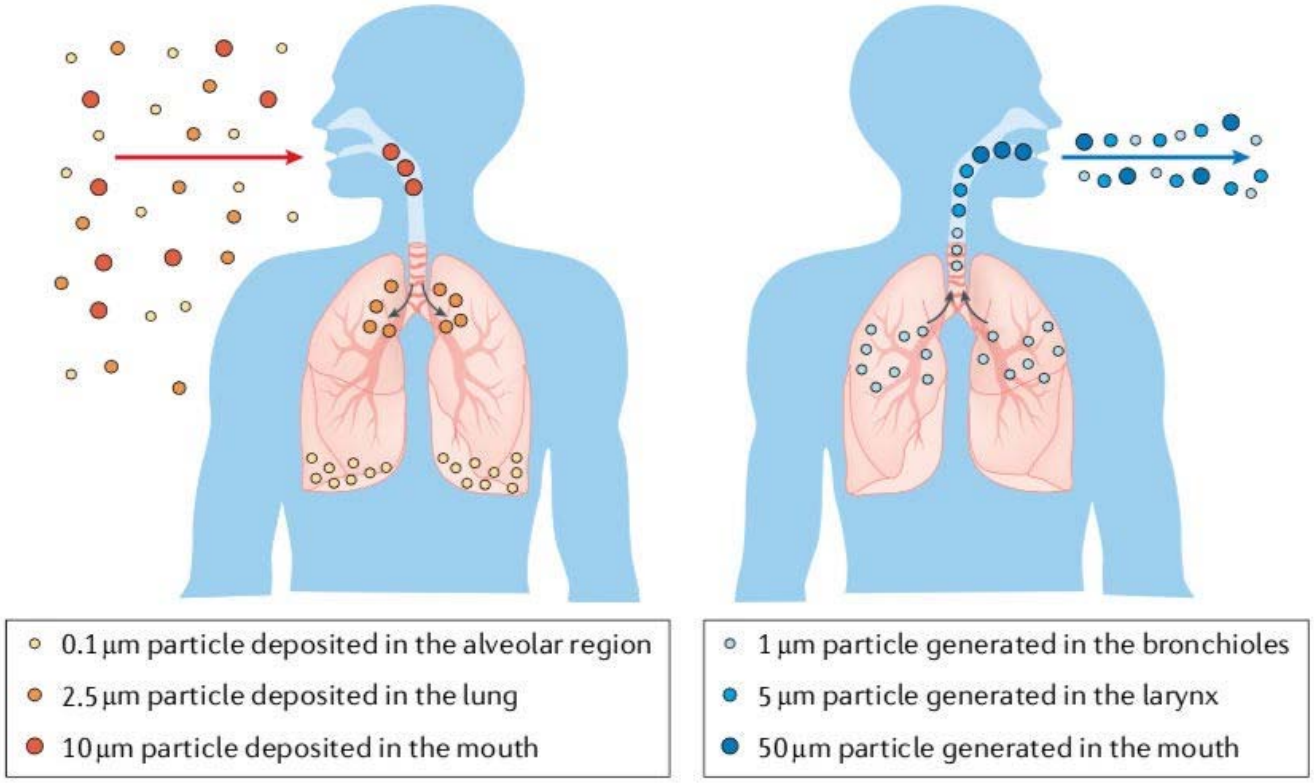
Trasmissione aerea di patogeni respiratori

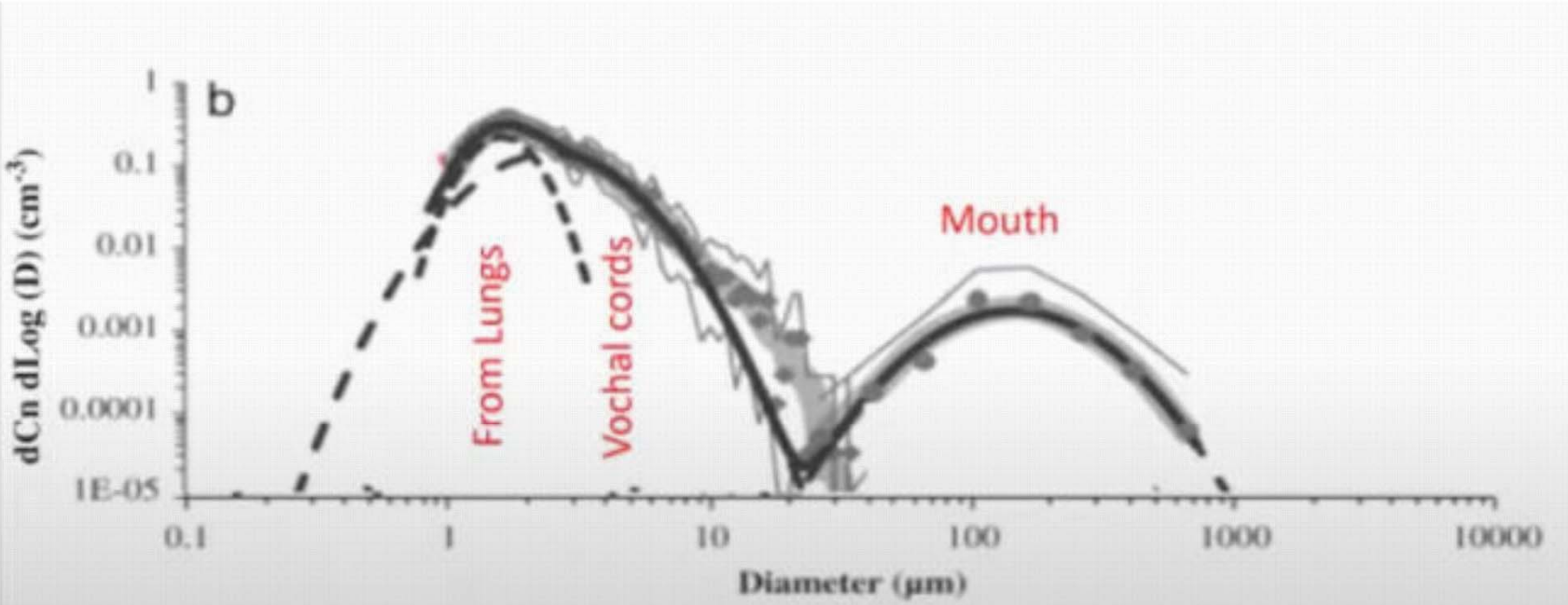
PROF. GIORGIO BUONANNO

Formazione delle goccioline respiratorie



Morawska L., Buonanno G., 2021, *Nature Reviews Physics*, https://doi.org/10.1038/ s42254-021-00307-4

Distribuzione dimensionale delle goccioline durante il parlato



From Johnson et al., *J. Aerosol Sci.* (2011)
Black line is best estimate
Emitted respiratory particles when speaking

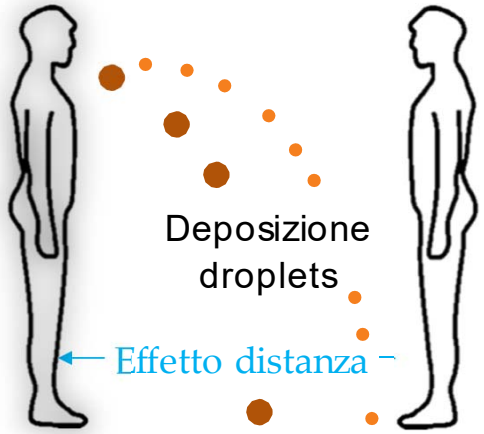
Il grande errore commesso da Autorità Sanitarie, virologi, epidemiologi, immunologi, infettivologi, ….

Superfici (fomiti)

- Trasmissione indiretta
- Lavaggio mani
- Sanificazione

Large droplets

- D > 5 µm
- Rapida deposizione al suolo
- Contatti **ravvicinati**



- **Lavaggio mani**
- **Distanziamento**

Rischio trascurabile?!?

Purtroppo per loro questa pandemia sta durando molto più della SARS-CoV-1…

Sanificazione superfici?

… the risk of SARS-CoV-2 infection via the fomite transmission route is low, and generally less than 1 in 10,000, which means that each contact with a contaminated surface has less than a 1 in 10,000 chance of causing an infection.

https://www.cdc.gov/coronavirus/2019-ncov/more/science-and-research/surface-transmission.html

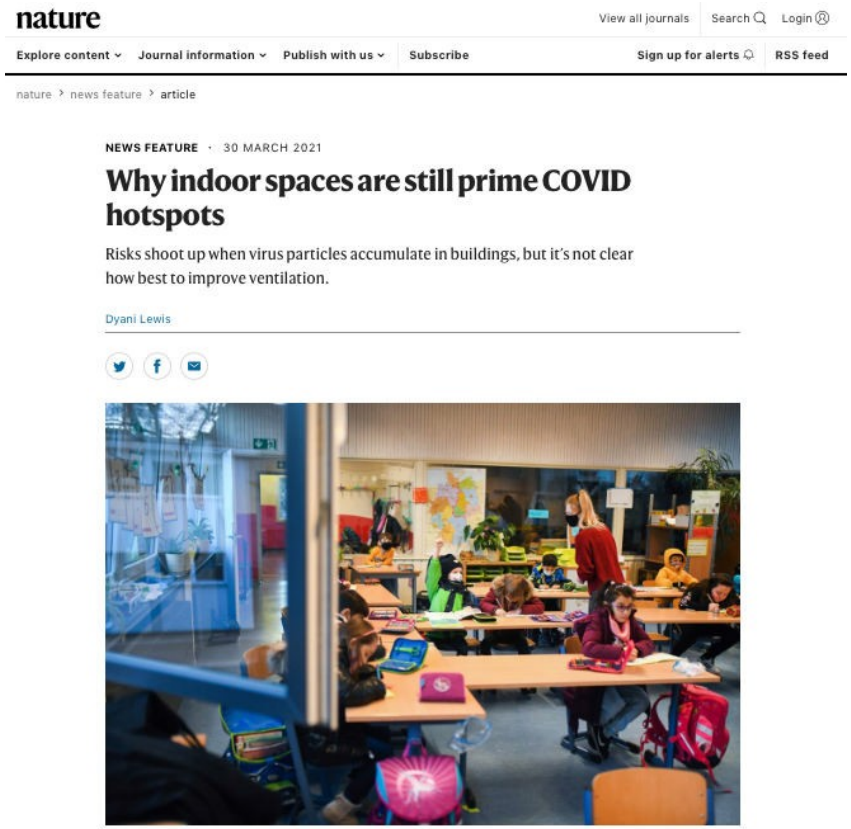
If less than 24 hours have passed since the person who is sick or diagnosed with COVID-19 has been in the space, clean and disinfect the space.

If more than 24 hours have passed since the person who is sick or diagnosed with COVID-19 has been in the space, cleaning is enough. You may choose to also disinfect depending on certain conditions or everyday practices required by your facility.

If more than 3 days have passed since the person who is sick or diagnosed with COVID-19 has been in the space, no additional cleaning (beyond regular cleaning practices) is needed.

https://www.cdc.gov/coronavirus/2019-ncov/community/disinfecting-building-facility.html

Outdoor molto più sicuro di indoor: droplets?



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NEWS FEATURE · 30 MARCH 2021

Why indoor spaces are still prime COVID hotspots

Risks shoot up when virus particles accumulate in buildings, but it's not clear how best to improve ventilation.

Dyani Lewis

BIG CITY

Schools Beat Earlier Plagues With Outdoor Classes. We Should, Too.

A century ago, children in New York City attended classes during a pandemic. It seemed to work.

Outdoor contribuisce allo 0.1% dei contagi…

Health Protection Surveillance Centre (HPSC), marzo 2021

Petition to WHO of the 36-group

1 April 2020

Dr. Tedros Adhanom Ghebreyesus
Director General
World Health Organization
Avenue Appia 20
1211 Geneva, Switzerland

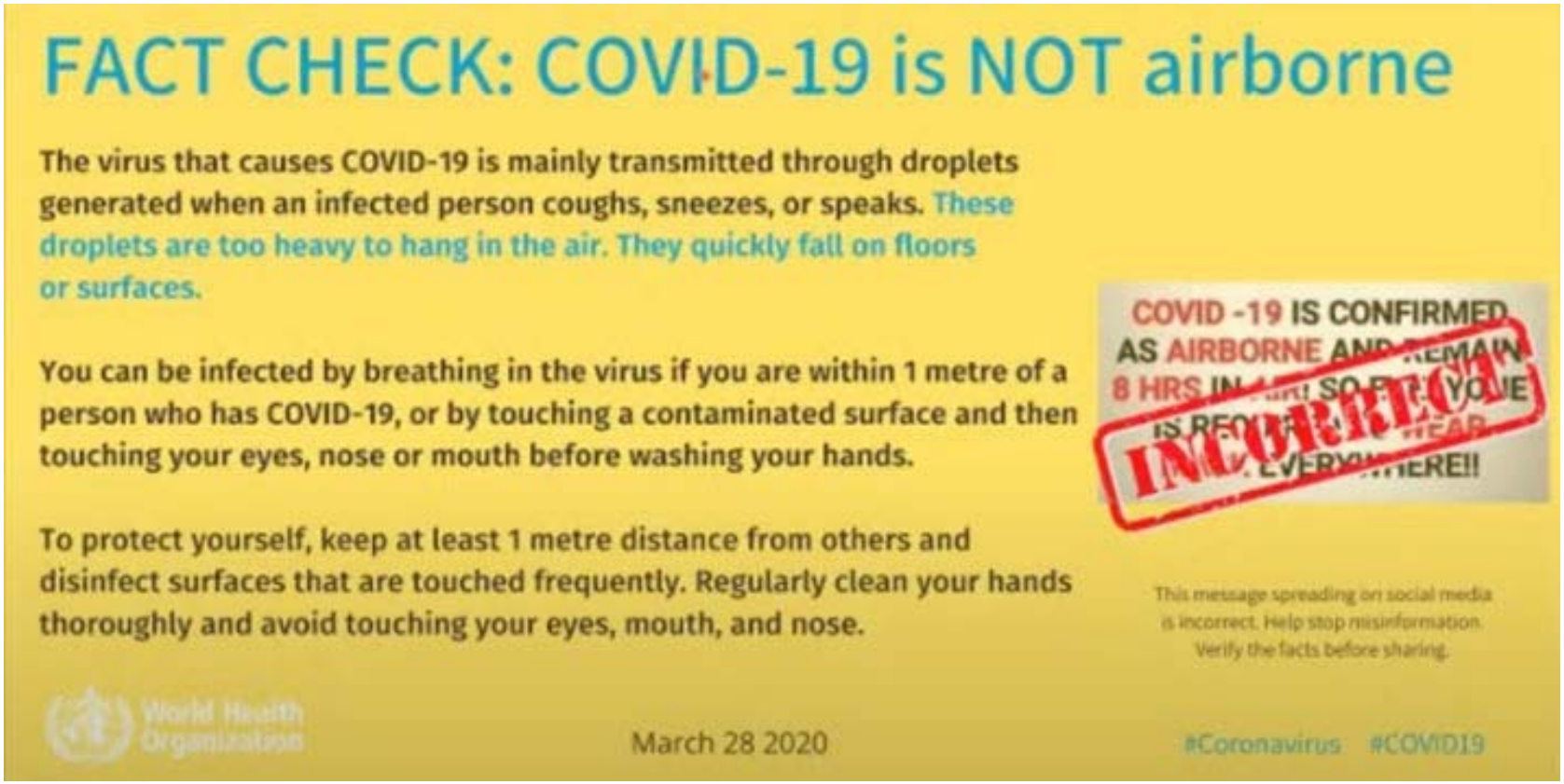
Dear Dr. Tedros Adhanom Ghebreyesus,

We, scientists from around the world, who have worked for many years on the characteristics and mechanisms behind the transport of droplets expired by humans, and on airflow patterns in buildings, appeal to you to recognize the significance of the airborne spread of SARS-CoV-2 (COVID-19) and advocate for preventive measures to mitigate this.

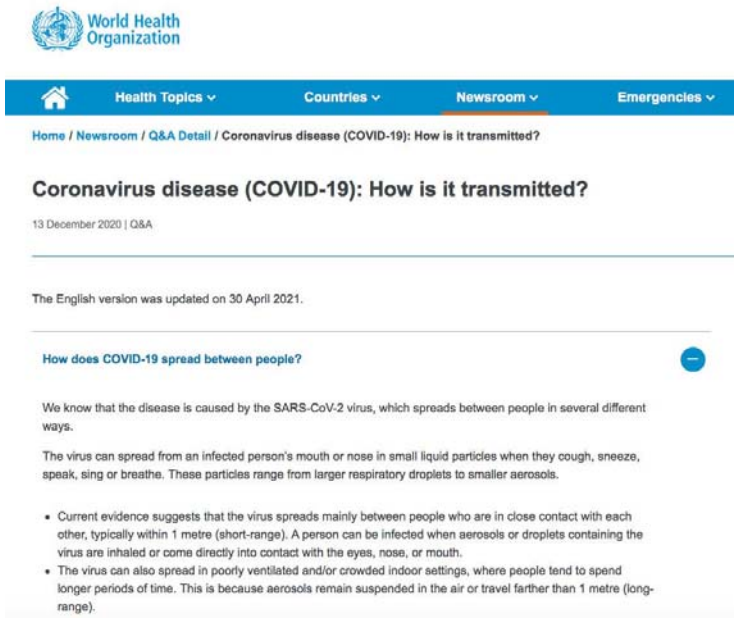
The current advice from the WHO is to wash your hands and maintain a social distance of about 1.0 m. However, these measures do not adequately protect the population from the small virus-carrying particles exhaled by infected people, and inhaled by others who share the same not-well-ventilated environments. These particles can travel tens of meters and remain airborne for prolonged periods.

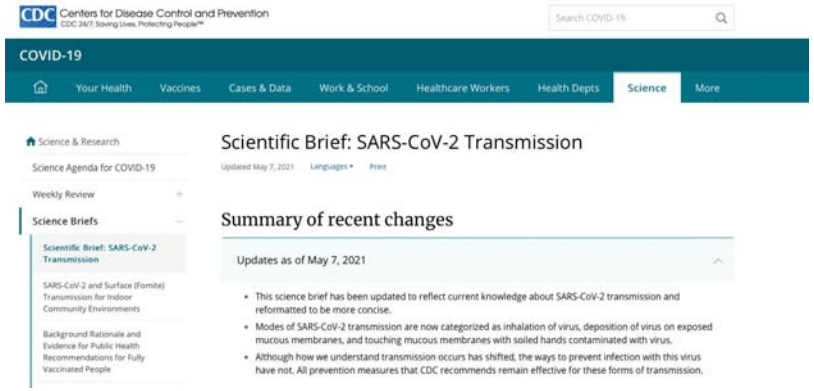
Health care workers are among those who best adhere to the recommendations and are well

Disinformazione degli scienziati o negazionismo all'OMS?



Maggio 2021: la trasmissione aerea esiste anche all'OMS





Modalità di trasmissione di un virus

Superfici (fomiti)

- **Trascurabile** (1/10000), https://www.cdc.gov/coronavirus/2019-ncov/more/science-and-research/surface-transmission.html

Large droplets

- **D = 100-1000 µm**
- Lenta evaporazione
- Rapida deposizione al suolo
- contatti **ravvicinati**
- Deposizione meno infettiva della inalazione
- Concentrazione virale maggiore aerosol
- **Trascurabile**

Cortellessa, …, Buonanno, 2021, Close proximity risk assessment for SARS-CoV-2 infection, Science of the Total Environment, 148749

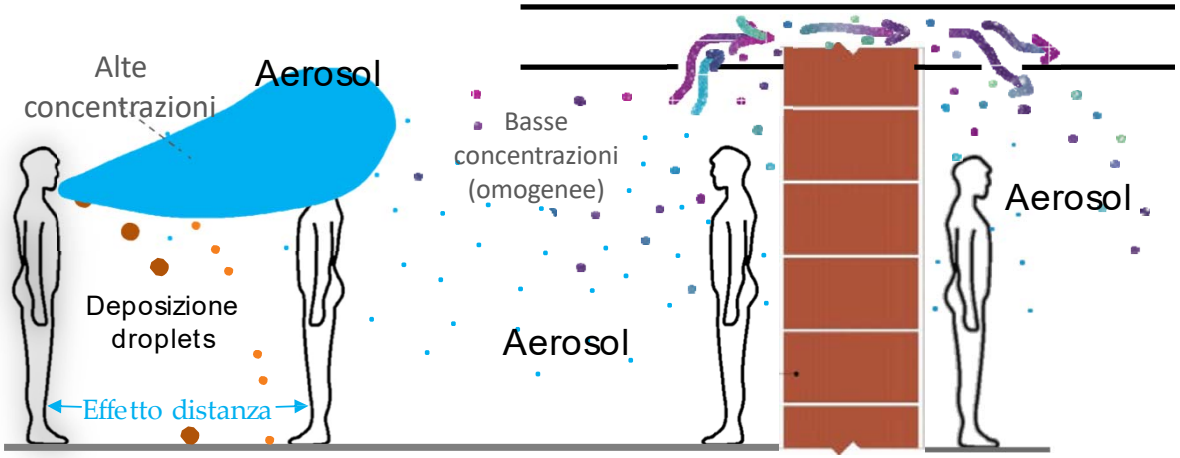
Airborne droplets

- **D = 1-100 µm**
- Rapida evaporazione (es. da 100 a 20 µm)
- Restano in sospensione (aerosol)
- Contatti **ravvicinati** e **non ravvicinati indoor**

Close proximity
Ambienti indoor ed outdoor

Sharing indoor air
Ambienti indoor

Long range
Ambienti indoor



Adattata da Li, 2021

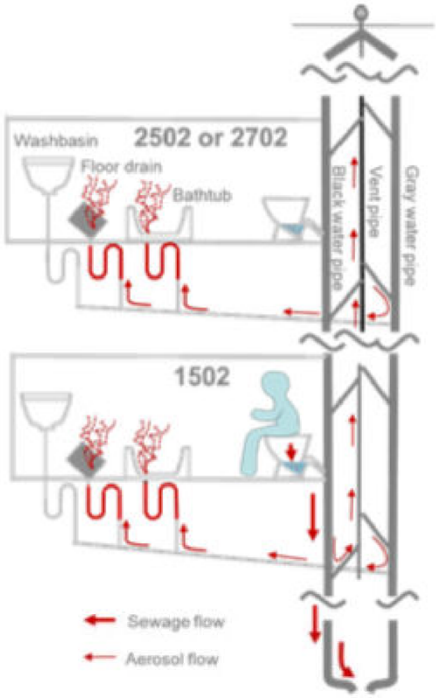
Le esalazioni non consistono solo di goccioline muco-salivari che seguono traiettorie di emissione semibalistiche a corto raggio ma, cosa importante, sono principalmente costituiti da una nuvola di gas turbolento multifase (puff) che trascina l'aria ambiente e intrappola e trasporta al suo interno gruppi di goccioline con un continuum di dimensioni delle gocce.

L. Bourouiba (Massachusetts Institute of Technology, MIT, Boston)

Trasmissione per via aerea attraverso colonne fecali

Guangzhou Block X: The infected families lived in 3 vertically aligned flats connected by drainage pipes in the master bathrooms.

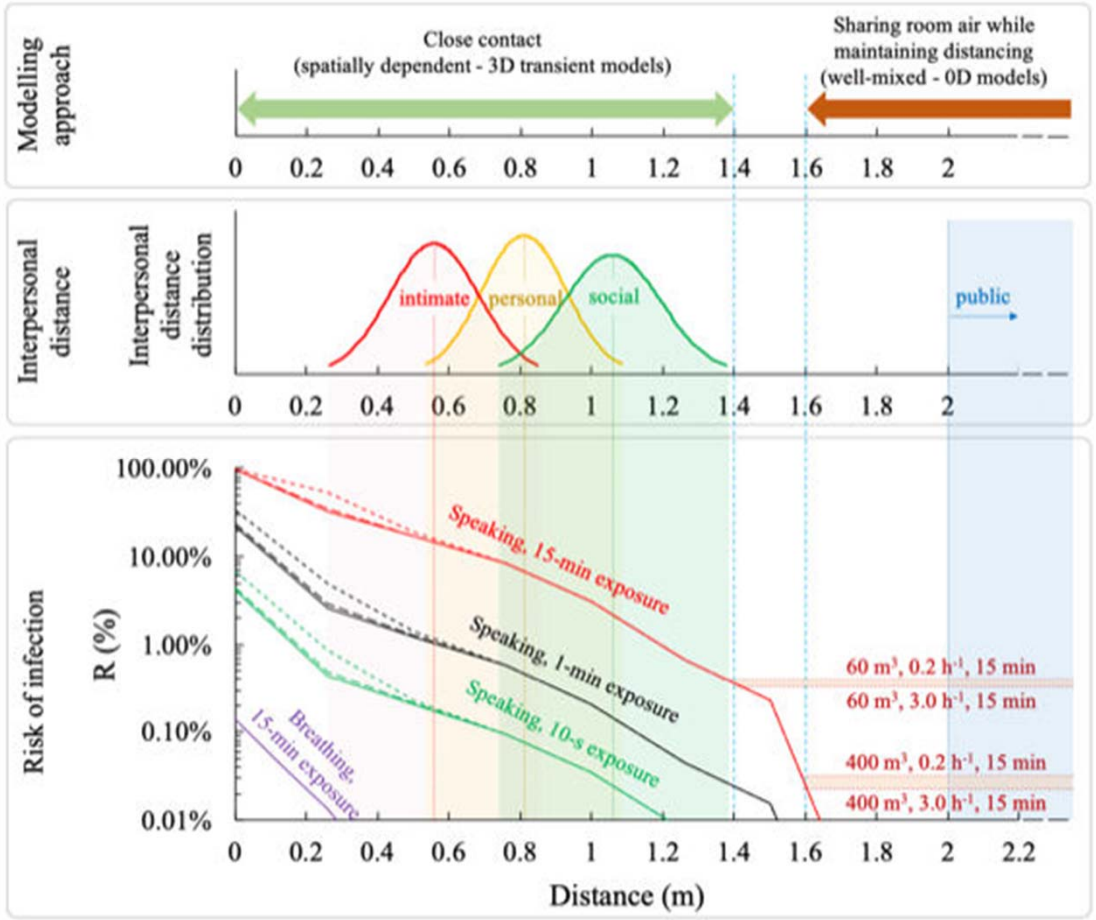
- Family 1502 visited Wuhan and got infected
- 2502 and 2702 used their master bedrooms, stayed at home most of time
- Lift video available
- Tracer dispersion on 21 Feb



Kang et al. Probable evidence of fecal aerosol transmission of sars-cov-2 in a high-rise building. Annals of Internal Medicine. https://doi.org/10.7326/M20-0928

We have found >10 such similar vertical outbreaks about 1% of the confirmed cases in HK, and performed tracer gas studies in 5 of them.

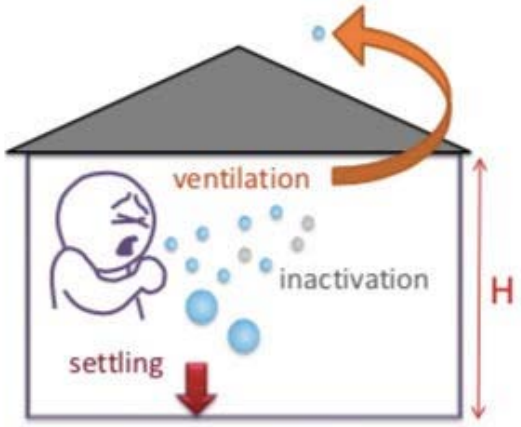
Rischio nelle brevi distanze



- Anisotropic infection has just been demonstrated for SARS-CoV-2 with monkeys (https://www.biorxiv.org/content/10.1101/2021.04.27.441510v1
- For all the pathogens where it has been measured, they are more concentrated on aerosols than large droplets. And in smaller rather than larger aerosols. (Fennelly KP. Particle sizes of infectious aerosols: implications for infection control. *Lancet Respir Med* 2020; **8:** 914–24.)

Trasmissione aerea su distanze maggiori

Virus Dynamics in Indoor Air



$$\frac{dC_d}{dt} = -\left(\frac{v}{H} + \lambda + k\right)C_d$$

settling

ventilation (air-exchange)

inactivation

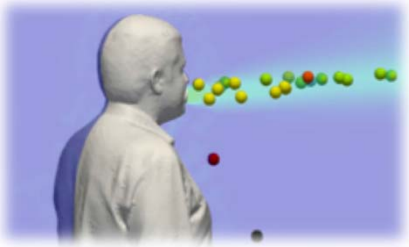
C_d: concentration of infectious virus in aerosols of diameter *d*

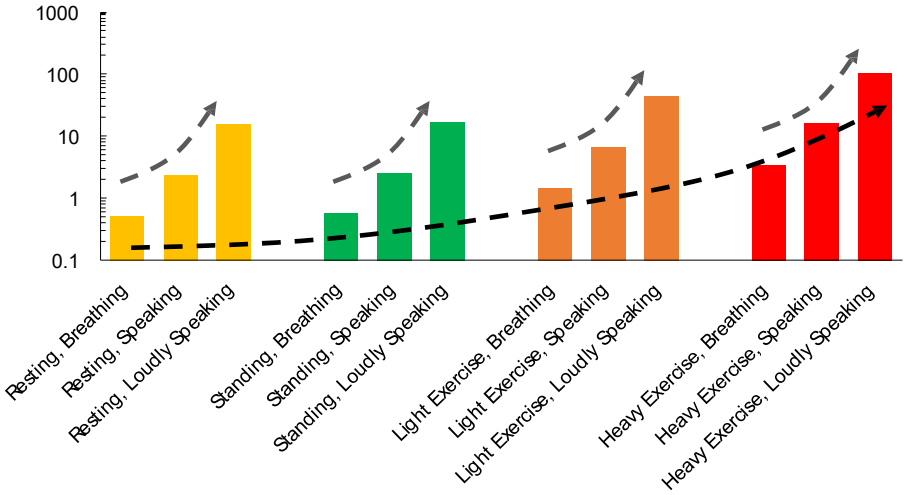
- Settling velocity *v* depends on diameter *d*
- Diameter depends on RH
- Inactivation rate *k* depends on RH

relative humidity (RH)

Modello emissivo (Buonanno et al., 2020)

- Volume droplets emesse (attività espiratoria)
- Portata d'aria emessa (attività fisica)
- Carica virale
- Dose minima per infezione





Emissione → Dinamica delle droplets e del virus → **Esposizione**
- Contatti ravvicinati
- Contatti non ravvicinati

→
- Durata dell'esposizione
- Modelli dosimetrici

→ **Dose** → Modelli dose-risposta → **Rischio di infezione**

Approccio per la stima del rischio infezione indoor

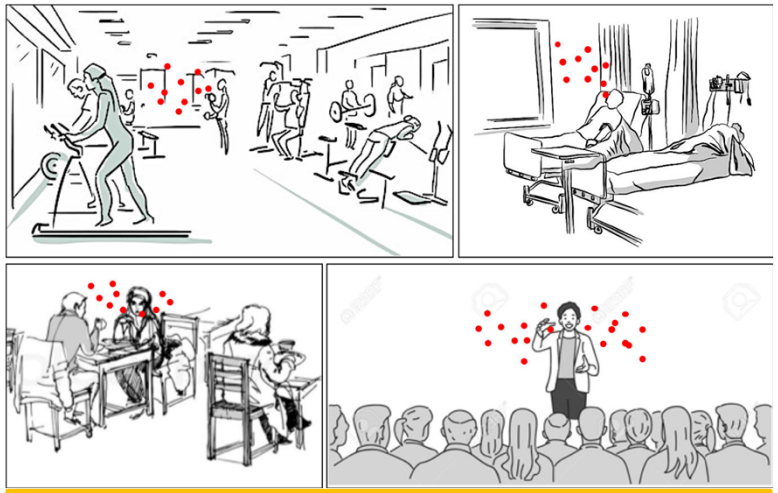
Novel approach for quantitative assessment of the individual infection risk of airborne transmission of SARS-CoV-2

Probability of infection
"Four step approach"

- quanta emission rate
- exposure to quanta concentration
- dose of quanta received
- dose–response model

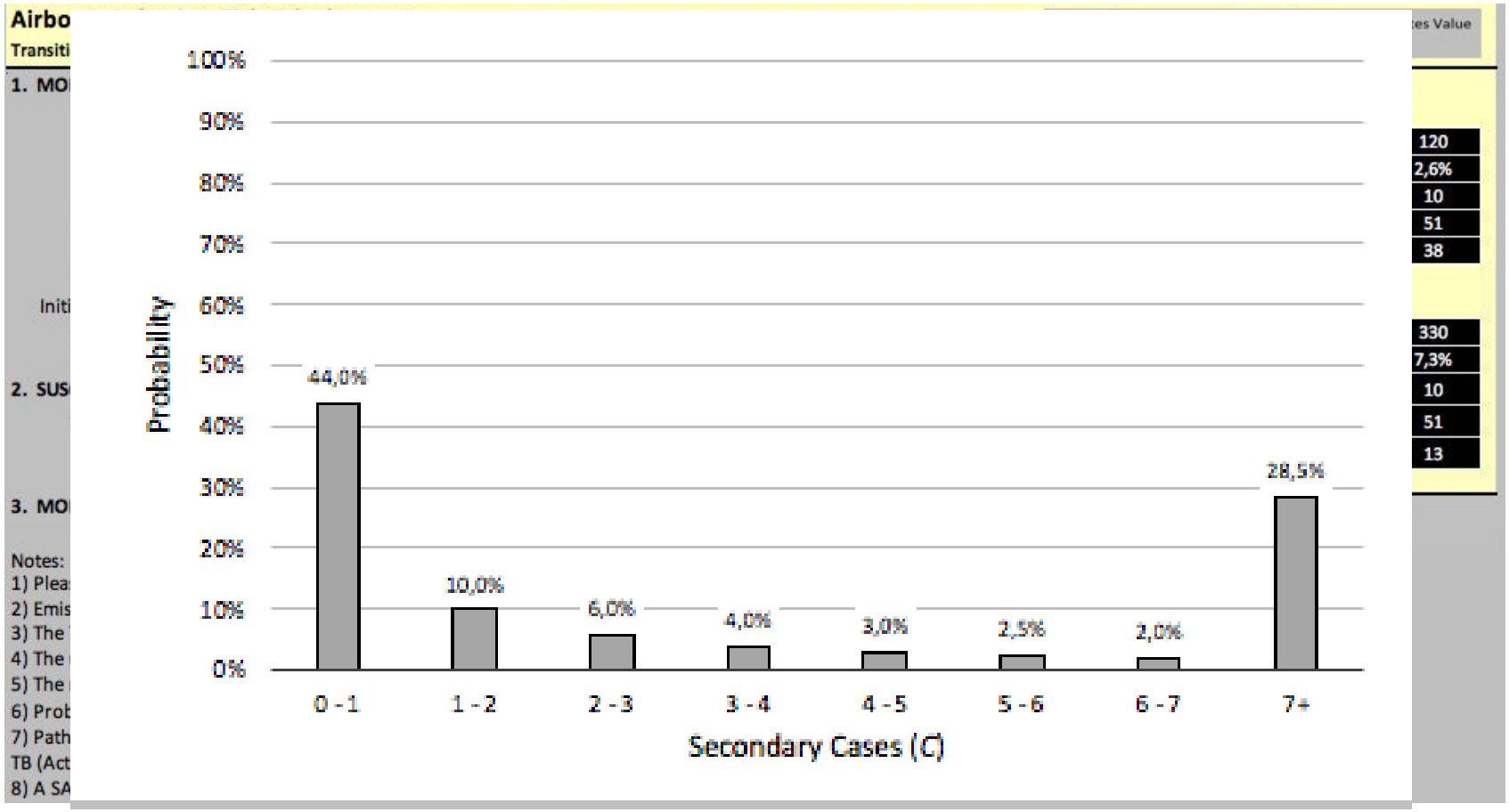
→ **Occurrence of the probability of infection** → **Estimate of the Individual infection risk**

Application of the approach to prospective and retrospective assessments

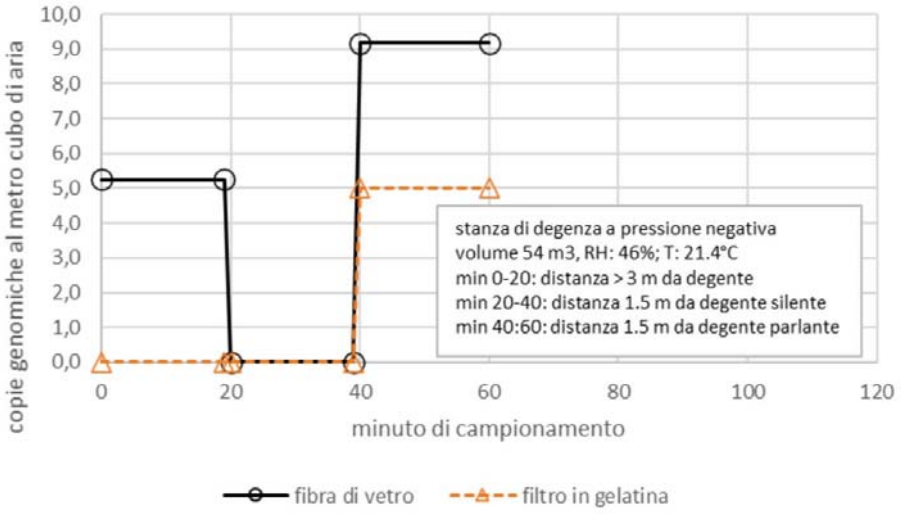


- Determination of the maximum exposure time to guarantee an acceptable individual infection risk
- Identification of "superspreading event"

Airbone Infection Risk Calculator (AIRC)



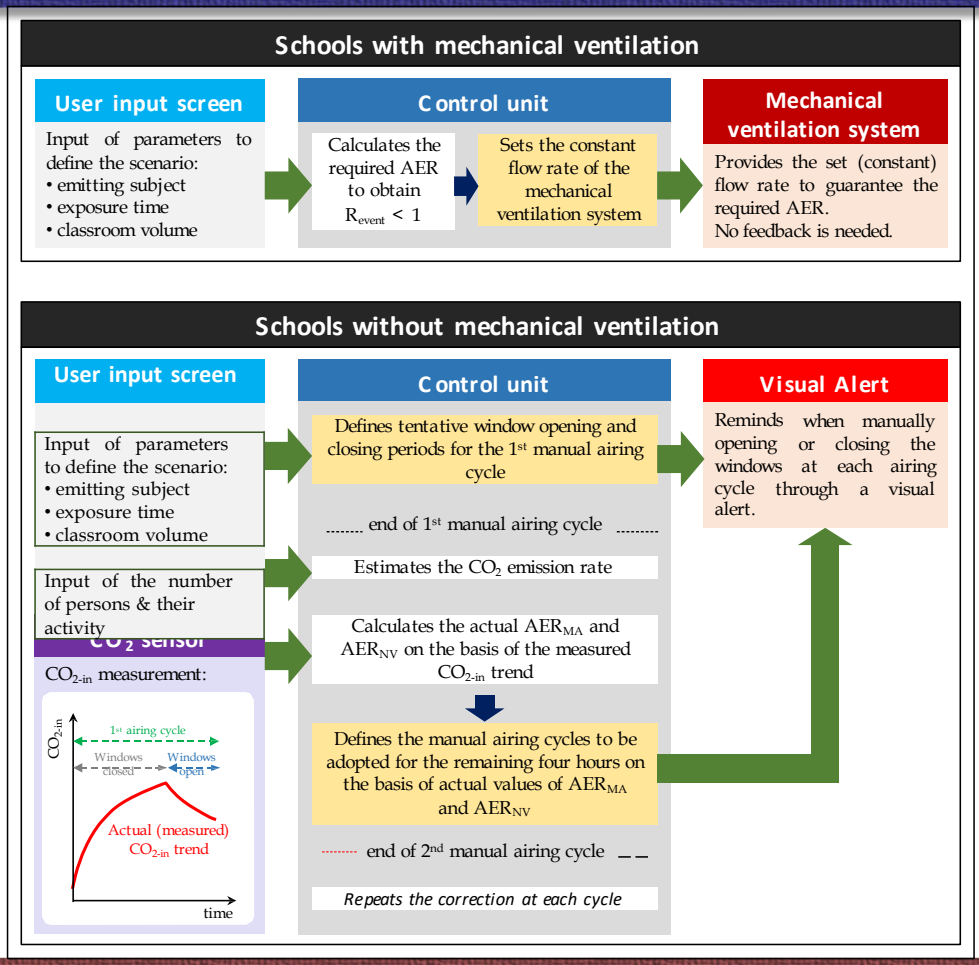
Verifica sperimentale sulla emissione durante speaking



C_v = 2.3 10^6 RNA copies/mL, 75th percentile…

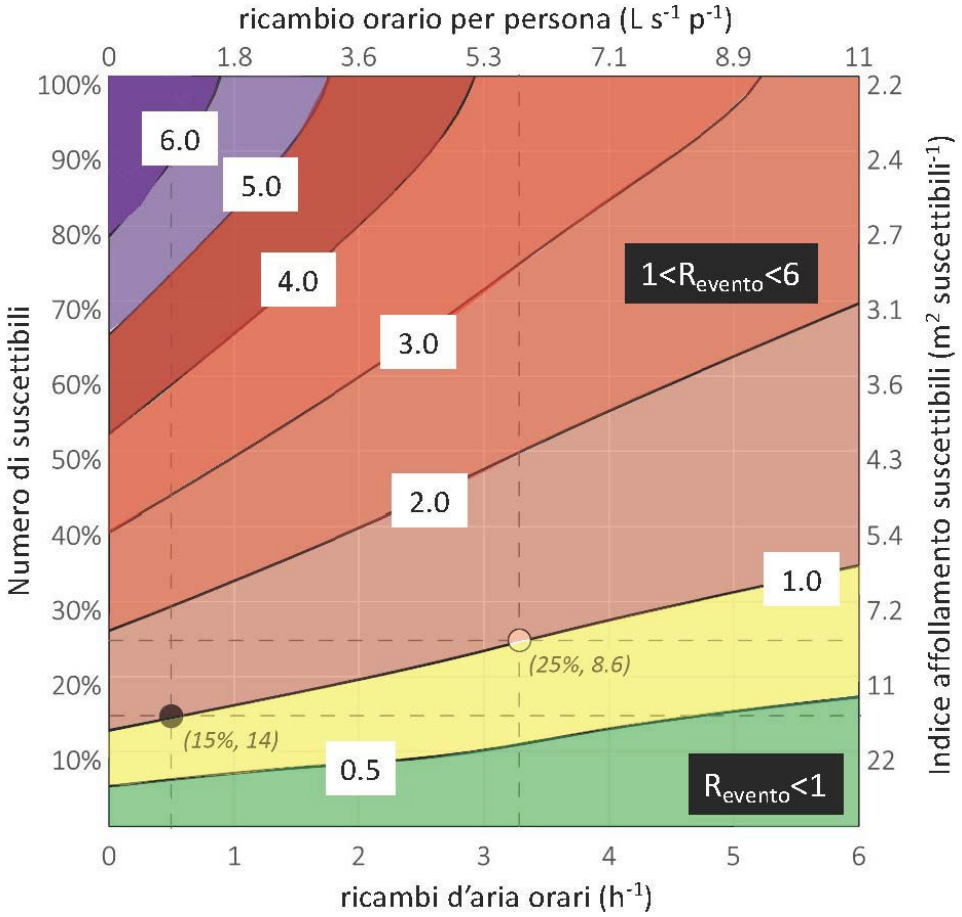
Come minimizzare il rischio a scuola: classe di 50x3 m3, 25 studenti, insegnante infetta su 2 ore che spiega ad alta voce, ventilazione naturale, tempo esposizione 300 min

		Rischio individuale infezione (%)	Massimo numero di persone contagiate	Numero massimo di persone per avere R0<1
1	Zero precauzioni	15	12	2
●	Ventilazione forzata (3 vol/h)	4.3	4	5
2	Mascherine	7.6	7	3
●	Microfono (bassa voce)	2.7	1,4	9
●	Mascherine + Ventilazione forzata	2.2	2	11
3	Mascherine +ventilazione forzata +microfono	0,8	0,4	30>25


Schools with mechanical ventilation
User input screen
Input of parameters to define the scenario:
• emitting subject
• exposure time
• classroom volume
Control unit
Calculates the required AER to obtain $R_{event} < 1$
Sets the constant flow rate of the mechanical ventilation system
Mechanical ventilation system
Provides the set (constant) flow rate to guarantee the required AER.
No feedback is needed.
Schools without mechanical ventilation
User input screen
Input of parameters to define the scenario:
• emitting subject
• exposure time
• classroom volume
Input of the number of persons & their activity
CO_2 sensor
$CO_{2\text{-in}}$ measurement:
$CO_{2\text{-in}}$
1st airing cycle
Windows closed
Windows open
Actual (measured) $CO_{2\text{-in}}$ trend
time
Control unit
Defines tentative window opening and closing periods for the 1st manual airing cycle
..... end of 1st manual airing cycle .....
Estimates the CO_2 emission rate
Calculates the actual AER_{MA} and AER_{NV} on the basis of the measured $CO_{2\text{-in}}$ trend
Defines the manual airing cycles to be adopted for the remaining four hours on the basis of actual values of AER_{MA} and AER_{NV}
..... end of 2nd manual airing cycle _ _
Repeats the correction at each cycle
Visual Alert
Reminds when manually opening or closing the windows at each airing cycle through a visual alert.

R_t in ristoranti

100 persone
Volume = 640 m³
Tempo di esposizione = 1.5 ore

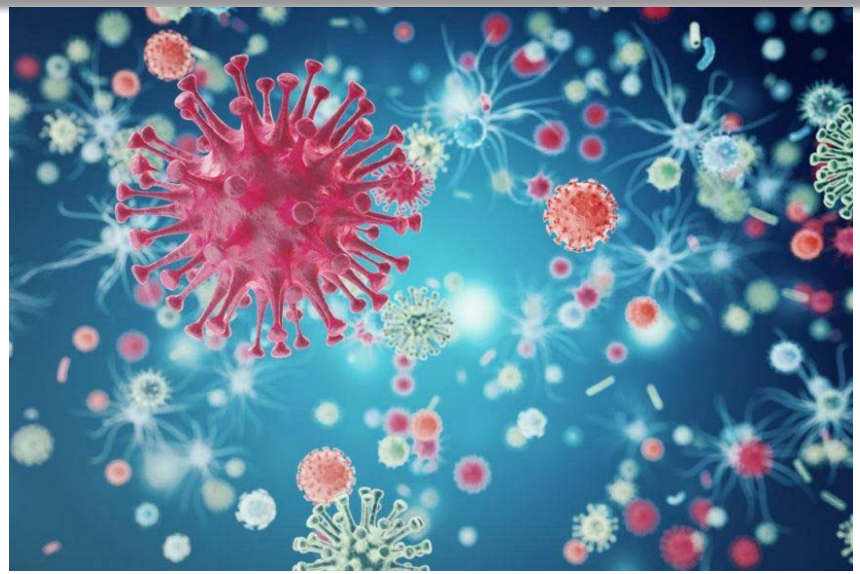


Articoli scientifici

- Buonanno, Stabile, Morawska, 2020. *Estimation of airborne viral emission: Quanta emission rate of SARS-CoV-2 for infection risk assessment*. Environment International;
- Buonanno, Stabile, Morawska, 2020. *Quantitative assessment of the risk of airborne transmission of SARS-CoV-2 infection: Prospective and retrospective applications.* Environment International;
- Moreno, Buonanno, Stabile, et al., 2021. *Tracing surface and airborne SARS-CoV-2 RNA inside public buses and subway trains.* Environment International;
- Stabile, Buonanno et al., 2021. *Ventilation procedures to minimize the airborne transmission of viruses at schools*. Building and Environment;
- Cortellessa, Stabile, Buonanno, et al., 2021. *Close contact risk assessment for SARS-CoV-2 infection.* Science of the Total Environment;
- Tang, Buonanno, et al., 2021. *Dismantling myths on the airborne transmission of severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2)*. Journal of Hospital Infection.
- Miller, Nazaroff, Buonanno et al., 2021. *Transmission of SARS-CoV-2 by inhalation of respiratory aerosol in the Skagit Valley Chorale superspreading event*. Indoor Air;
- Mikszewski, Stabile, Buonanno, Morawska, 2021. *Estimating the vaccination threshold for control of sars-cov-2: application of airborne infection risk modeling*. PNAS.
- Mikszewski, Stabile, Buonanno, Morawska, 2021. *The airborne contagiousness of respiratory viruses: a comparative analysis and implications for mitigation*. Journal of Infectious Diseases.
- Morawska, Buonanno, 2021. *The physics of particle formation and deposition during breathing*. Nature Reviews Physics;
- Torkmahalleh, Stabile, Buonanno et al., 2021. *Global air quality and covid-19 pandemic: Do we breathe cleaner air?* Aerosol and Air Quality Research.
- Morawska, Buonanno et al., 2021. Paradigm shift to combat indoor respiratory infection. Science

e pur si muove …

Grazie per l'attenzione



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