UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

Aerosol or droplet transmission; The impact on non-pharmaceutical interventions to reduce transmission of COVID-19

Prof Derk Brouwer

PhD Exposure Science, ROH

WITS School of Public Health

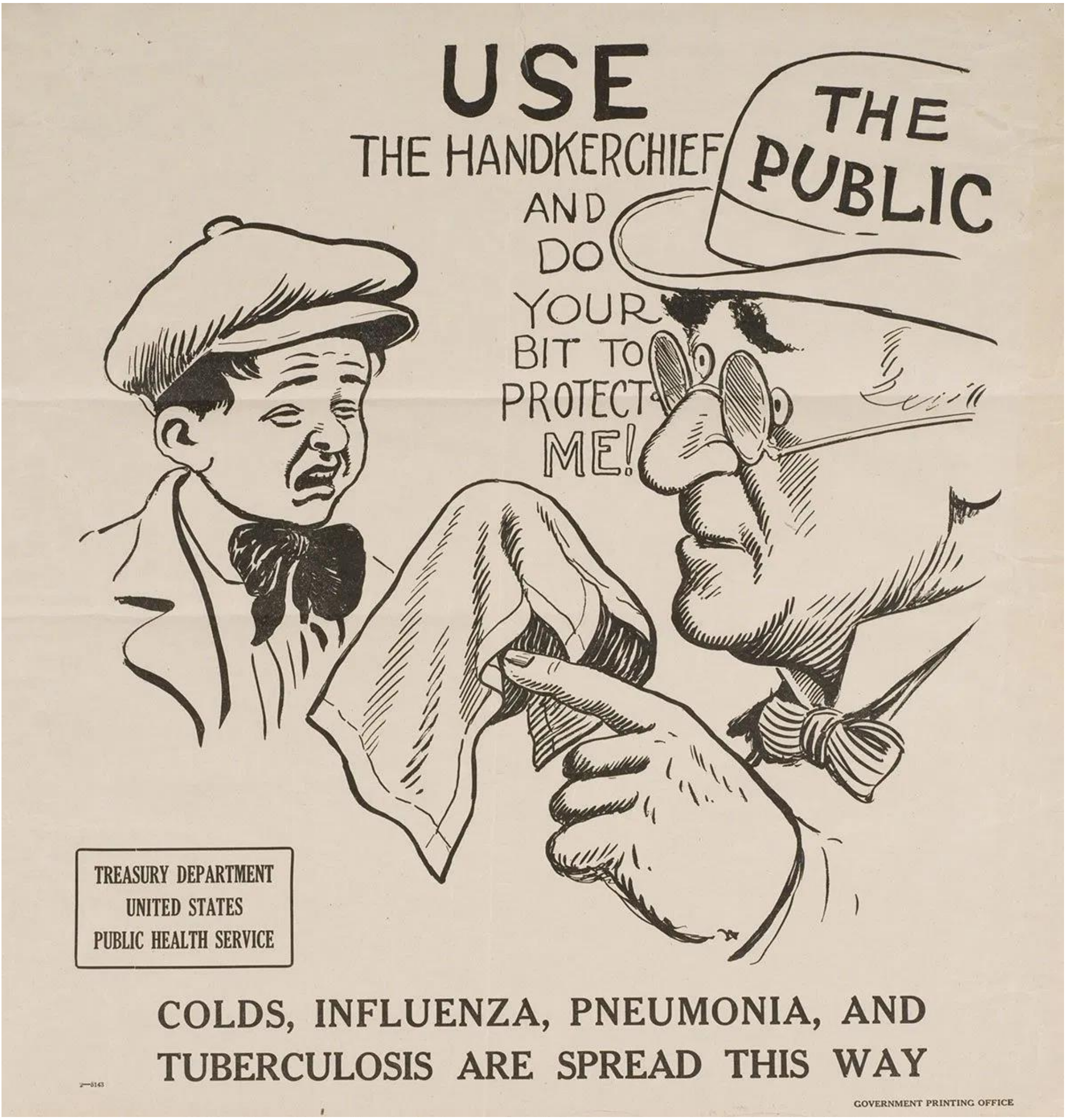
Disclaimer

- The presenter is neither a virologist nor an aerosol scientist, but just an exposure scientist.
- The presentation is grounded on published papers and not on the presenter's original work.

Droplets……

February 2020
https://www.youtube.com/watch?v=SO9JfbZBSDg

Awareness campaigns: Past…



November 1918

United States Public Health Service

Awareness campaigns: 2020

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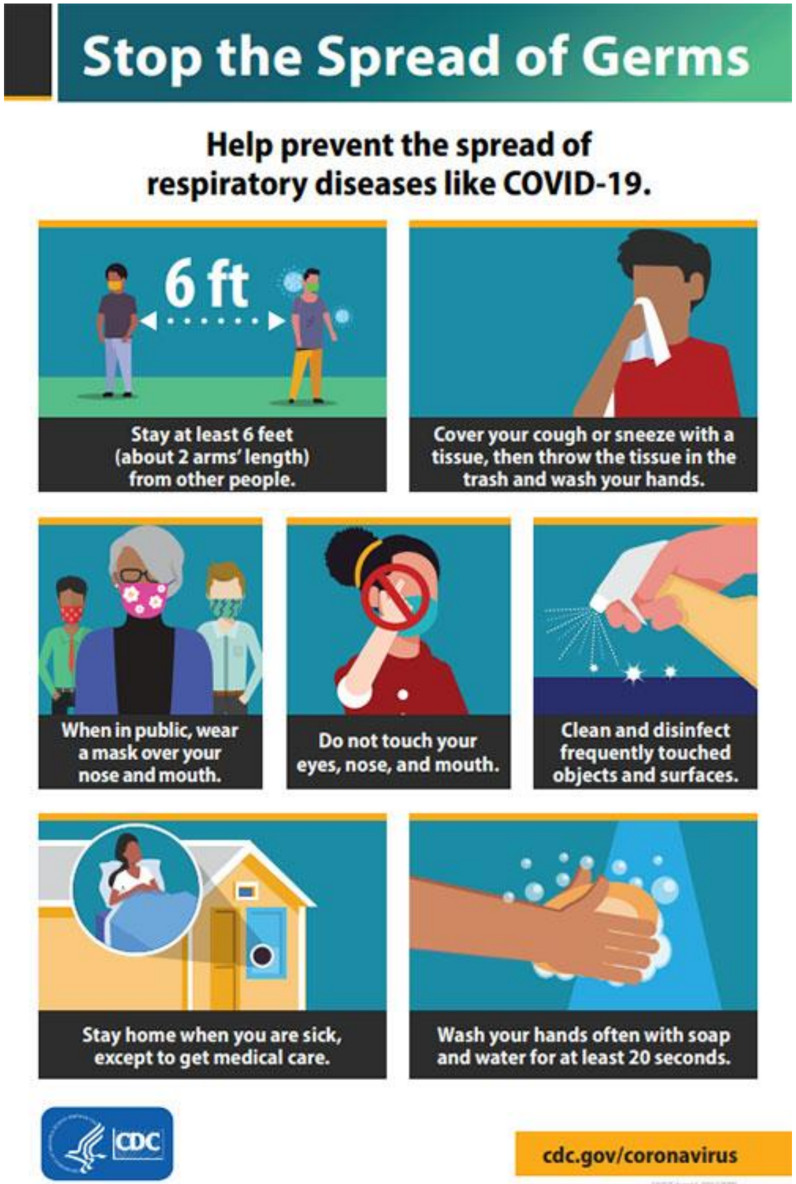
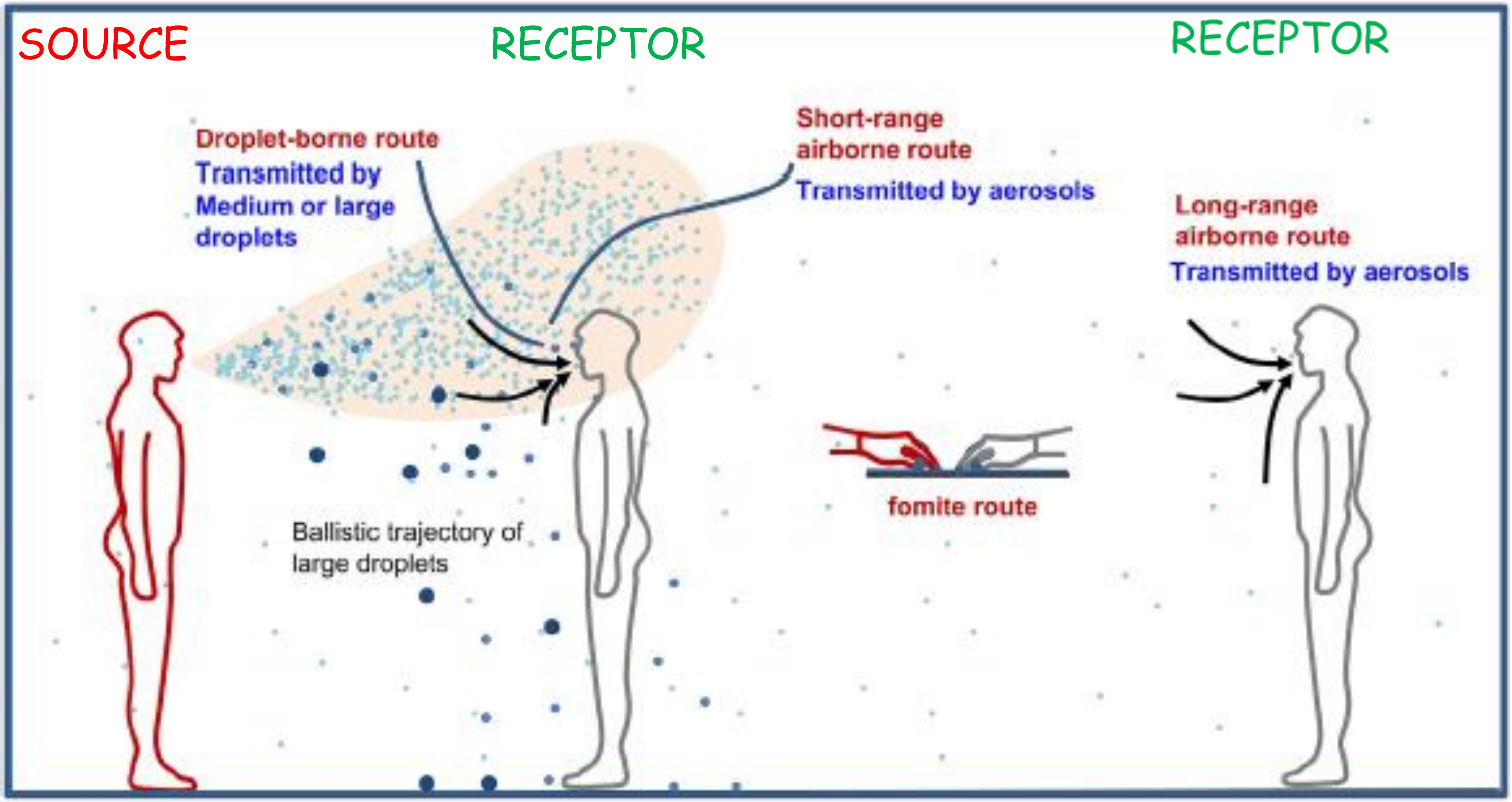


August 2020
US-CDC Centers for Disease Control and Prevention

The transmission paradigm

J. Wei, Y. Li / American Journal of Infection Control 44 (2016) S102-S108



- Large droplets (>100 µm) : Fast deposition due to the domination of gravitational force
- Medium droplets between 5 and 100 µm
- Small droplets or droplet nuclei, or aerosols (< 5 µm): Responsible for airborne transmission

Source:
Wei & Li,2016

The 'controversial' issues regarding SARS-CoV-2

Public Health Agencies ⟷ Aerosol Science community

Dominance of transmission pathway: droplet vs aerosol or short-range vs long-range

Definition of aerosol/ cut-off size

Historical perspective (1)

thebmj covid-19 Research Education News & Views Campaigns Jobs

Analysis

Two metres or one: what is the evidence for physical distancing in covid-19?

BMJ 2020 ; 370 doi: https://doi.org/10.1136/bmj.m3223 (Published 25 August 2020)
Cite this as: *BMJ* 2020;370:m3223

Read our latest coverage of the coronavirus outbreak

Two metres or one: what is the evidence for physical distancing in covid-19?

Rigid safe distancing rules are an oversimplification based on outdated science and experiences of past viruses, argue **Nicholas R Jones and colleagues**

Nicholas R Jones, Zeshan U Qureshi, [2] Robert J Temple, [3] Jessica P J Larwood, [4] Trisha Greenhalgh, [1] Lydia Bourouiba[5]

Historical perspective (2)

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How Did We Get Here: What Are Droplets and Aerosols and How Far Do They Go? A Historical Perspective on the Transmission of Respiratory Infectious Diseases

17 Pages • Posted: 28 Apr 2021

Katherine Randall
Virginia Tech

E. Thomas Ewing
Department of History

Linsey Marr
Virginia Tech

Jose Jimenez
University of Colorado

L. Bourouiba
Massachusetts Institute of Technology

Randall, Katherine and Ewing, E. Thomas and Marr, Linsey and Jimenez, Jose and Bourouiba, Lydia, How Did We Get Here: What Are Droplets and Aerosols and How Far Do They Go? A Historical Perspective on the Transmission of Respiratory Infectious Diseases (April 15, 2021). Available at SSRN: https://ssrn.com/abstract=3829873

Origins of the 5 micron cut-off(?)

(Randell et al., 2021)

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William Wells
(1887 – 1963)

Not just what stays suspended but what would truly infectious based on the ability to reach the deepest lungs, e.g. particles 1-5 μm

Wells, William Firth. Airborne Contagion and Air Hygiene. An Ecological Study of Droplet Infections. **1955.** Cambridge : Harvard University Press

Droplet size is relevant because of where the aerosols are deposited in the lungs.
(Distinguish large droplets and aerosols (< 5 μm))

Langmuir AD Airborne Infection: how important for public Health? **1964** AM J Pub Health,

Alexander Langmuir
(1910 - 1993)

Origins of the 1-2 m rule

(Randell et al., 2021)

- Short-range liquid droplet fallout on other persons or surfaces
- Ballistic: / distance travelled by droplet
- Limitations (historical studies)
  - Resolution optical techniques
  - Deposition on colony growing plates and short sampling times
    - Threshold of infectious dose (TB)

Carl Flügge
(1847 – 1923)

Visualization of a sneeze
(Jones et al., 2020 BMJ)

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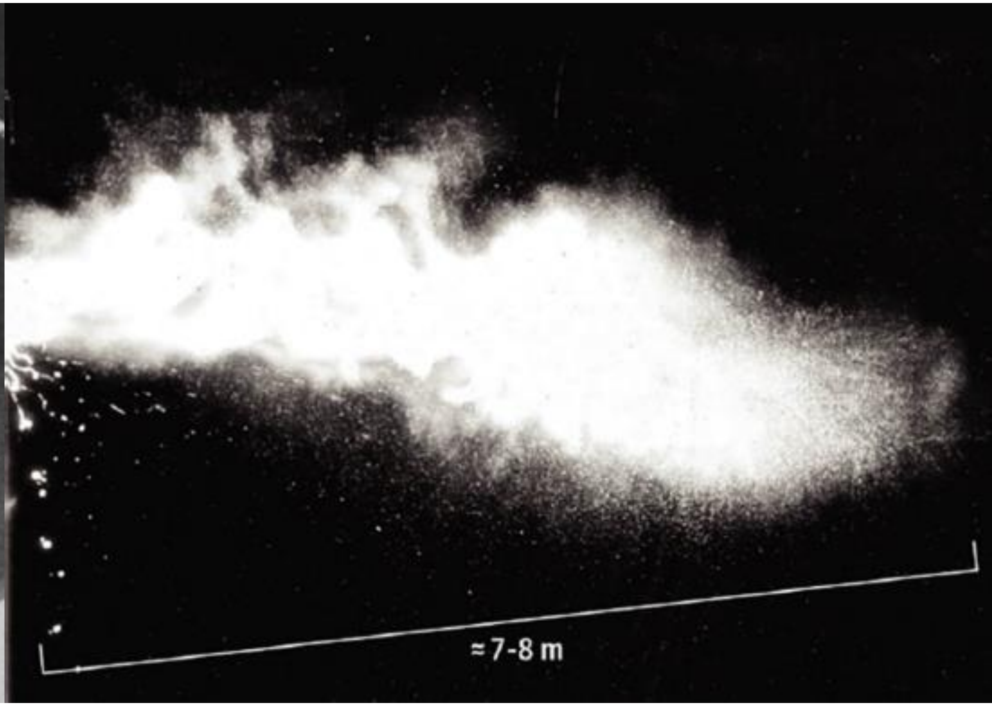
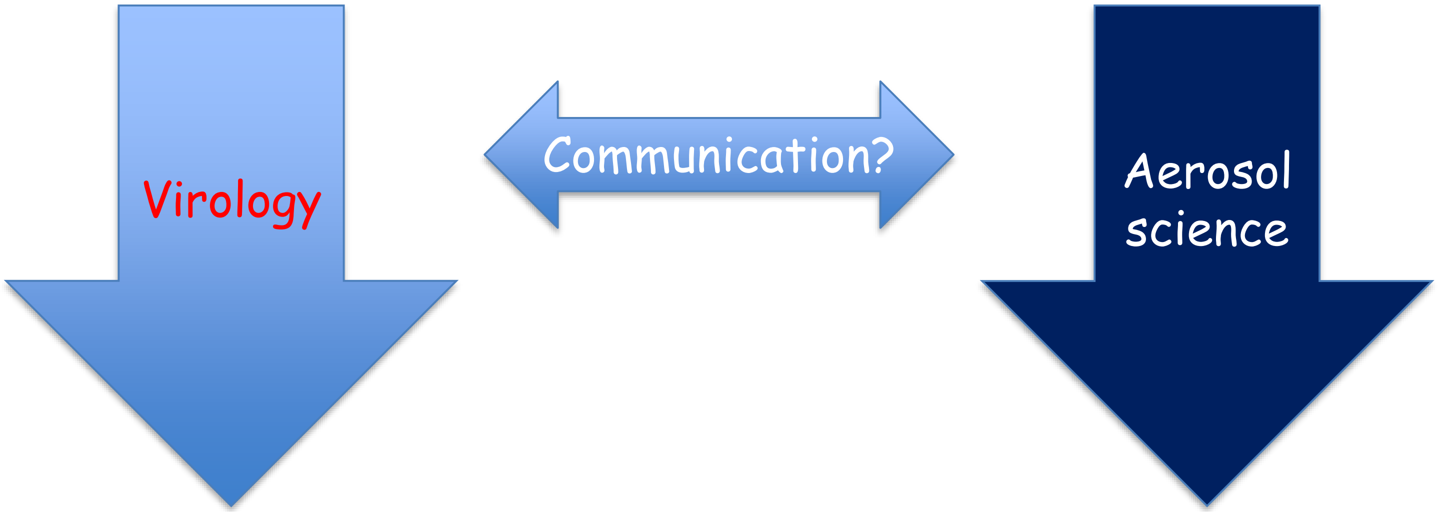
1942

2020



Two worlds..



Focus on droplet fate and the 'receptor'

Focus on emission and transport

Input from aerosol science

Available online at www.sciencedirect.com

Journal of Hospital Infection

journal homepage: www.elsevier.com/locate/jhin

Review

Tang et al, 2021 J Hosp Inf 110:89-96

Dismantling myths on the airborne transmission of severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2)

J.W. Tang [a], W.P. Bahnfleth [b], P.M. Bluyssen [c], G. Buonanno [d], J.L. Jimenez [e], J. Kurnitski [f], Y. Li [g], S. Miller [h], C. Sekhar [i], L. Morawska [j], L.C. Marr [k], A.K. Melikov [l], W.W. Nazaroff [m], P.V. Nielsen [n], R. Tellier [o], P. Wargocki [l], S.J. Dancer [p, q, *]

Myth 1: 'aerosols are droplets with a diameter of 5 μm or less'

This myth originated from a historically incorrect definition, reported more recently by the World Health Organization as '... droplets <5 μm in diameter are referred to as droplet nuclei or aerosols' [2].

Respiratory droplets, formed from respiratory secretions and saliva, are emitted through talking, coughing, sneezing and even breathing. Their diameters span a spectrum from <1 μm to >100 μm. The smaller droplets desiccate rapidly to 20–40% of their original diameter, leaving residues called 'droplet nuclei' which most clinicians believe to be synonymous with

size threshold to distinguish droplets from aerosols, in terms of their physical behaviour and route of exposure, is 100 μm [20]. To clarify the terminology used in this review, therefore, droplets are particles that fall to the ground (or any surface including vertical surfaces) under the influence of gravity and/or the momentum of an infected person's exhaled air; and aerosols are particles that remain suspended due to size and/or environmental conditions. The term 'particles' will be used to refer to droplets/aerosols in general.

Myth 2: 'all particles larger than 5 μm fall within 1–2 m of the source'

This is an oft-repeated but scientifically false statement.

Same terminology…
different silos..different meanings

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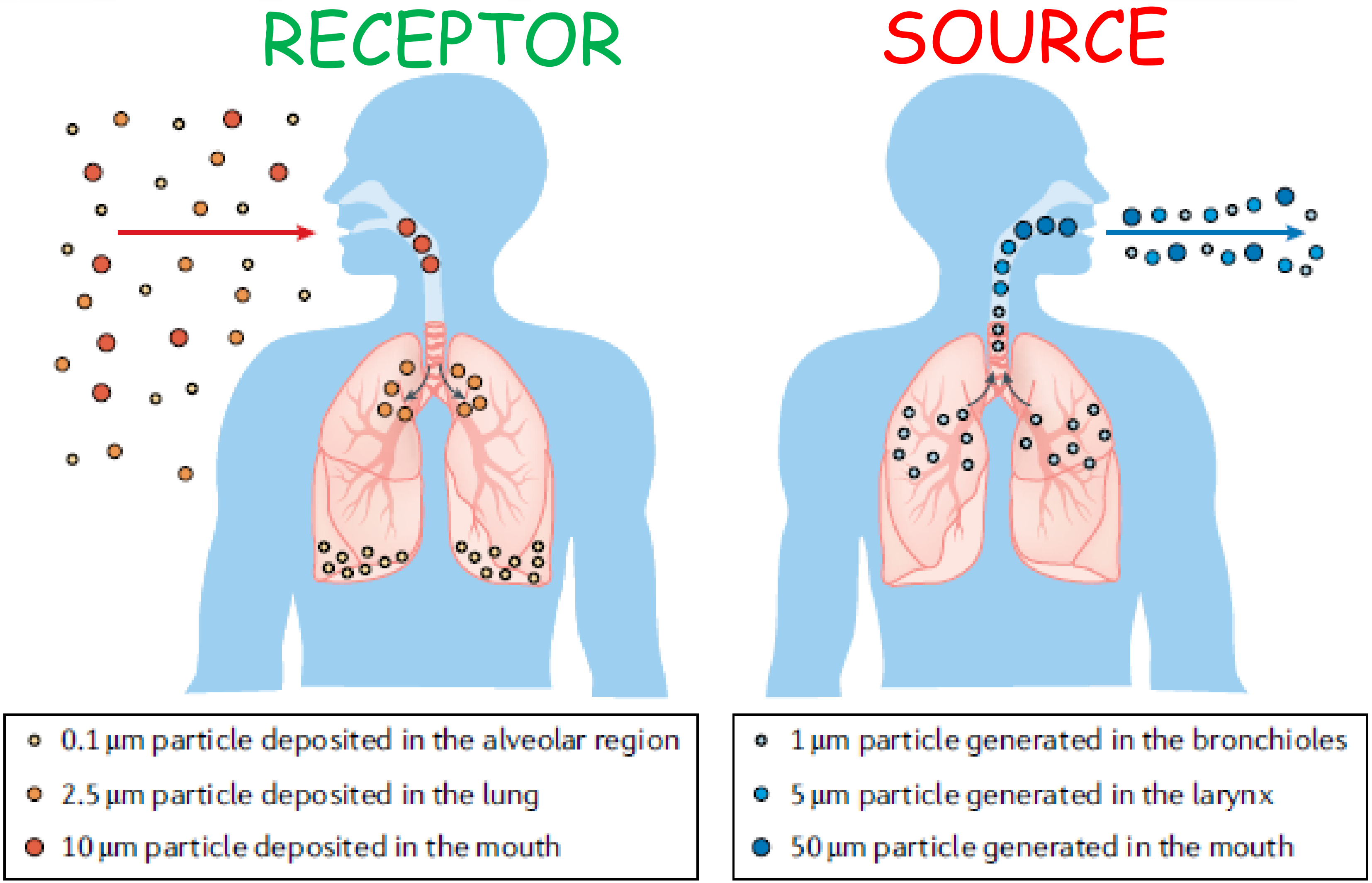
Table I
Differences between clinicians, aerosol scientists and the general public in understanding of airborne terminology

Term	Clinicians	Aerosol scientists	General public
Airborne	Long-distance transmission, such as measles; requires an N95/FFP2/FFP3 respirator (or equivalent) for infection control	Anything in the air	Anything in the air
Aerosol	Particle <5 μm that mediates airborne transmission; produced during aerosol-generating procedures and also requires an N95 respirator	Collection of solid or liquid particles of any size suspended in a gas	Hair spray and other personal/cleaning products
Droplet	Particle >5 μm that falls rapidly to the ground within a distance of 1–2 m from source; requires a surgical mask for infection control	Liquid particle	What comes out of an eyedropper
Droplet nuclei	Residue of a droplet that has evaporated to <5 μm; synonymous with 'aerosol'	A related term, 'cloud condensation nuclei', refers to small particles on to which water condenses to form cloud droplets	Never heard of!
Particle	Virion	Tiny solid or liquid 'blob' in the air	Like soot or ash

Particle size distributions



Morawska & Buonanno, 2021
Nature Review Physics

Aerosol Dynamics and droplet fate

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Environmental Science & Technology

pubs.acs.org/est

Article

Aerosol Dynamics Model for Estimating the Risk from Short-Range Airborne Transmission and Inhalation of Expiratory Droplets of SARS-CoV-2

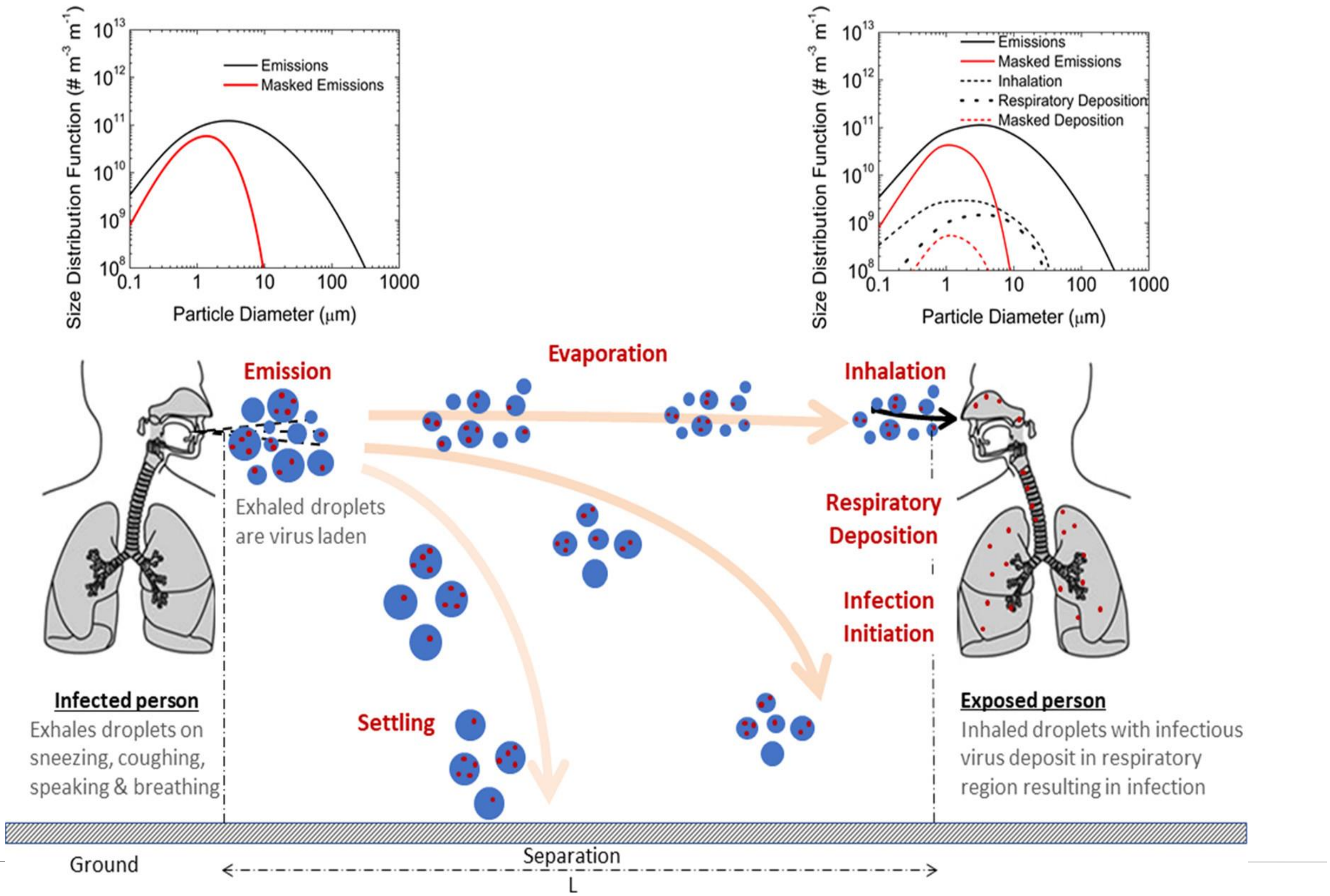
Sukrant Dhawan and Pratim Biswas*

Cite This: https://doi.org/10.1021/acs.est.1c00235

Read Online

Dhawan & Biswas, EST 2021

Aerosol Dynamics and droplet fate



DOI: (10.1021/acs.est.1c00235)

Horizonatal distance traversed

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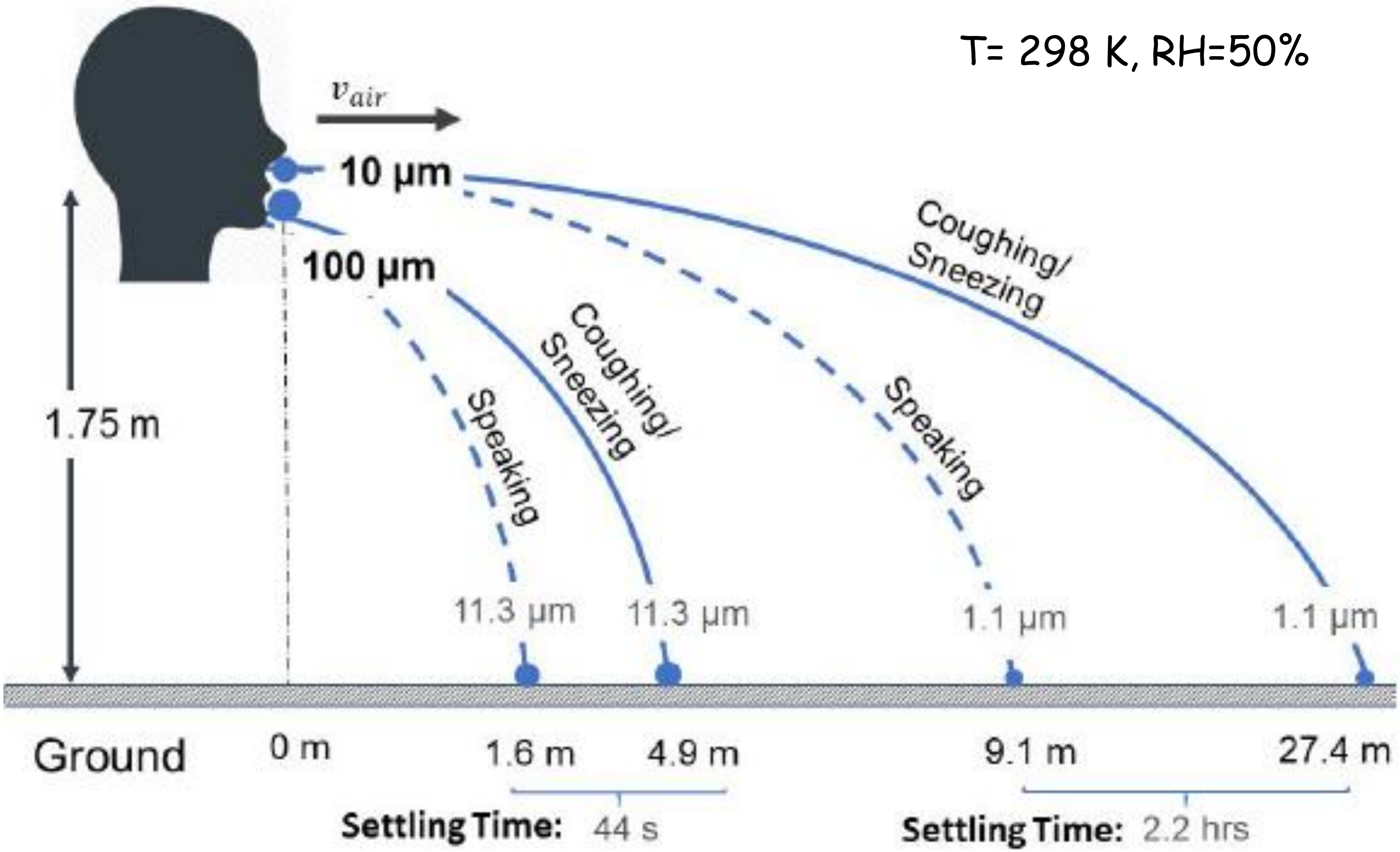
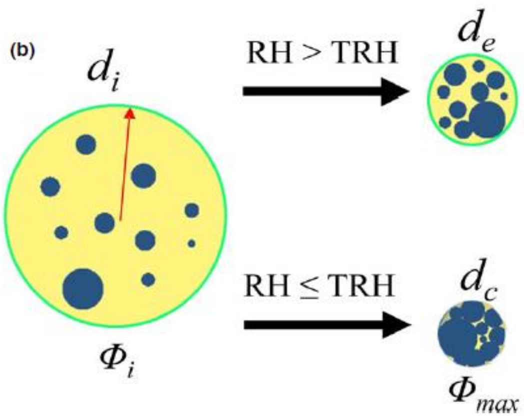
T= 298 K, RH=50%



Dhawan & Biswas, EST 2021

Droplet composition and RH

Liu et al, 2016b
Indoor Air



Droplet nuclei formation;
At high RH (> Threshold RH) equilibrium is maintained;
At low RH a crust is formed

Evaporation
100 μm at 95% RH ~ 100s
10μm at 35% RH ~ 2s

Dried –out droplet nuclei ~ 30% initial droplet size

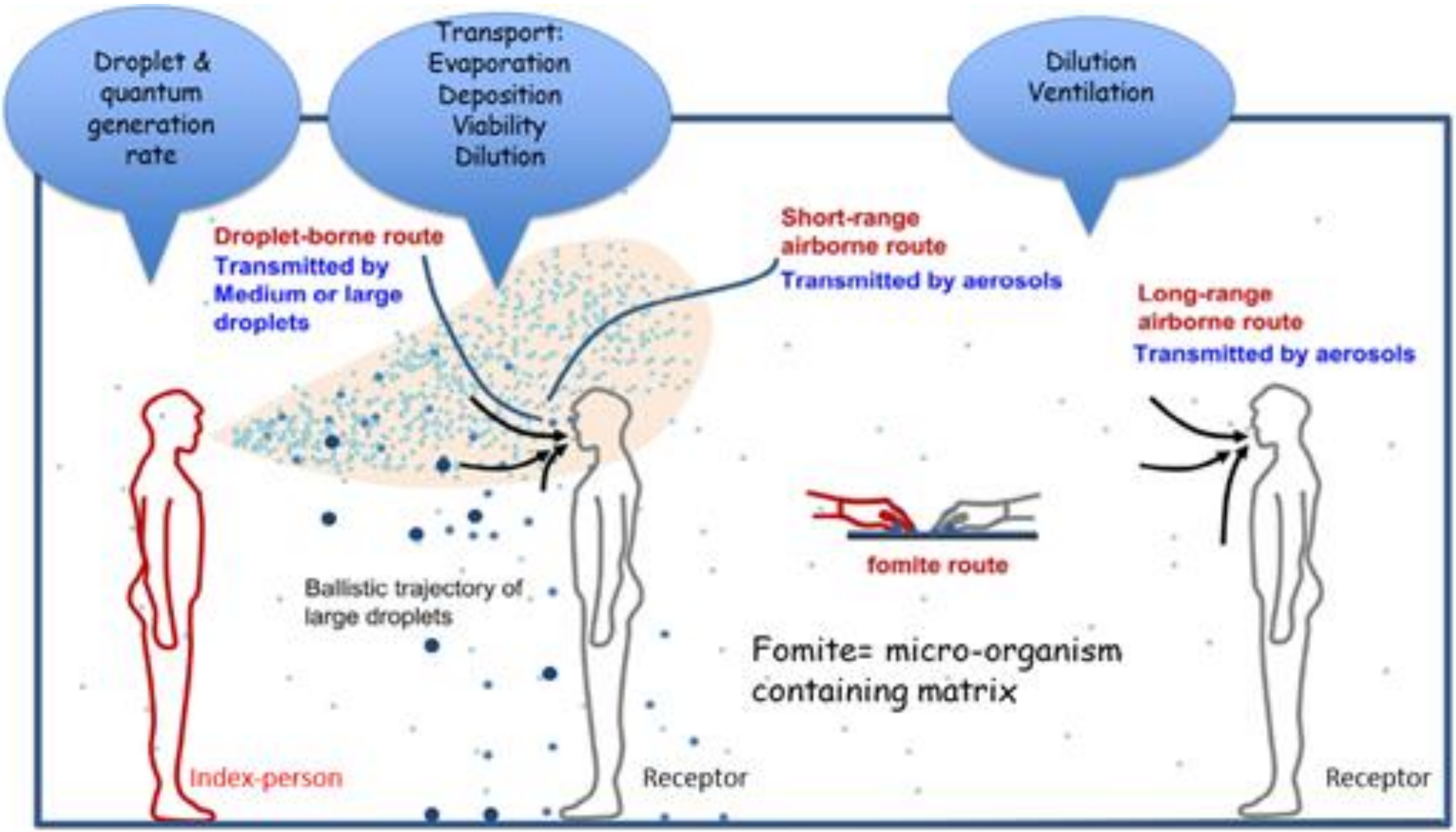
Implications

- Droplets generated by both (symptomatic and asymptomatic) infected persons (suspended in air) can travel beyond 2 m in indoor air
- Droplets will decrease their initial size due to (environmental conditions depending) evaporation and remain suspended for several hours

Summary of source-receptor model parameters

	Parameters		Affects
SOURCE			
Emission of aerosolized sputum and saliva	Symptomatic	Sneezing Coughing	Initial particle size distribution (PSD) Initial particle velocity Quanta rate
	Asymptomatic	Speaking Breathing	
TRANSPORT	Environ-mental conditions	RH T Air velocity	Evaporation rate Deposition rate -final PSD Virus inactivation rate Loss
	Ventilation	AER	
RECEPTOR	Distance to source Activity pattern/ breathing rate		BZ viral concentration Lung deposition (efficacy location in RT)

The transmission paradigm (2)



- Large droplets (>100 μm) : Fast deposition due to the domination of gravitational force
- Medium droplets between 5 and 100 μm
- Small droplets or droplet nuclei, [redacted] : Responsible for airborne transmission

Quantative risk assessment modelling

Early 2020

Environment International 145 (2020) 106112

Contents lists available at ScienceDirect

Environment International

journal homepage: www.elsevier.com/locate/envint

Quantitative assessment of the risk of airborne transmission of SARS-CoV-2 infection: Prospective and retrospective applications

G. Buonanno [a,b], L. Morawska [b], L. Stabile [a,*]

Research

A Section 508–conformant HTML version of this article is available at https://doi.org/10.1289/EHP7886.

Quantitative Microbial Risk Assessment for Airborne Transmission of SARS-CoV-2 via Breathing, Speaking, Singing, Coughing, and Sneezing

Jack Schijven,[1,2] Lucie C. Vermeulen,[1*] Arno Swart,[1] Adam Meijer,[1] Erwin Duizer,[1] and Ana Maria de Roda Husman[1,3]*

[1] Centre for Infectious Disease Control, National Institute for Public Health and the Environment (RIVM), Bilthoven, Netherlands
[2] Department of Earth Sciences, Utrecht University, Utrecht, Netherlands
[3] Institute for Risk Assessment Sciences, Utrecht University, Utrecht, Netherland

Environmental Science & Technology

pubs.acs.org/est Article

Aerosol Dynamics Model for Estimating the Risk from Short-Range Airborne Transmission and Inhalation of Expiratory Droplets of SARS-CoV-2

Sukrant Dhawan and Pratim Biswas*

Cite This: https://doi.org/10.1021/acs.est.1c00235 Read Online

Modelled risk of infection
at separation of 2.4 m with no background velocity

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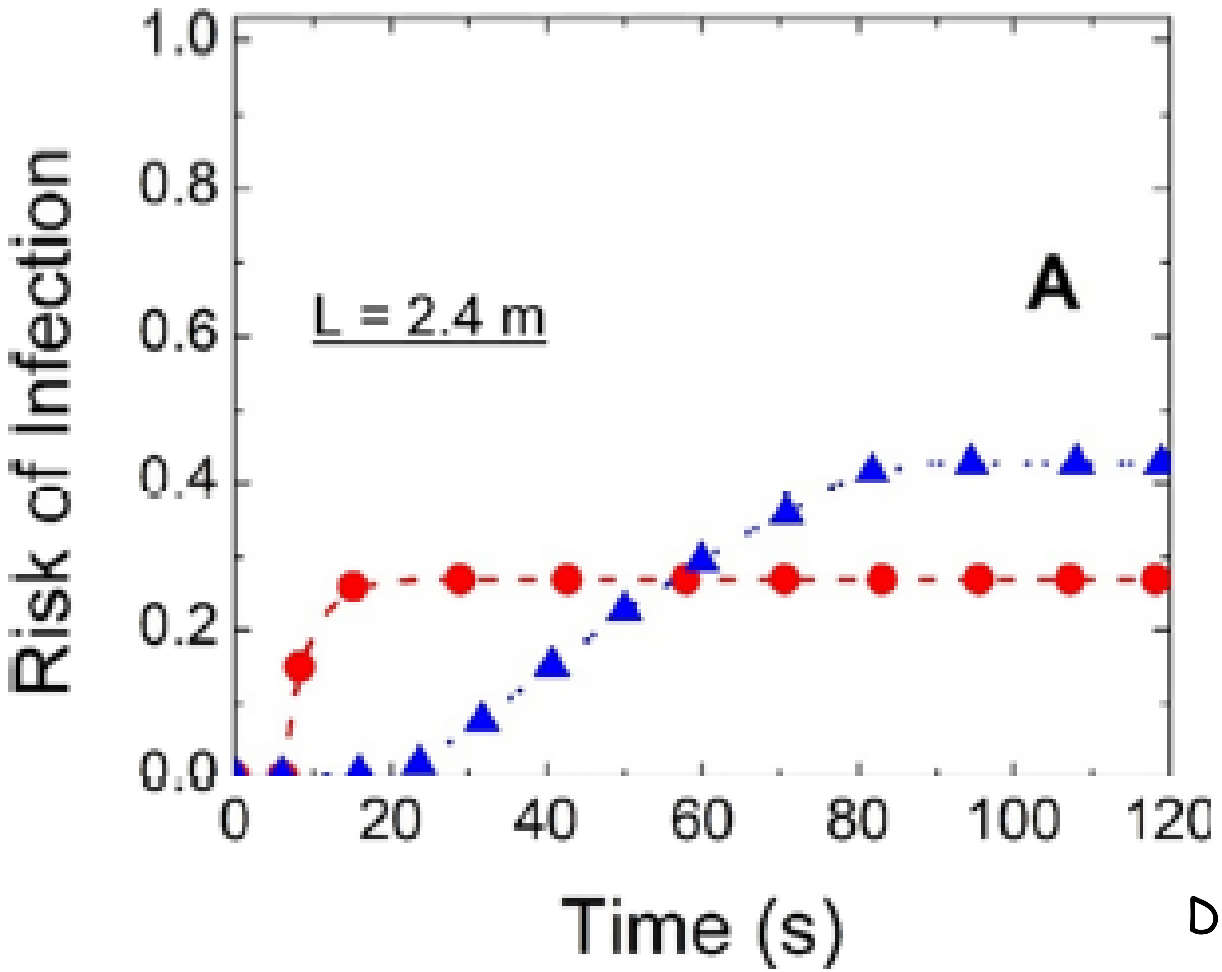
Risk as a function of time



LEGEND

5s cough

1 min speaking

Dhawan & Biswas, EST 2021

Modelled risk of infection with no background velocity

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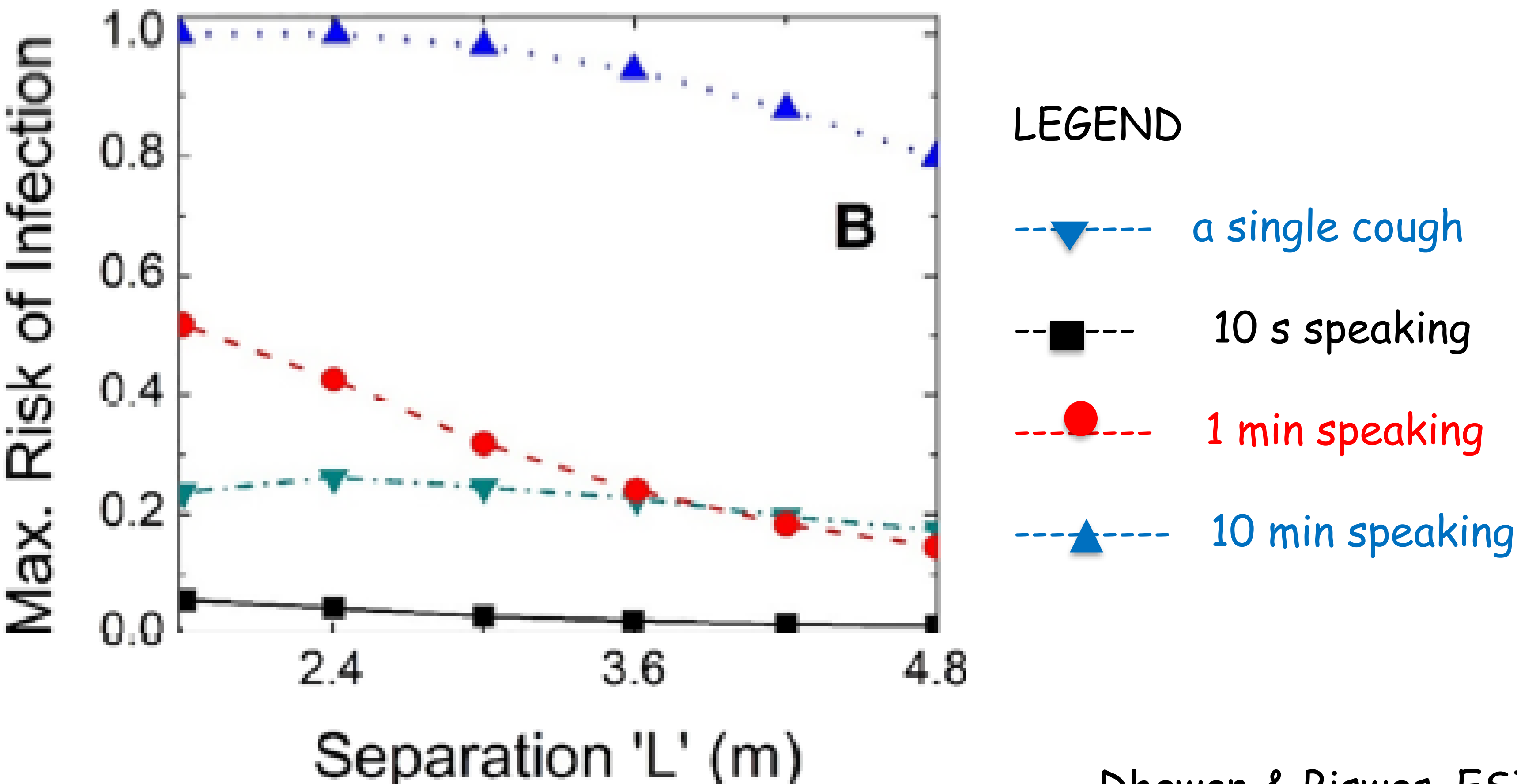
Risk as a function of separation



Dhawan & Biswas, EST 2021

Journal of Theoretical Biology 372 (2015) 100–106

Contents lists available at ScienceDirect

Journal of Theoretical Biology

journal homepage: www.elsevier.com/locate/yjtbi

ELSEVIER

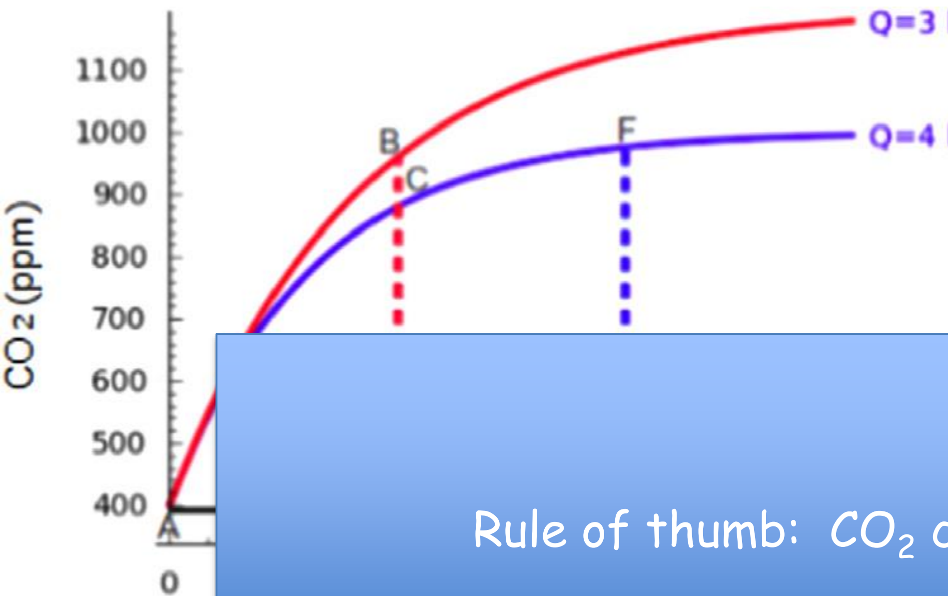
Modelling the risk of airborne infectious disease using exhaled air

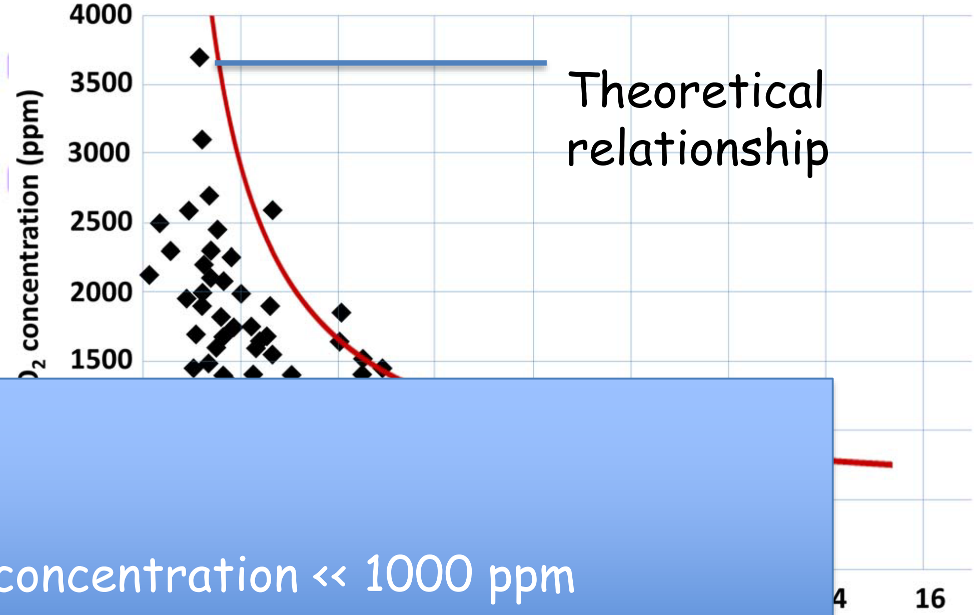
Chacha M. Issarow[a], Nicola Mulder[a,*], Robin Wood[b]

Room occupancy and CO_2-concentration

CO_2 as indicator for level of exhaled air

Determinants: number of occupants, room volume and air ventilation





Rule of thumb: CO_2 concentration << 1000 ppm

Issarow et al , 2015

Concentration in Ambient air

Richardson et al, 2014

Indoor scenario: Classroom

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Building and Environment 202 (2021) 108042

Contents lists available at ScienceDirect

Building and Environment

journal homepage: www.elsevier.com/locate/buildenv

ELSEVIER

Ventilation procedures to minimize the airborne transmission of viruses in classrooms

L. Stabile [a], A. Pacitto [a,*], A. Mikszewski [b], L. Morawska [b], G. Buonanno [a,b]

Modelled risk as function of exhalation rate and room ventilation

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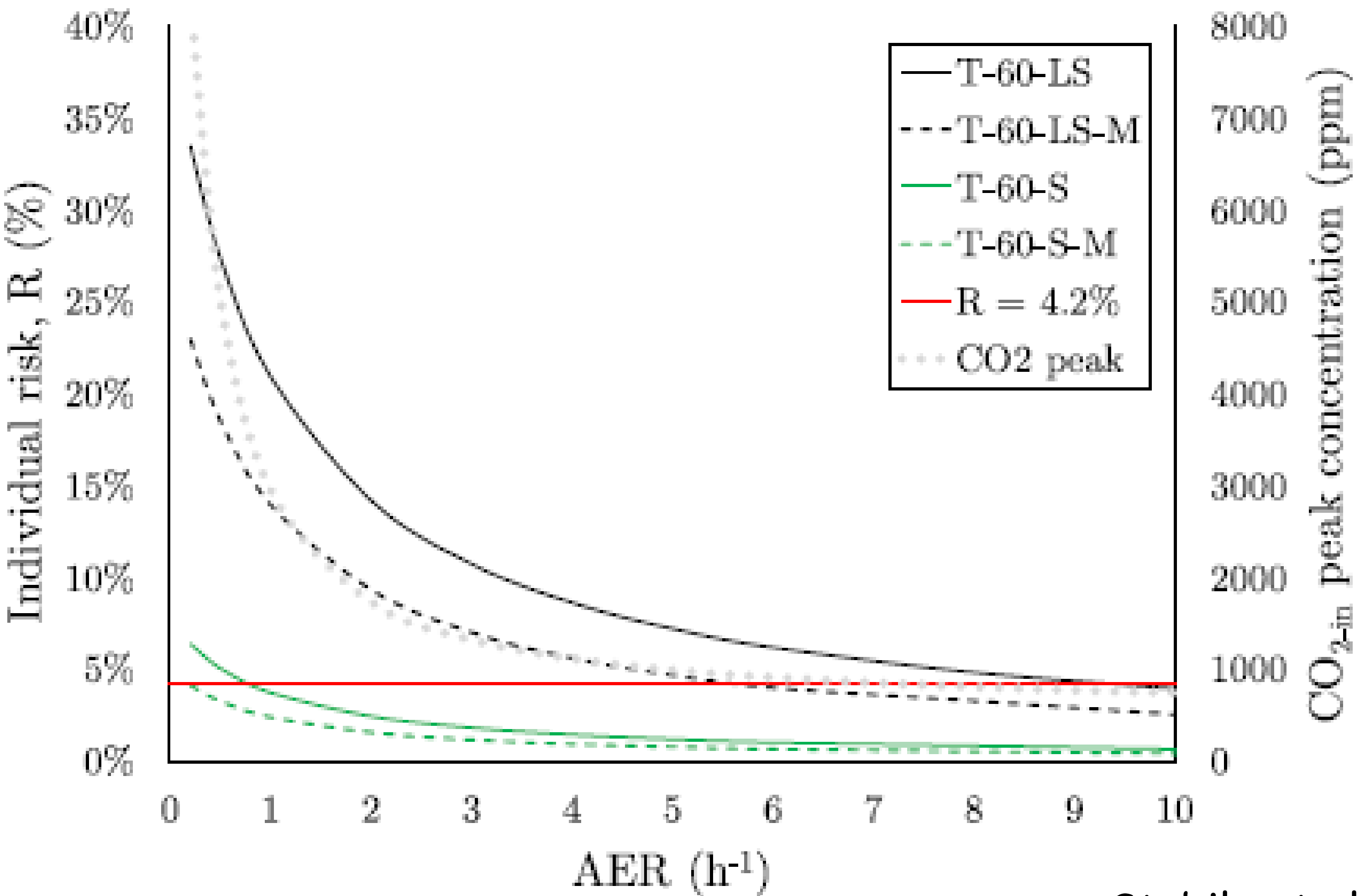

T-60-LS = teacher loudly speaking for 60 mins

T-60-S= teacher speaking

M= effect of mask

Stabile et al., 2021

Proposal for a more flexible risk assessment

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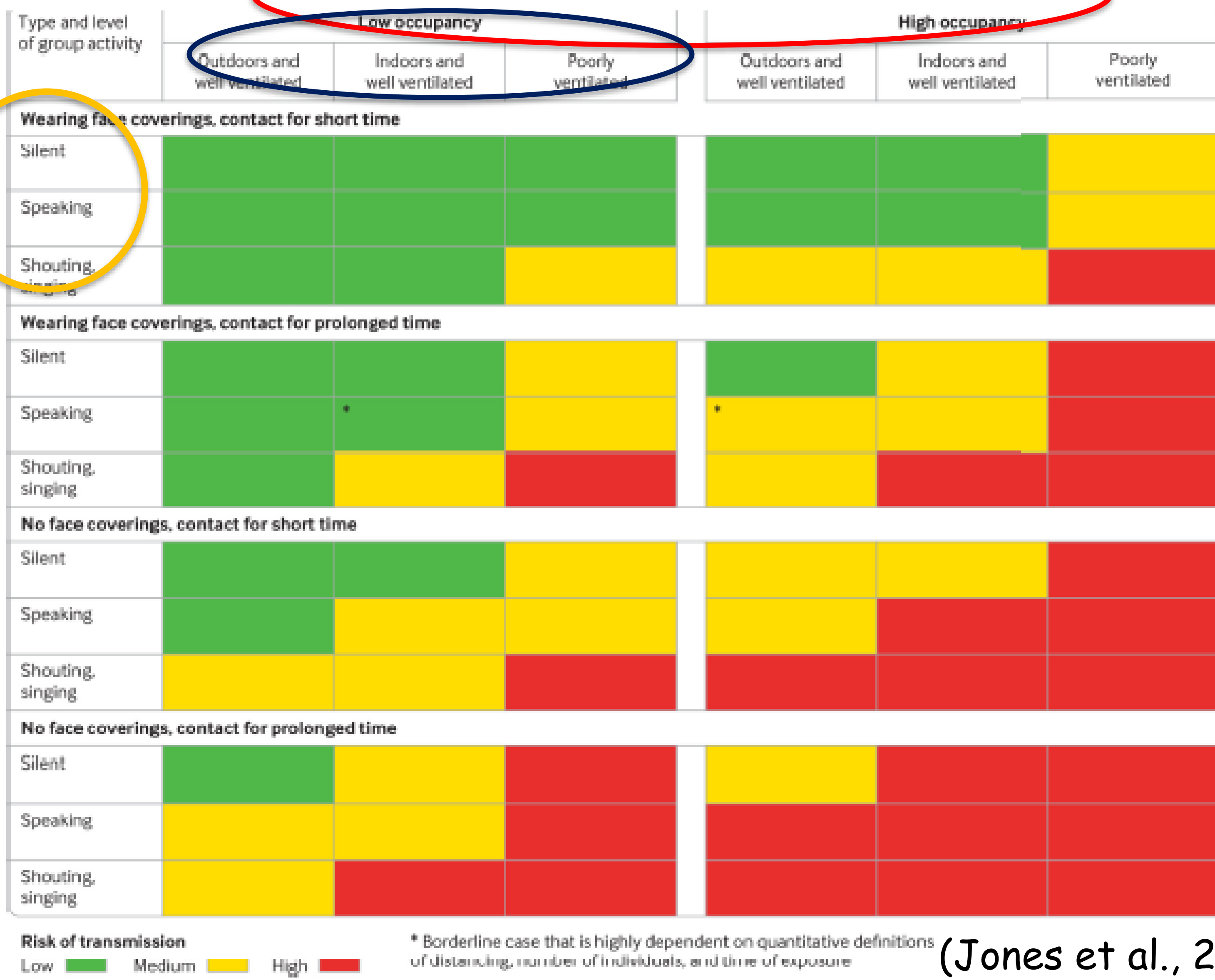


(Jones et al., 2020 BMJ)

Conclusions

- Current rules on safe physical distancing are based on outdated science
- Evidence suggests that substantial infection risk may exist beyond 2 m distance
- Non-pharmaceutical interventions (especially for indoor scenarios should be risk-based
- Ventilation is a key risk management measure!

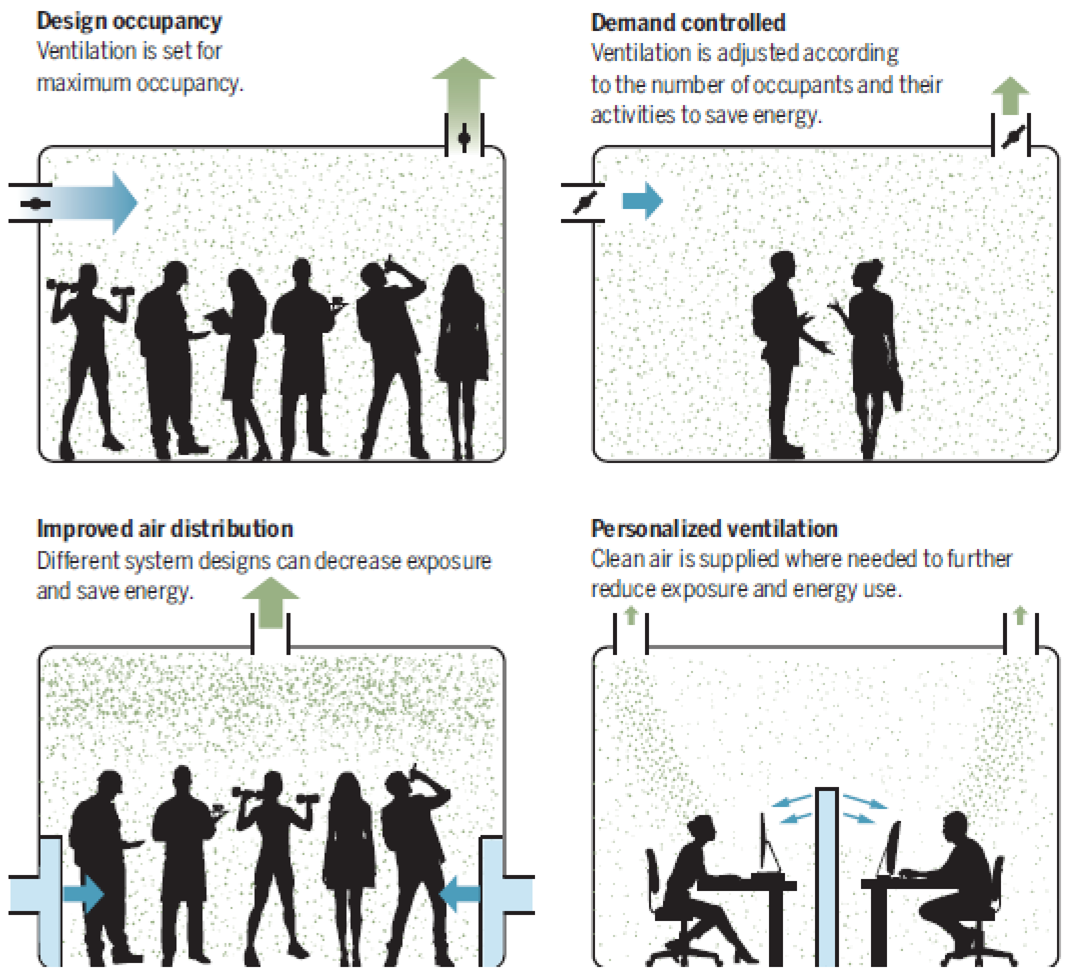
POLICY FORUM

INFECTIOUS DISEASE

A paradigm shift to combat indoor respiratory infection

Building ventilation systems must get much better

By Lidia Morawska, Joseph Allen, William Bahnfleth, 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, Jarek Kurnit Yuguo Li, Marcel Loomans, Guy Marks, Linsey C. Marr, Livio Mazzarella, Arsen Krikor Melikov Shelly Miller, Donald K. Milton, William Nazaroff, Peter V. Nielsen, Catherine Noakes, Jordan Peccia, Kim Prather, Xavier Querol, Chandra Sekhar, Olli Seppänen, Shin-ichi Tanabe, Julian V Tang, Raymond Tellier, Kwok Wai Tham, Pawel Wargocki, Aneta Wierzbicka, Maosheng Yao



Morawska et al., 201,
Science 372:6543

Awareness campaigns: present

derk.brouwer@wits.ac.za