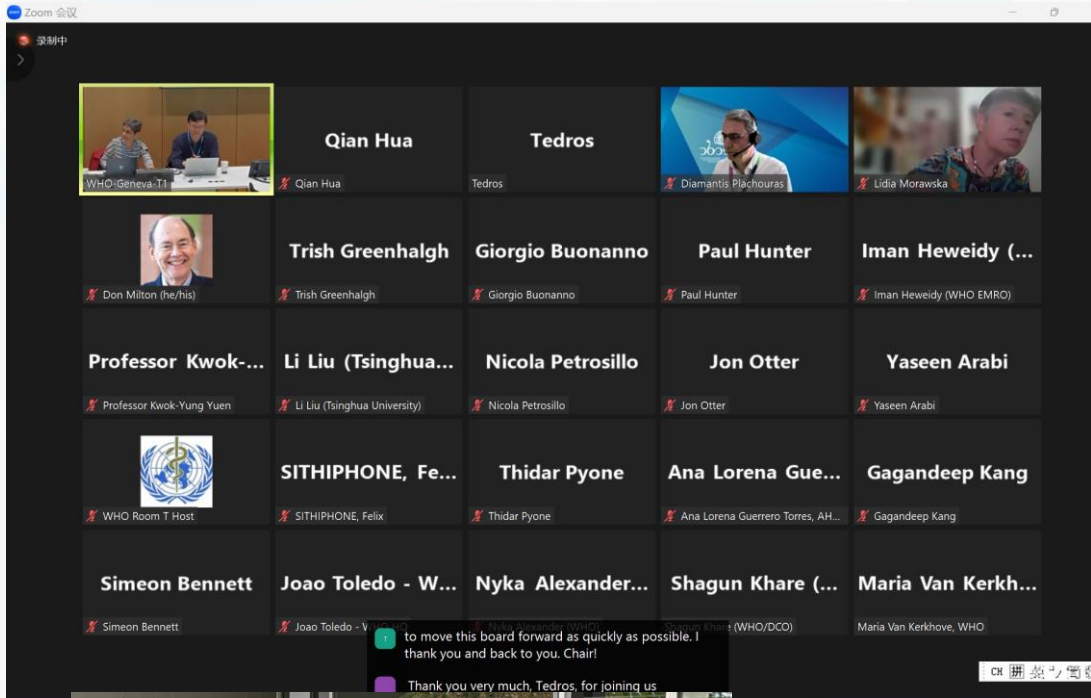
Deposition of virus carried in exhaled droplets and particles onto exposed mucous membranes (i.e., “splashes and sprays”, such as being coughed on). Risk of transmission is likewise greatest close to an infectious source where the concentration of these exhaled droplets and particles is greatest.

Touching mucous membranes with hands soiled by exhaled respiratory fluids containing virus or from touching inanimate surfaces contaminated with virus

Scientific Brief: SARS-CoV-2 Transmission

USA CDC

世卫组织认可



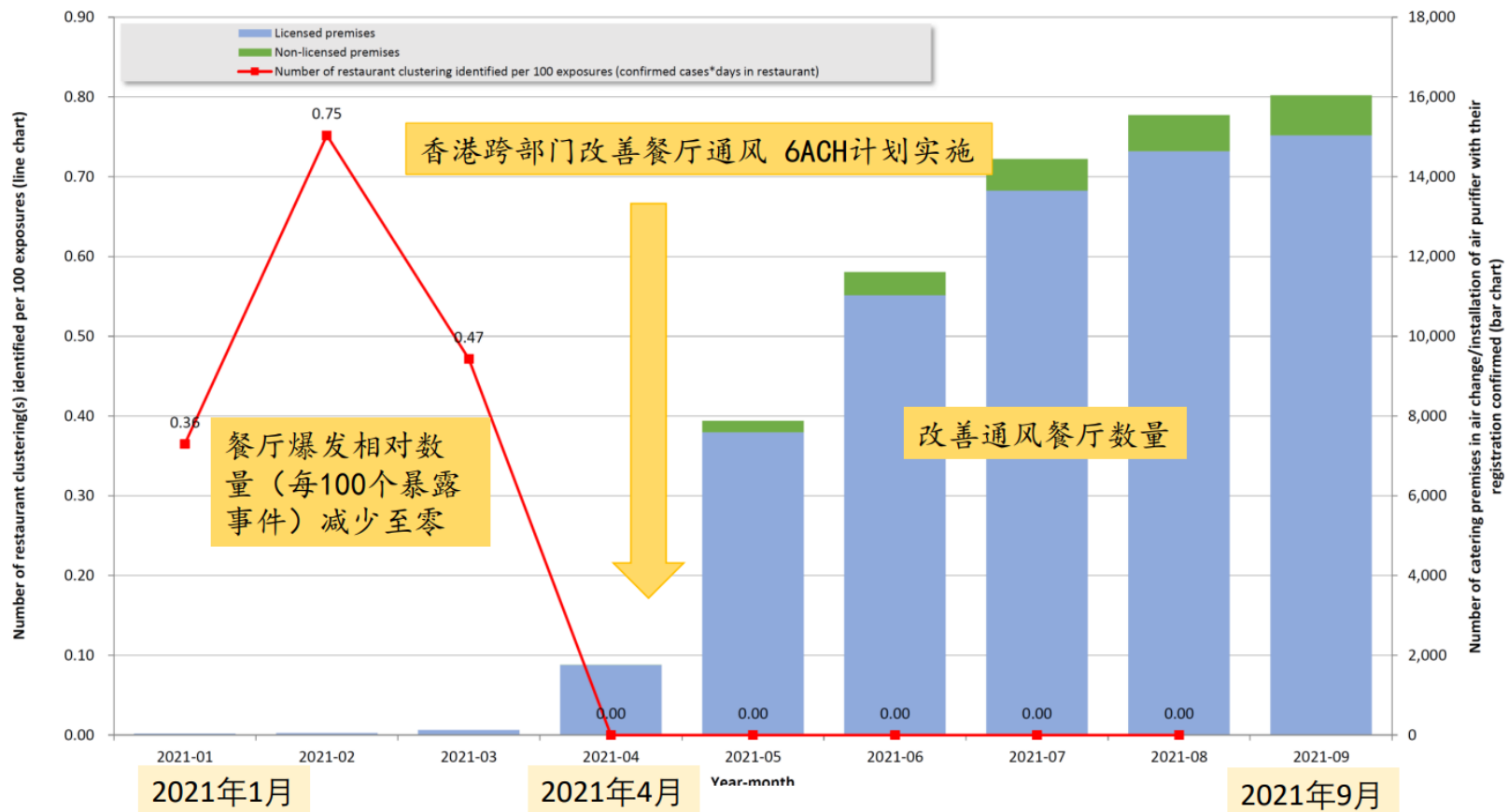
The WHO DG, Dr Tedros, would like us to finalize this phase of the consultation and agree on the main outcome/report and its content.

For this and upon request from the DG, we would like to invite you all for 2 days meeting on **April 27-28** to finalize the discussions and agree on the last draft version of the document with you, and get the final feedbacks and comments during the consultation.

Dr Tedros would like to have as many experts as possible to come to Geneva for the proposed above date for an in-person meeting. However,

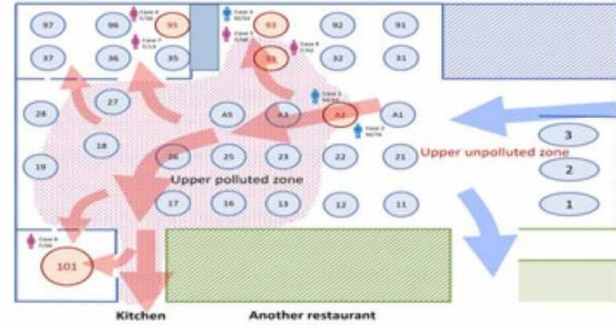
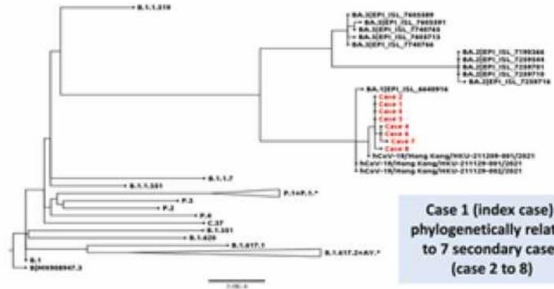


通风和稀释非常重要

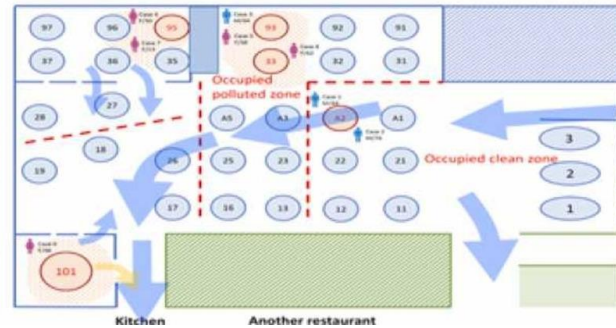


"The number of restaurant clustering per 100 episodes of exposure by COVID-19 patients was inversely related to the number of air purifiers being installed in the restaurants." Cheng VCC, et al, 2022

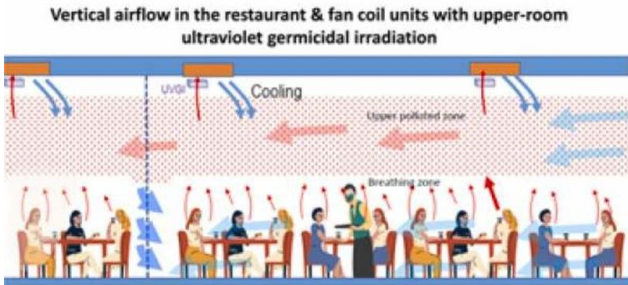
Outbreak investigation of airborne transmission of Omicron (B.1.1.529) - SARS-CoV-2 Variant of Concern in a restaurant: implication for enhancement of indoor air dilution



Floor plan of the restaurant & horizontal airflow in the upper & occupied zones



Floor plan of the restaurant & vertical airflow in the upper & occupied zones



Vertical airflow in the restaurant & fan coil units with upper-room ultraviolet germicidal irradiation

Table 2

Comparison of secondary attack rate during COVID-19 outbreaks in two Chinese restaurants before and after enhancement of indoor air dilution.

	Outbreak R1	Outbreak R2	P value
Customers			
Number of exposed	76	207	
Number of secondary infected	22	7 ^a	
Secondary attack rate	28.9%	3.4%	P<0.001
Restaurant staff			
Number of exposed	19	22	
Number of secondary infected	10	0	
Secondary attack rate	52.6%	0%	P<0.001
Secondary attack rate (overall)	33.7%	2.6%	P<0.001

Note. Outbreak R1 occurred on 19th February 2021 (before enhancement of indoor air dilution). Outbreak R2 occurred on 27th December 2021 (after enhancement of indoor air dilution).

^a Excluding the index case (case 1), there were 7 secondary infected cases in this outbreak.

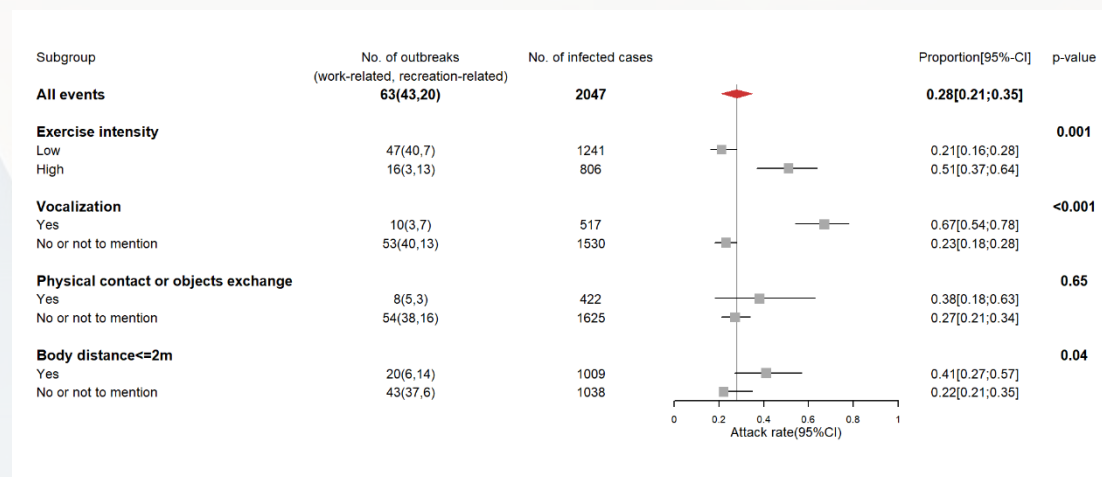
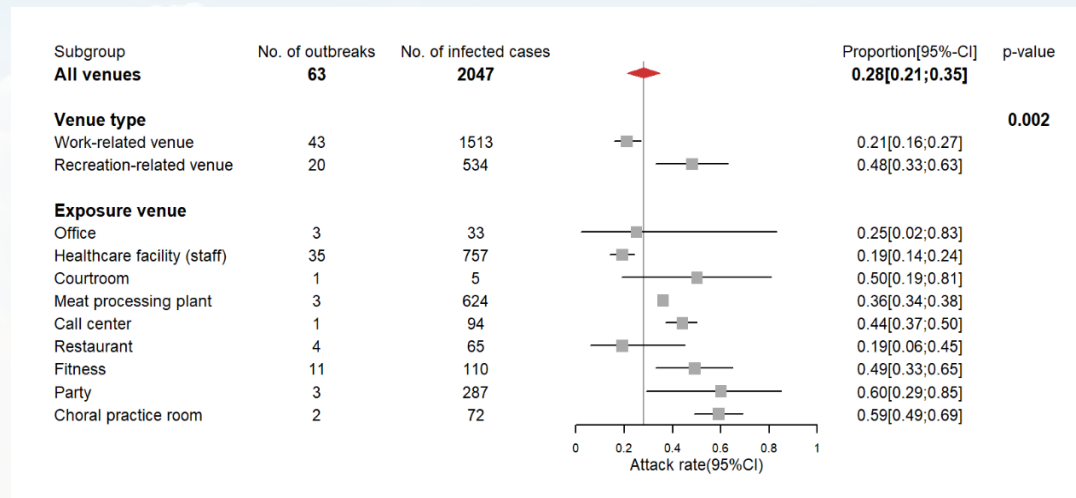
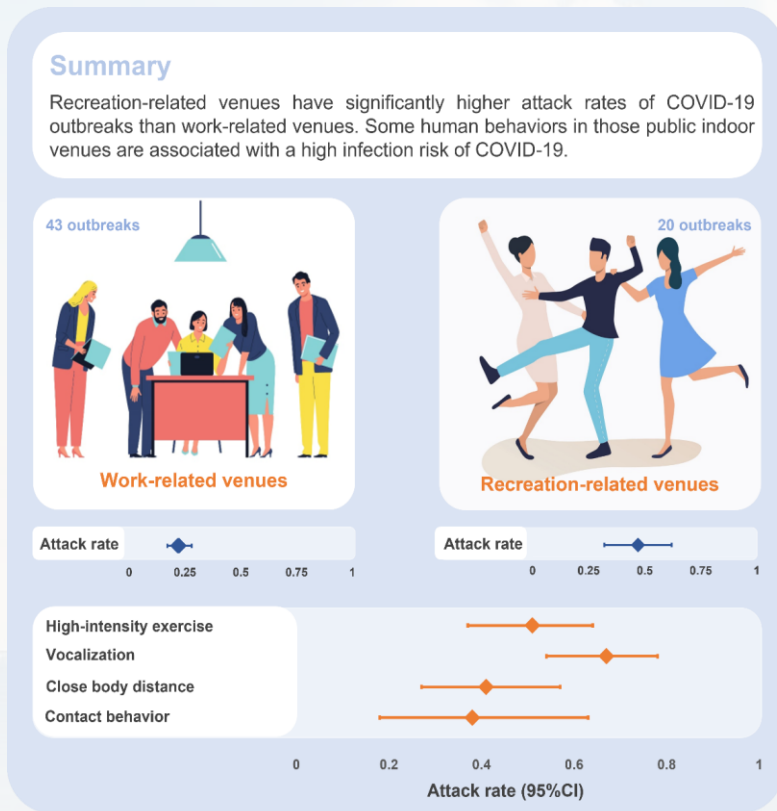


问题2： 不同环境风险一样吗？

不同室内环境控制风险所需要的通风量一样吗？

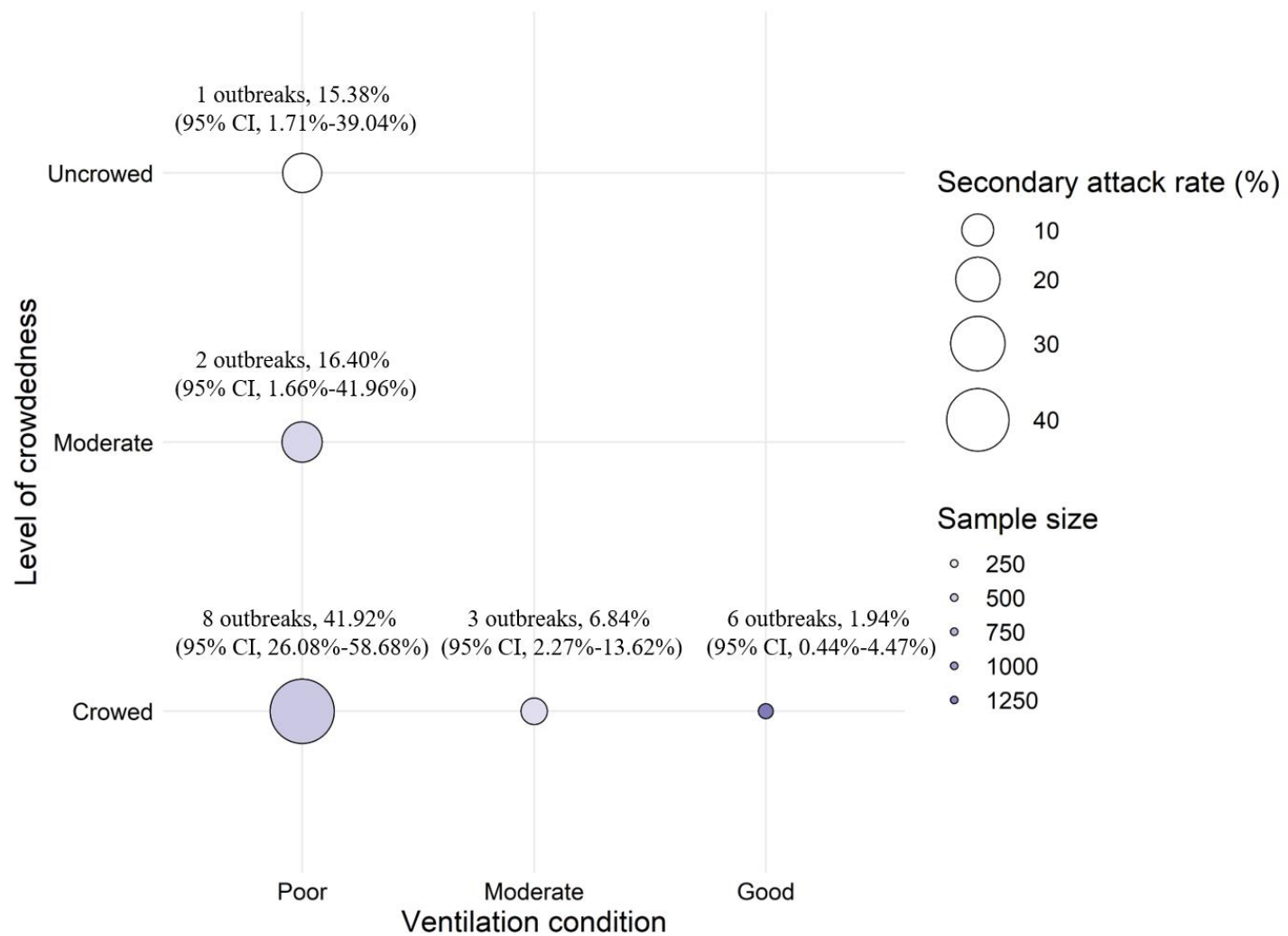
问题1:

不同环境风险是类似的吗?



Huang, W.W..... Qian, H., *Risk evaluation of venue types and human behaviors of COVID-19 outbreaks in public indoor environments: A systematic review and meta-analysis. Environmental Pollution, 2024. 341.*

拥挤和良好通风



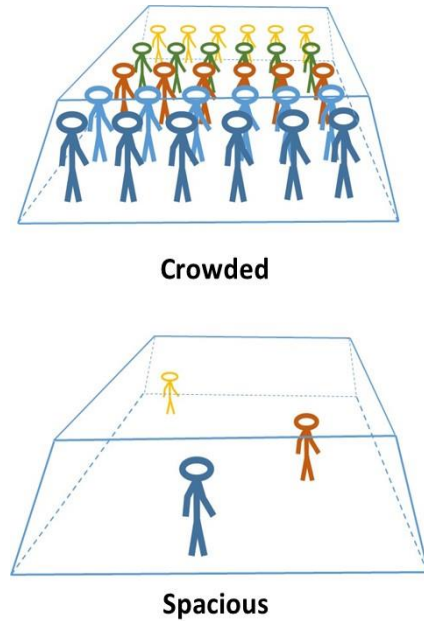
The image features a blue-tinted cityscape in the background, with a large blue geometric shape on the right side. The text is white and bold, positioned on the blue shape.

问题3：多少通风量合适？

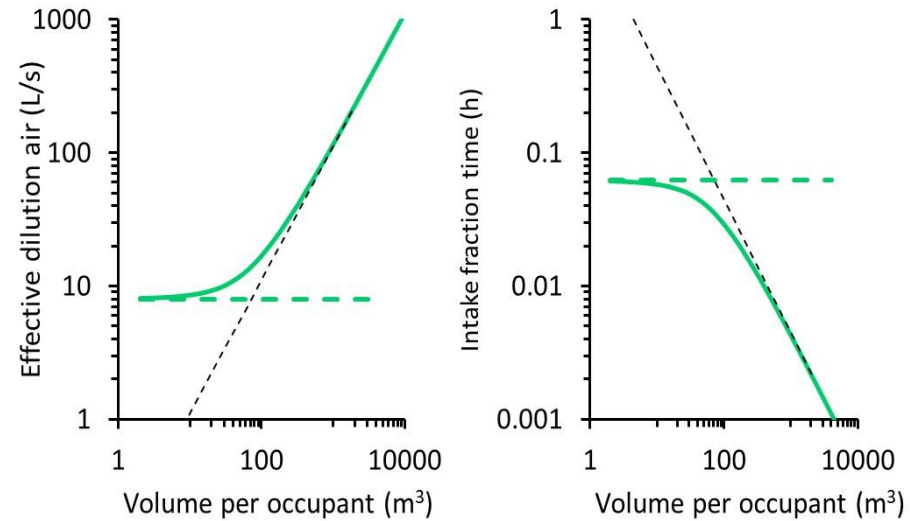
为控制疫情，我们需要的最小通风量是多少？

感染风险为0？ 还是 $R_0 < 1$

Equivalence of volume and ventilation (dilution)



Overcrowding reduces the effective dilution air and increases the intake fraction time

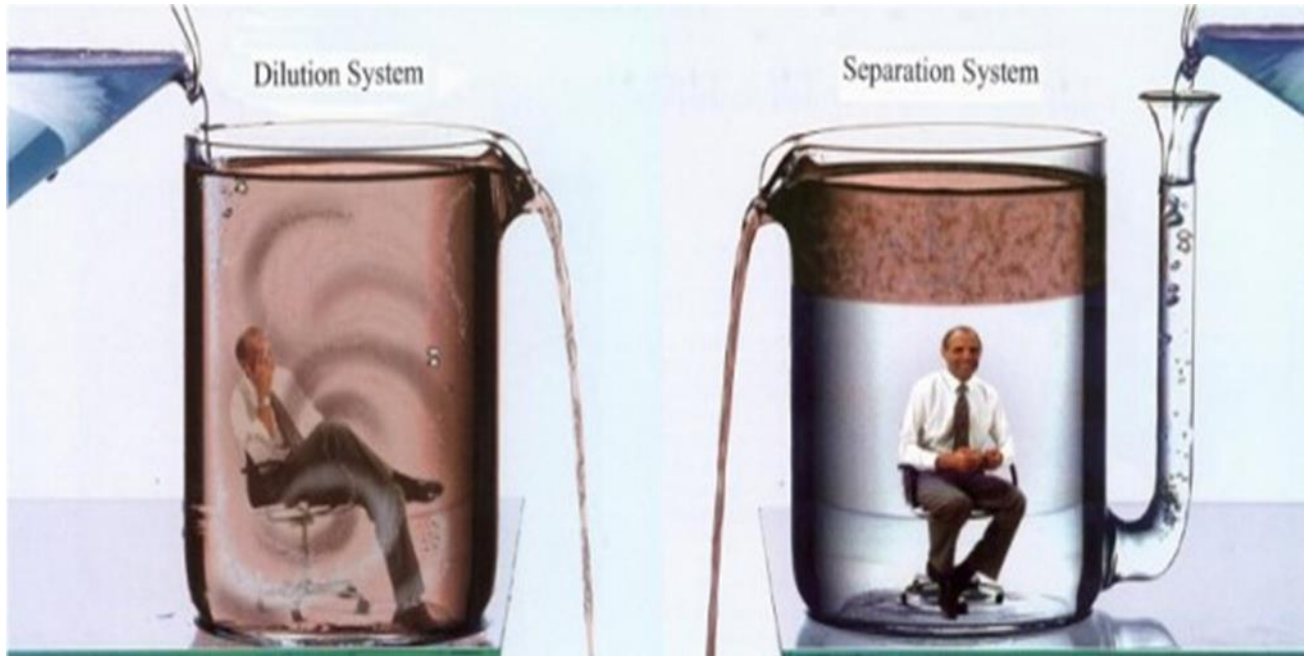


The image features a city skyline, likely New York City, with various skyscrapers and buildings. The sky is a vibrant blue with large, fluffy white clouds. A large, dark blue geometric shape, resembling a triangle or a large 'L' shape, is overlaid on the right side of the image, partially obscuring the skyline and sky. The text is positioned within this blue area.

问题4： 我们能否像提供清洁水一样提供清洁空气？

A paradigm shift to combat indoor respiratory infection

Building ventilation systems must get much better



Flexible ventilation systems, dependent on the building's purpose

Ventilation airflow rates must be controlled by the number of occupants in the space and their activity.

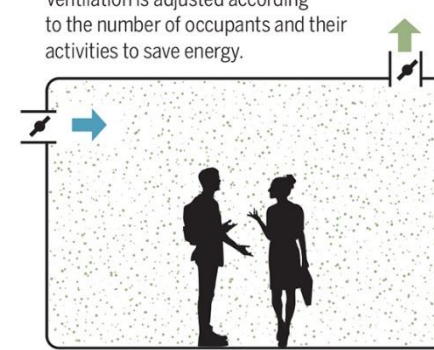
Design occupancy

Ventilation is set for maximum occupancy.



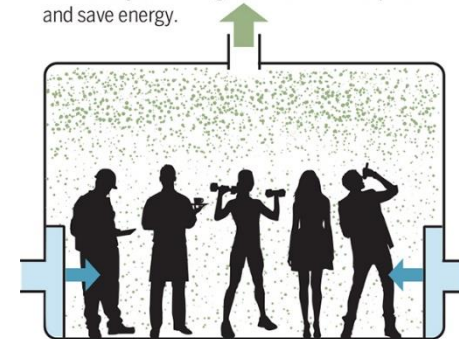
Demand controlled

Ventilation is adjusted according to the number of occupants and their activities to save energy.



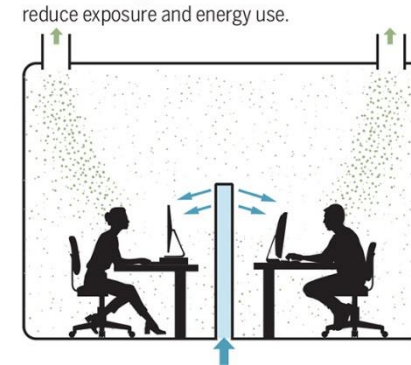
Improved air distribution

Different system designs can decrease exposure and save energy.



Personalized ventilation

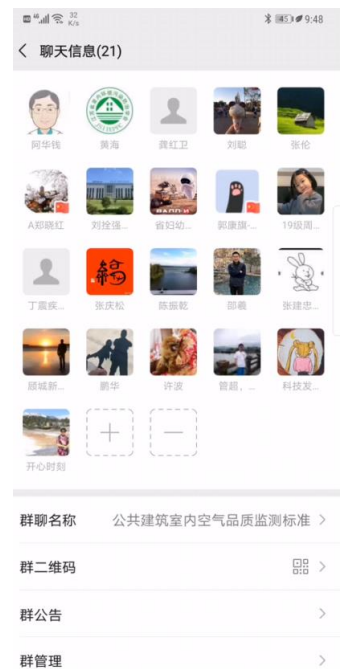
Clean air is supplied where needed to further reduce exposure and energy use.





问题5：设计的通风量是否等于实际通风量？

公共建筑室内空气质量监测系统技术规程



2020.6
指南发布

2020.6.12
筹备工作会
确定大纲和编写队伍
建立微信工作群

2020.8.15
指南结果公示
分工各单位完成各章节初稿
主编单位进行归拢和修改

2020.9.17
工作会议，集中修改

2020.10.28
集中考察南京、常州现场
工作会议，集中再次修改

2020.11.3
初审

2021.5
征求意见稿完成修改，项目示范

Details



Science
Volume 383, Issue 6690
Mar 2024

ARTICLE

Mandating indoor air quality for public buildings

[View article page](#)

Lidia Morawska, Joseph Allen, William Bahnfleth, Belinda Bennett, Philomena M. Bluyss: ... [See all authors](#)

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Pages	1418 - 1420



INSIGHTS

POLICY FORUM

PUBLIC HEALTH

Mandating indoor air quality for public buildings

If some countries lead by example, standards may increasingly become normalized

By Lidia Morawska, Joseph Allen, William Bahnfleth, Belinda Bennett, Philomena M. Bluyssen, Atze Boerstra, Giorgio Buonanno, Junji Cao, Stephanie J. Dancer, Andres Floto, Francesco Franchimon, Trish Greenhalgh, Charles Haworth, Jaap Hogeling, Christina Isaxon, Jose L. Jimenez, Amanda Kennedy, Prashant Kumar, Jarek Kurnitski, Yuguo Li, Marcel Loomans, Guy Marks, Linsey C. Marr, Livio Mazzarella, Arsen Krikor Melikov, Shelly L. Miller, Donald K. Milton, Jason Monty, Peter V. Nielsen, Catherine Noakes, Jordan Peccia, Kimberly A. Prather, Xavier Querol, Tunga Salthammer, Chandra Sekhar, Olli Seppänen, Shin-ichi Tanabe, Julian W. Tang, Raymond Tellier, Kwok Wai Tham, Pawel Wargocki, Aneta Wierzbicka, Maosheng Yao

People living in urban and industrialized societies, which are expanding globally, spend more than 90% of their time in the indoor environment, breathing indoor air (IA). Despite decades of research and advocacy, most countries do not have legislated indoor air quality (IAQ) performance standards for public spaces that address concentration levels of IA pollutants (1). Few building codes address operation, maintenance, and retrofitting, and most do not focus on airborne disease transmission. But the COVID-19 pandemic has made all levels of society, from community members to decision-makers, realize the importance of IAQ for human health, well-being, productivity, and learning. We propose that IAQ standards be mandatory for public spaces. Although enforcement of IAQ performance standards in homes is not possible, homes must be designed and equipped so that they could meet the standards.

in the derivation procedure; the complex political, social, and legislative situation regarding IAQ; the lack of an open, systematic, and harmonized approach (4); and that establishing an IAQ standard is always the result of a compromise between scientific knowledge and political will (5). Because of the heterogeneous landscape of approaches needed, such barriers remain intact despite the considerable IAQ research and evidence base developed over the past decades.

CHALLENGES

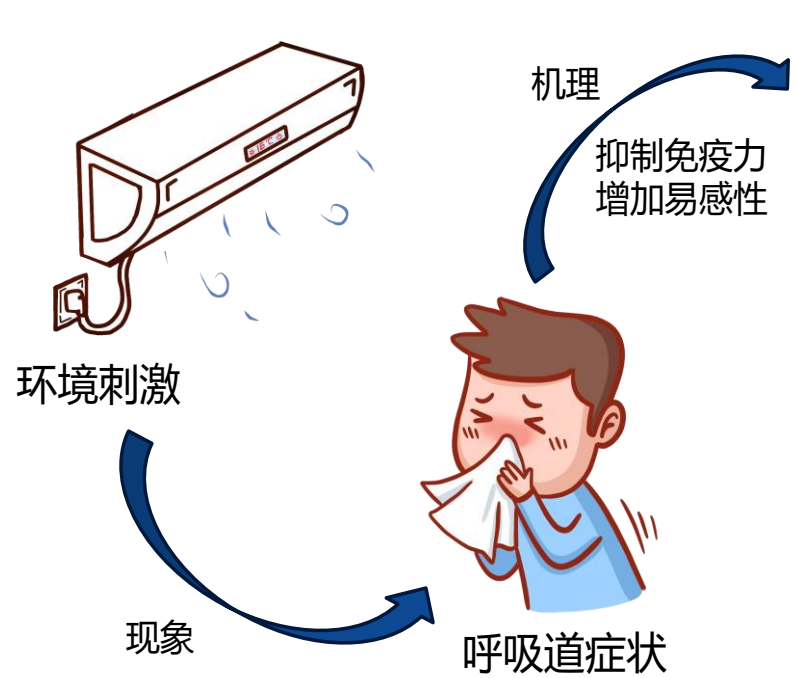
Source contributions

IA pollution originates from sources indoors (including humans) and outdoors and from chemical reactions between pollutants in IA (6). Compliance with IAQ standards (that refer to the concentrations of indoor pollutants) would require controlling indoor emission sources (such as combustion, building products, and cleaning products) and mini-

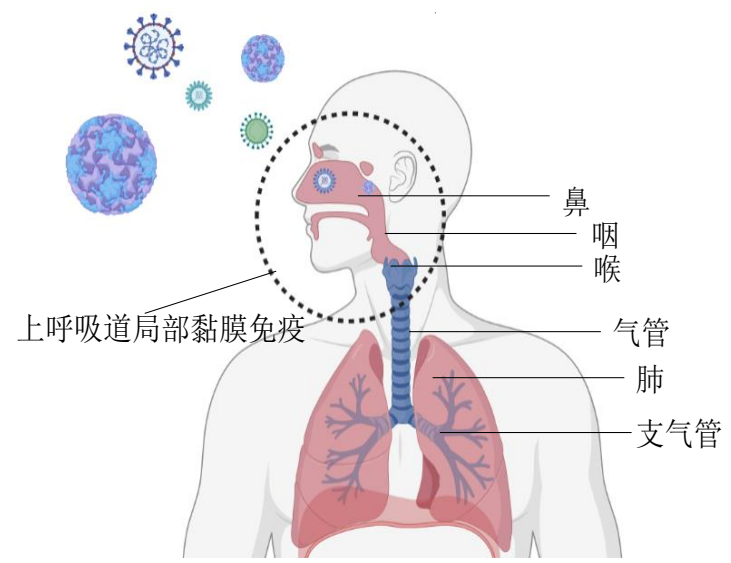
is different and is used differently, and we cannot use modeling to predict pollution concentration in one space by using the concentrations measured in other spaces. Compliance monitors are too costly and complex to deploy in all indoor spaces to monitor for all six pollutants included in the WHO AQG (3). However, there are environmental parameters that can already be monitored in each room of each building, such as temperature and relative humidity. The feasibility of monitoring IAQ parameters in buildings depends on the size, cost, robustness, and silent operation of the sensor or monitor; calibration; and ease of interpreting data. But routine, real-time monitoring of indoor pathogens is currently infeasible. In the absence of information on the concentration of pathogens in IA, the question is which proxy parameter or pollutant should be the basis for legislation that targets airborne infection transmission.

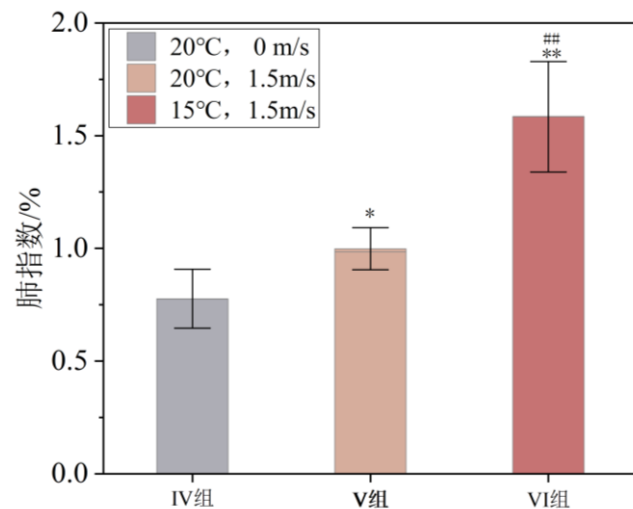
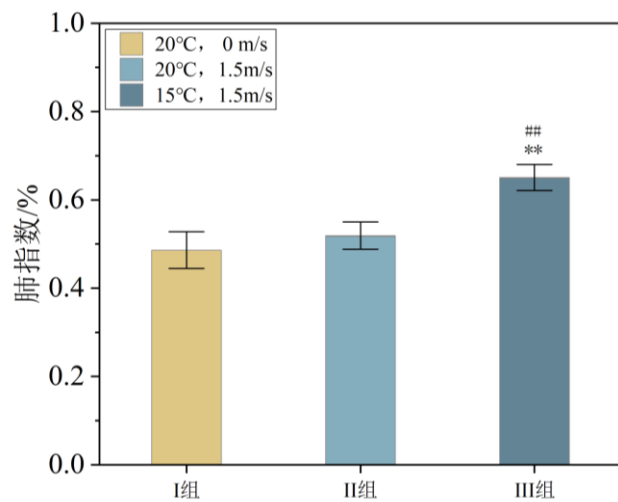
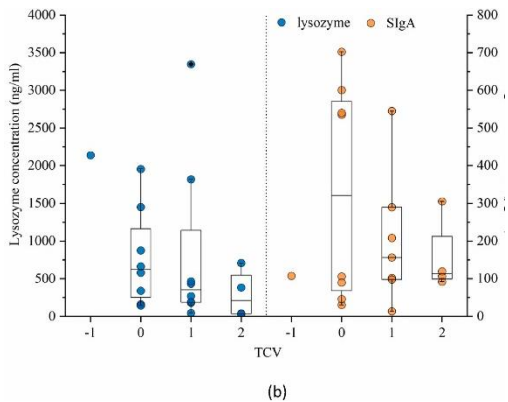
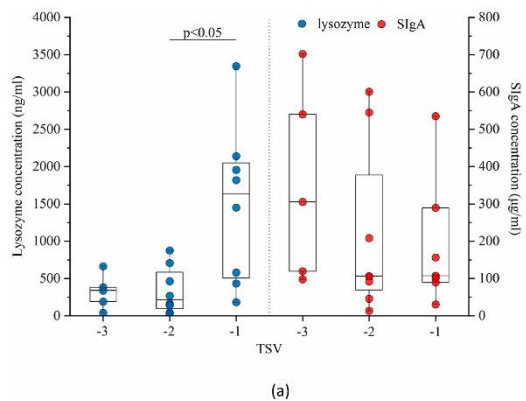


问题6：室内环境对人抵抗力影响

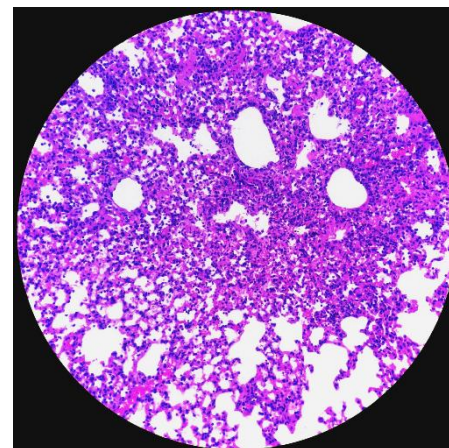
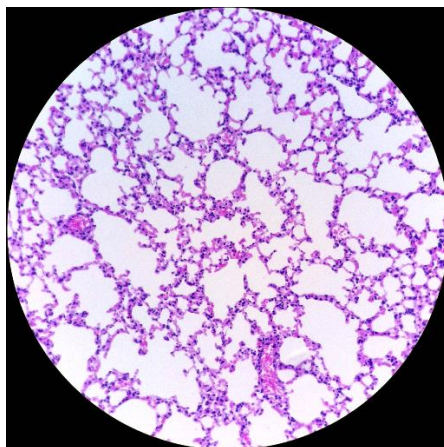


呼吸道感染风险不仅取决于病原体暴露，
人体呼吸系统的免疫能力也是重要的影响因素





非感染组小鼠肺指数；(b)感染组小鼠肺指数 与病毒对照IV组比较，



对照组和染毒吹风组小鼠肺切片图

医工结合



ealth

致谢

- 国家自然科学基金资助
- 香港大学李玉国教授、广东呼研所 杨子峰教授、清华大学 刘荔教授、中山大学 杭建教授、北京工业大学张楠副教授 等.....
- 课题组：郑晓红副教授、罗丹婷、王聖齐、周梓莹、程小雪、黄玮玮等同学



谢谢大家