Atic

for HVAC professionals

WAT IS ‘BINNENLUCHTKWALITEIT’ IN TIJDEN VAN CORONA?

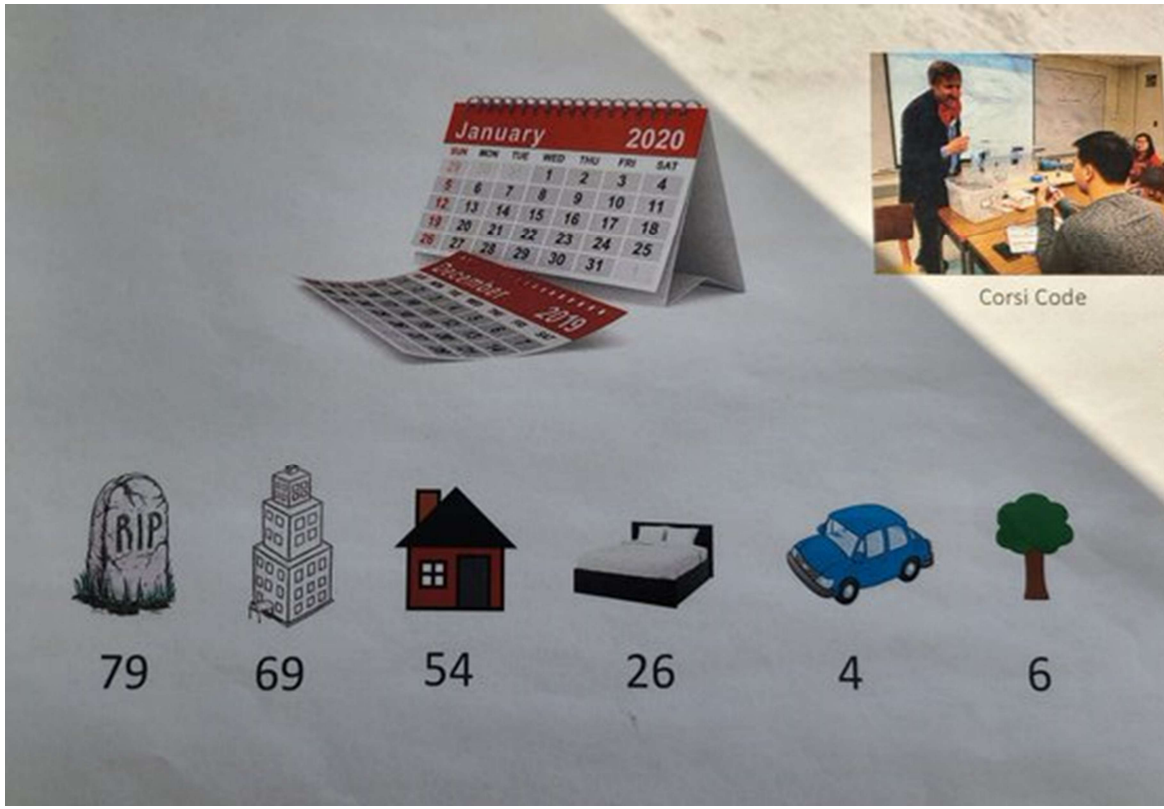
ATIC webinar Last van Corona?

GHENT UNIVERSITY

WAARAAN WORDEN WE BLOOTGESTELD?

inname per jaar:

- water: 1 ton
- voedsel: 1 ton
- lucht: 2.5 ton



GHENT UNIVERSITY

Atic
for HVAC professionals

”THE DEVIL IS IN THE DETAILS”

Chemische samenstelling van normale omgevingslucht

Stof	% van het volume in droge lucht
Stikstof (N_2)	78.09%
Zuurstof (O_2)	20.94%
Argon (Ar)	0.93%
Koolstofdioxide (CO_2)	0.03%

= 99,99%

GHENT UNIVERSITY

Atic for HVAC professionals

Indoor air pollution: new EU research reveals higher risks than previously thought

Do you really know what you are breathing when sitting at home? Europeans spend 90% of their time indoors. But closed environments are not always the healthiest. The latest studies on human exposure to indoor pollution, released today by the European Commission at its Joint Research Centre (JRC)[1] facilities in Ispra (Italy), reveal that indoor environments pose their own threats to health and, in some cases, can be at least twice as polluting as outdoor environments. Hundreds of volatile components have been detected and some of them are toxic, mutagenic or carcinogenic. The number of potential sources is enormous.

GHENT UNIVERSITY

Atic for HVAC professionals

IP/03/1278

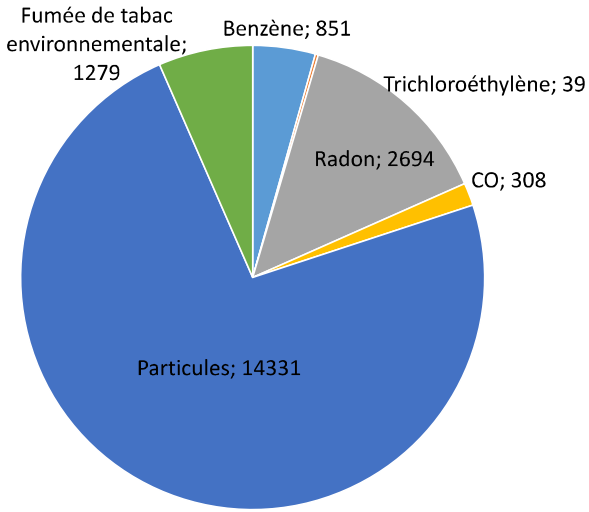
Brussels, 22 September 2003

Table 2
Costs (millions €) of indoor air pollution exposure for the target pollutants, France, 2004.

	Benzene	Trichloroethylene	Radon	CO	Particles	ETS	Total
External costs							
Premature death	− 453	− 19.6	− 2089	− 237	− 5760	− 322	− 8880
Quality of life loss	− 383	− 6.7	− 309	0	− 7350	− 837	− 8886
Lost productivity	− 38	− 1.5	− 282	− 72	− 1102	− 85	− 1580
Total external costs	− 874	− 27.8	− 2680	− 309	− 14,212	− 1244	− 19,347
Public finances							
Health	− 18	− 2.9	− 61	− 3	− 236	− 37	− 358
Research	*	*	*	*	*	*	− 11
Unpaid pensions	10.7	0.45	49	4	136.5	88	289
Raw costs for public finances	− 7.3	− 2.45	− 12	0.9	− 99.5	− 29	− 80
Total costs for public finances	− 8.8	− 2.9	− 14.4	1.1	− 119.4	− 35	− 96
Total costs	− 883	− 30.7	− 2694	− 308	− 14,331	− 1182	− 19,443

* : overall evaluation for all the selected pollutants; CO: carbon monoxide; ETS: environmental tobacco smoke.

Boulanger et al. 2017



Kopp et al. 2014

GHENT UNIVERSITY

Atic for HVAC professionals

Volatile organic chemicals in a strawberry

Esters
- Methyl butyrate
- Ethyl butyrate
- Methyl hexanoate
- Ethyl hexanoate
- Hexyl acetate
- (E)-2-hexenyl acetate
- Butyl hexanoate
- Hexyl butyrate
- Methyl octanoate
- Ethyl octanoate
- Octyl acetate
- Octyl butyrate
- Octyl-2-methyl butyrate
- Hexyl hexanoate
- Octyl isovalerate
- Decyl acetate
- Octyl hexanoate
- Decyl butyrate

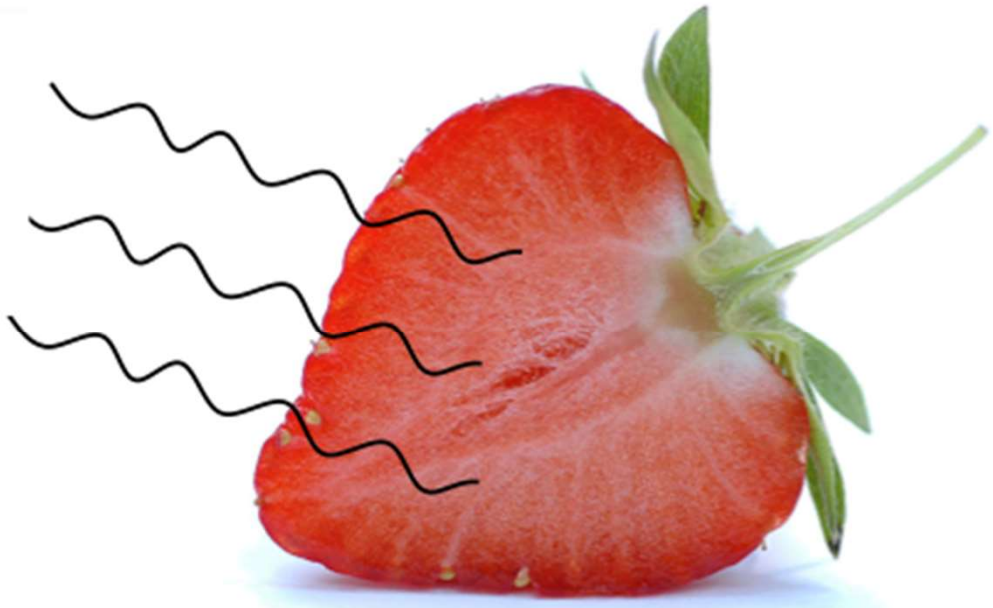
Lactones
- Gamma-decalactone
- Gamma-dodelactone

Aldehydes
- Furfural
- 5-hydroxy methyl furfural

Terpenes
- Limonene
- Linalool
- (E)-Nerolidol

Alcohols
- Hexanol
- Octanol

these put together are what you "smell"



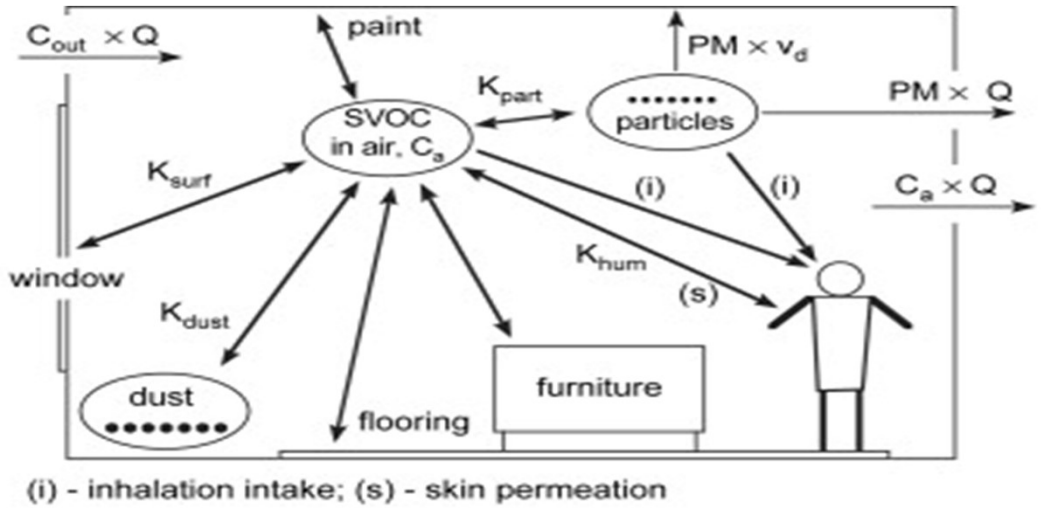
from Kafkas and Paydas, *World Journal of Agricultural Sciences* **3**(2) 191-195 (2007)

WELKE POLLUENTEN?

- Gasvormig ((V)VOC)
- Gasvormig maar met hoog kookpunt (SVOC)
  - grote ‘vloeibare’ hoeveelheid in ruimte
- Partikels (PM)
  - vloeibaar en vaste stof
  - verschillende diameters

GHENT UNIVERSITY

Atic for HVAC professionals



Weschler et al.

EU-LCI WORKING GROUP DG GROWTH

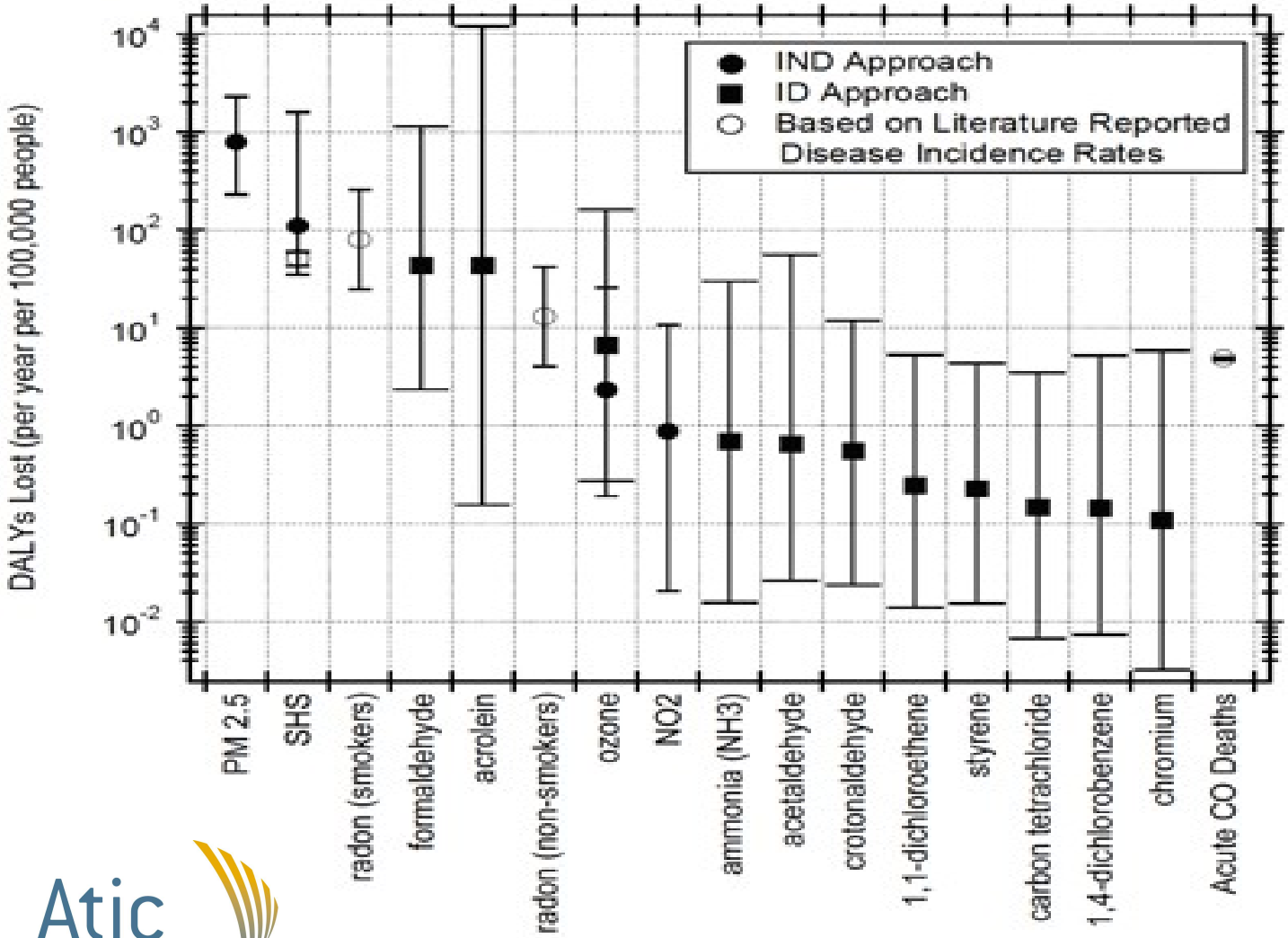
- 153 harmonised LCI values so far
- +- 80 additional in preparation

No.	CAS no.	Compound	EU-LCI (µg/m³)	Status of EU-LCI value	Year of adoption
1		*Aromatic hydrocarbons*			
1-1	108-88-3	Toluene	2900	Derived EU-LCI	2013
1-2	100-41-4	Ethylbenzene	850	Derived EU-LCI	2013
1-3	1330-20-7 106-42-3 108-38-3 95-47-6	Xylene (o-, m-, p-) and mix of o-, m- and p-xylene isomers	500	Derived EU-LCI	2013
1-4*	98-82-8	Isopropylbenzene (cumene)	1700	Derived EU-LCI	2017
1-5	103-65-1	n-Propylbenzene	950	Derived EU-LCI	2013
1-6	108-67-8 95-63-6 526-73-8	Trimethylbenzene (1,2,3-,1,2,4-,1,3,5-)	450	Derived EU-LCI	2013
1-7	611-14-3	2-Ethyltoluene	550	Derived EU-LCI	2014
1-8	527-84-4 535-77-3 99-87-6 25155-15-1	Cymene (o-, m- ,p-,) (1-isopropyl-2(3,4)-methylbenzene) and mix of o-, m-, and p-cymene	1000	Ascribed EU-LCI	2013
1-9	95-93-2	1,2,4,5-Tetramethylbenzene	250	Derived EU-LCI	2016
1-10	104-51-8	n-Butylbenzene	1100	Derived EU-LCI	2014
1-11	99-62-7 100-18-5	Diisopropylbenzene (1,3-, 1,4-)	750	Derived EU-LCI	2013

Procedure based on ECA report 29

GHENT UNIVERSITY

Atic for HVAC professionals



GHENT UNIVERSITY

Atic for HVAC professionals

J. Logue, LBNL

Binnenmilieubesluit

Woningen en publieke gebouwen

Update 2018:

‘interventiewaarden’ voor 17 individuele polluenten en TVOC

(NIET voor CO_2 = tracer)

GHENT UNIVERSITY

stof/factor	richtwaarde	interventie-waarde	blootstellings-duur waarop richt- en interventie-waarden van toepassing zijn
2-ethylhexanol	100 µg/m³	810 µg/m³	chronisch*
acetaldehyde	160 µg/m³	480 µg/m³	chronisch*
asbest chrysotiel	28 vezels/m³	280 vezels/m³	chronisch*
asbest amfibool	3 vezels/m³	30 vezels/m³	chronisch*
asbest gemengde stalen	$\frac{amfibool[vezels/m^3]}{3\,[vezels/m^3]} + \frac{chrysotiel\,[vezels/m^3]}{28\,[vezels/m^3]} \leq 1$	$\frac{amfibool[vezels/m^3]}{30\,[vezels/m^3]} + \frac{chrysotiel\,[vezels/m^3]}{280\,[vezels/m^3]} \leq 1$	chronisch*
benzeen		0,4 µg/m³ **	chronisch*
C_4-C_{11}-aldehydes	650 µg/m³	1600 µg/m³	chronisch*
C_9-C_{14}-alkanen	250 µg/m³	490 µg/m³	chronisch*
formaldehyde		100 µg/m³	chronisch*
koolstofdioxide	<500 ppm boven de buitenluchtconcentratie	-	-
koolstofmonoxide		8 mg/m³	24 uur
metallisch kwik (damp)	0,05 µg/m³	0,6 µg/m³	chronisch*
naftaleen	3 µg/m³	31 µg/m³	chronisch*
nicotine	0,1 µg/m³	-	-
ozon	40 µg/m³	78 µg/m³	8 uur
polycyclische aromatische koolwaterstoffen met benzo(A)pyreen als indicator	0,012 ng/m³	0,1 ng/m³	chronisch*
PM2,5 (fijn stof)	10 µg/m³	-	chronisch*
stikstofdioxide	20 µg/m³	40 µg/m³	chronisch*
styreen	260 µg/m³	2500 µg/m³	chronisch*
tetrachloor-ethyleen	4 µg/m³	38 µg/m³	chronisch*
tolueen	5000 µg/m³	14000 µg/m³	chronisch*
trichloorethyleen	0,2 µg/m³	2,5 µg/m³	chronisch*
totale vluchtige organische stoffen	300 µg/m³	1000 µg/m³	chronisch*

*blootstelling van > 365 dagen, geldig voor levenslange blootstelling
**van toepassing als concentratie buitenlucht ≤ 0,4 µg/m³ is; in elk ander geval geldt de buitenconcentratie als interventiewaarde.

EN 13779:2004

Table 5 — Basic classification of indoor air quality (IDA)

Category	Description
IDA 1	High indoor air quality
IDA 2	Medium indoor air quality
IDA 3	Moderate indoor air quality
IDA 4	Low indoor air quality

Table 9 CO_2-level in rooms

Categorie	CO_2-level above level of outdoor air in ppm	
	Typical range	Default value
IDA 1	≤ 400	350
IDA 2	400 – 600	500
IDA 3	600 – 1,000	800
IDA 4	> 1,000	1,200

buildings. In cases with high activity levels (met >1,2), the outdoor rates should be increased by a factor of met/1,2.

GHENT UNIVERSITY

Atic for HVAC professionals

Binnenmilieubesluit

Woningen en publieke gebouwen

ook ‘biotische’ en omgevingsfactoren

GHENT UNIVERSITY

Atic for HVAC professionals

1° de biotische factoren, de richt- en interventiewaarden ervan, en de blootstellingsduur waarop die waarden van toepassing zijn:

stof/factor	richtwaarde	interventie-waarde	blootstellings-duur waarop richt- en interventie-waarden van toepassing zijn
zichtbare schimmel **omvang beschimmeld oppervlak** **aanwezigheid van *Stachybotrys chartarum*** **aanwezigheid van schimmelmijten**	<0,3 m²/kamer 0/gebouw 0/gebouw	-	-
ongedierte	0/gebouw		-

2° de fysische factoren, de richt- en interventiewaarden ervan, en de blootstellingsduur waarop die waarden van toepassing zijn:

stof/factor	richtwaarde	interventie-waarde	blootstellings-duur waarop richt- en interventie-waarden van toepassing zijn
extreem laag frequente elektromagnetische straling	0,4 µT	20 µT	richtwaarde: chronisch* interventiewaarde: acuut****
temperatuur **koude jaarhelft**** **warme jaarhelft*****	 20 °C ≤ T < 24 °C 22 °C ≤ T < 26 °C	 -	 -
tocht **koude jaarhelft**** **warme jaarhelft*****	 < 0,15 m/s < 0,25 m/s	 -	 -
relatieve vochtigheid **- koude jaarhelft**** **- warme jaarhelft*****	 40 % ≤ RV < 60% 30 % ≤ RV < 70%	 -	 -

*blootstelling van > 365 dagen, geldig voor levenslange blootstelling

Binnenmilieubesluit

Woningen en publieke gebouwen

ook ‘biotische’ en omgevingsfactoren

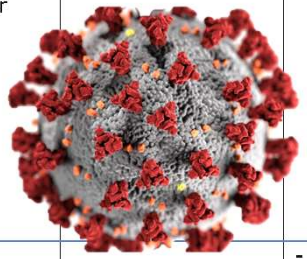
Update 202x?

GHENT UNIVERSITY

Atic for HVAC professionals

1° de biotische factoren, de richt- en interventiewaarden ervan, en de blootstellingsduur waarop die waarden van toepassing zijn:

stof/factor	richtwaarde	interventie-waarde	blootstellings-duur waarop richt- en interventie-waarden van toepassing zijn
zichtbare schimmel **omvang beschimmeld oppervlak** **aanwezigheid van *Stachybotrys chartarum*** **aanwezigheid van schimmelmijten**	<0,3 m²/kamer 0/gebouw 0/gebouw	-	-
ongedierte	0/gebouw		-



2° de fysische factoren, de richt- en interventiewaarden ervan, en de blootstellingsduur waarop die waarden van toepassing zijn:

stof/factor	richtwaarde	interventie-waarde	blootstellings-duur waarop richt- en interventie-waarden van toepassing zijn
extreem laag frequente elektromagnetische straling	0,4 µT	20 µT	richtwaarde: chronisch* interventiewaarde: acuut****
temperatuur **koude jaarhelft**** **warme jaarhelft*****	 20 °C ≤ T < 24 °C 22 °C ≤ T < 26 °C	 -	 -
tocht **koude jaarhelft**** **warme jaarhelft*****	 < 0,15 m/s < 0,25 m/s	 -	 -
relatieve vochtigheid **- koude jaarhelft**** **- warme jaarhelft*****	 40 % ≤ RV < 60% 30 % ≤ RV < 70%	 -	 -

*blootstelling van > 365 dagen, geldig voor levenslange blootstelling

Bourouiba and Bush (2014)

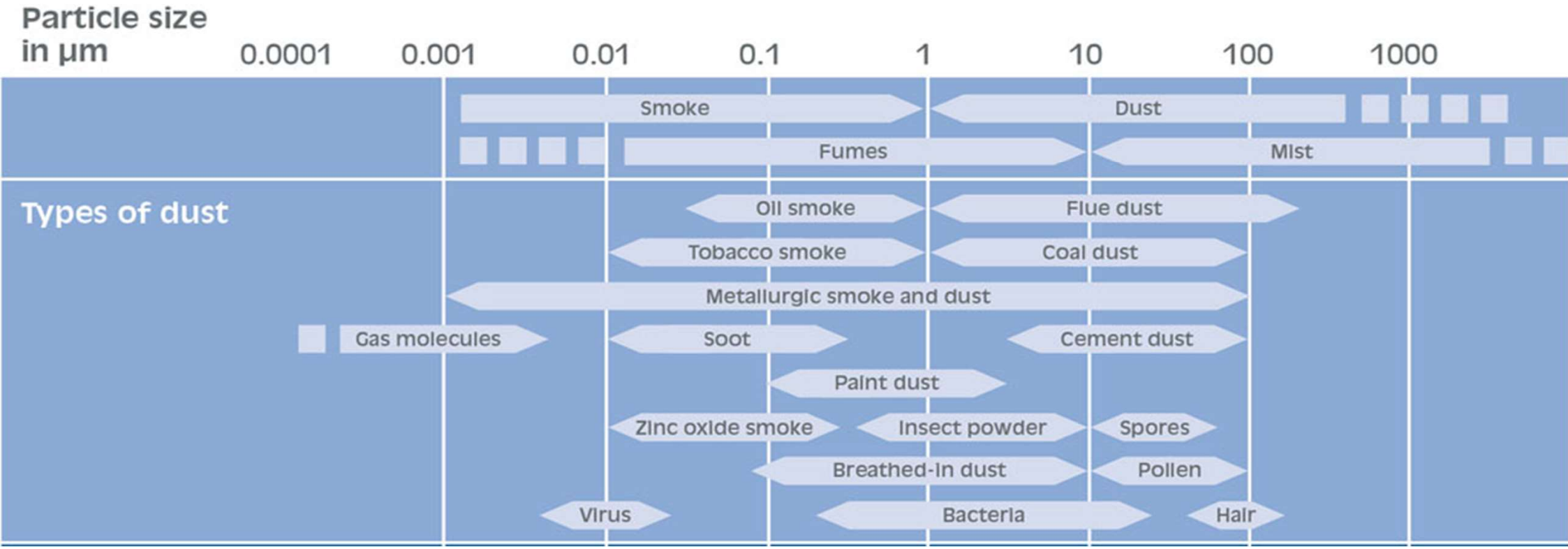
WELKE POLLUENTEN?

- Gasvormig ((V)VOC)
- Gasvormig maar met hoog kookpunt (SVOC)
  - grote ‘vloeibare’ hoeveelheid in ruimte
- **Partikels (PM)**
  - verschillende diameters

Microbiologische elementen (bacteriën en virussen)
= levende partikels

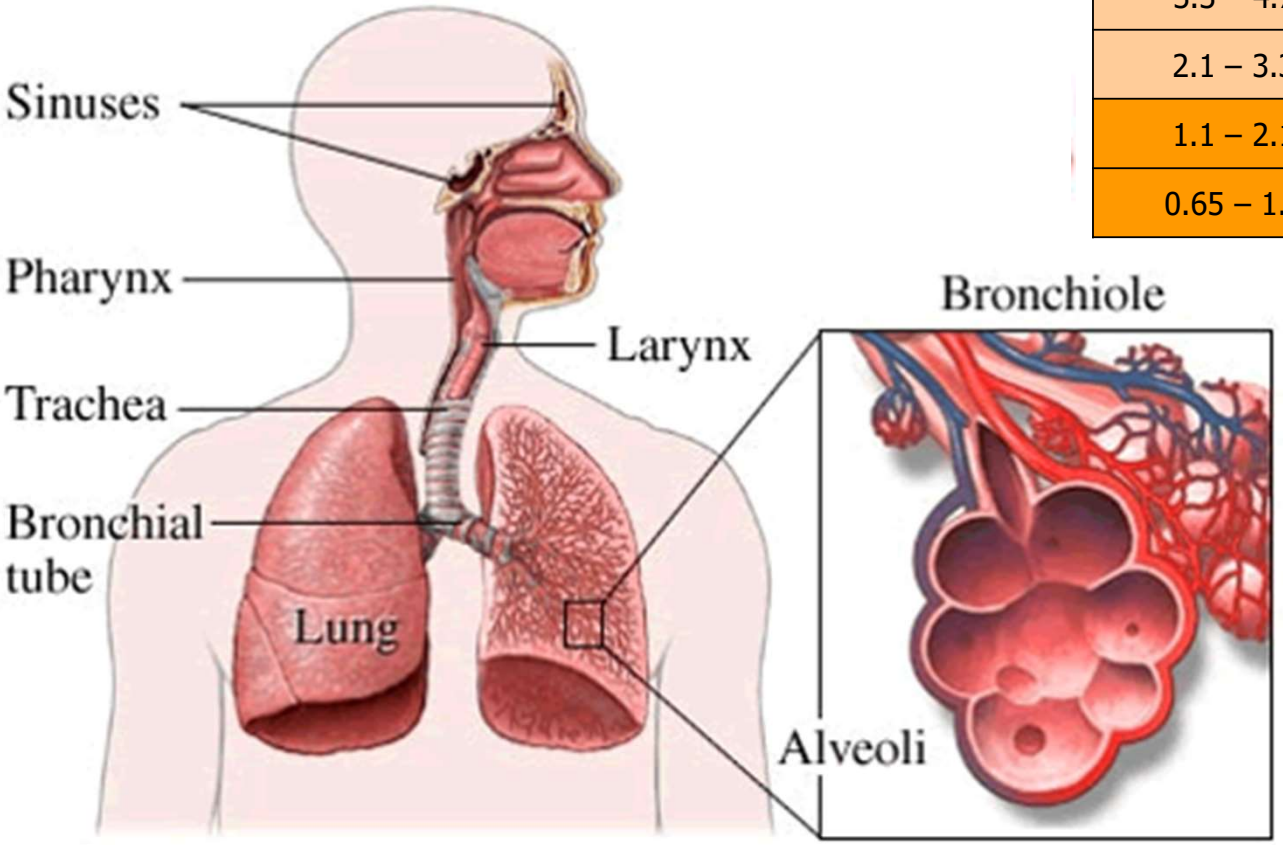
GHENT UNIVERSITY

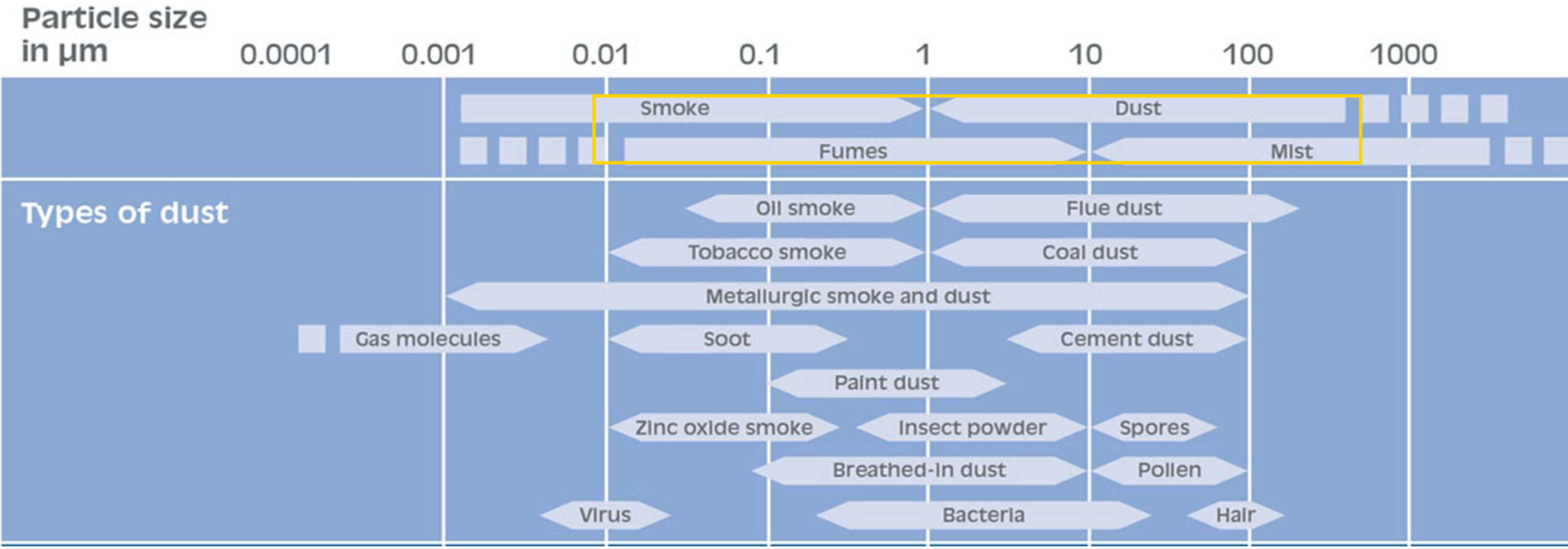
Atic
for HVAC professionals


Particle size
in µm
0.0001
0.001
0.01
0.1
1
10
100
1000
Smoke
Dust
Fumes
Mist
Types of dust
Oil smoke
Flue dust
Tobacco smoke
Coal dust
Metallurgic smoke and dust
Gas molecules
Soot
Cement dust
Paint dust
Zinc oxide smoke
Insect powder
Spores
Breathed-in dust
Pollen
Virus
Bacteria
Hair

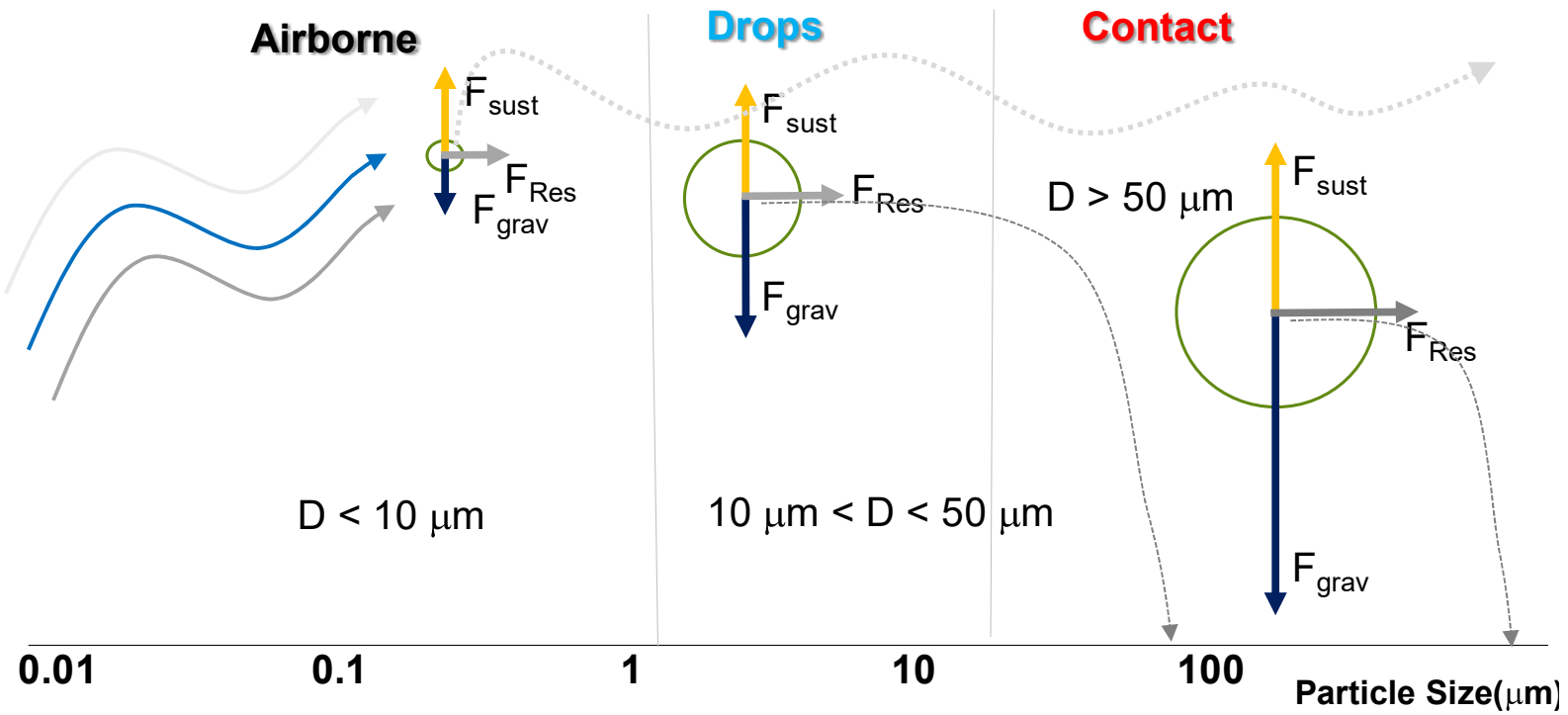
BELANG DIAMETER (1)

Diameter (μm)	Penetration Level	Classification
> 7	Oral and Nasal Cavities	Inhalable
4.7 – 7	Larynx	
3.3 – 4.7	Trachea and Bronchi	Thoragics
2.1 – 3.3	Secondary Bronchioles	
1.1 – 2.1	Bronchioles	Breathable
0.65 – 1.1	Alveoli	




Particle size
in µm
0.0001
0.001
0.01
0.1
1
10
100
1000
Smoke
Dust
Fumes
Mist
Types of dust
Oil smoke
Flue dust
Tobacco smoke
Coal dust
Metallurgic smoke and dust
Gas molecules
Soot
Cement dust
Paint dust
Zinc oxide smoke
Insect powder
Spores
Breathed-in dust
Pollen
Virus
Bacteria
Hair

FYSIQUE ET AEROSOLS

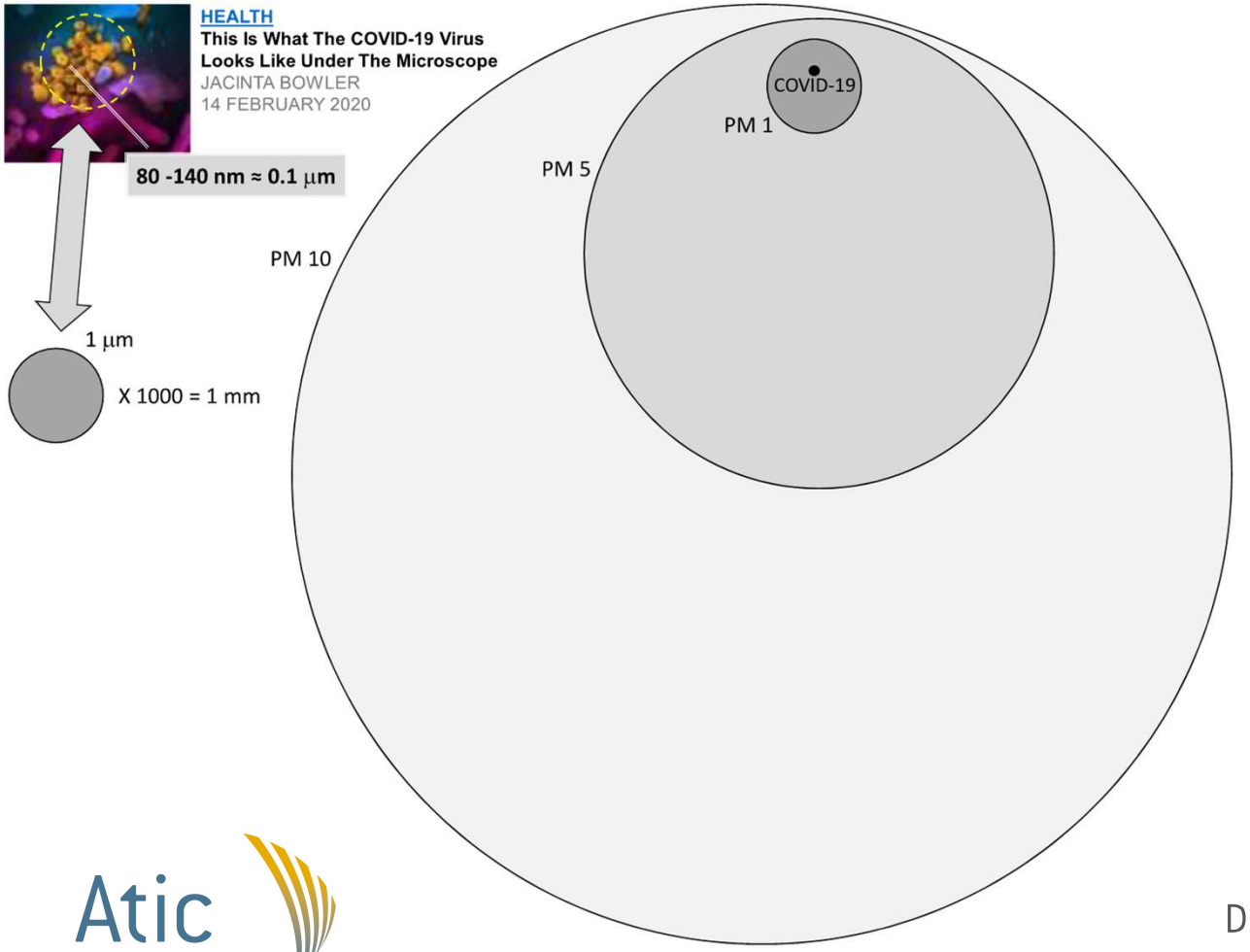


GHENT UNIVERSITY

Atic for HVAC professionals

Gameiro Da Silva, 2020
DOI: 10.13140/RG.2.2.28663.78240

AEROSOLS ET SARS-COV-2

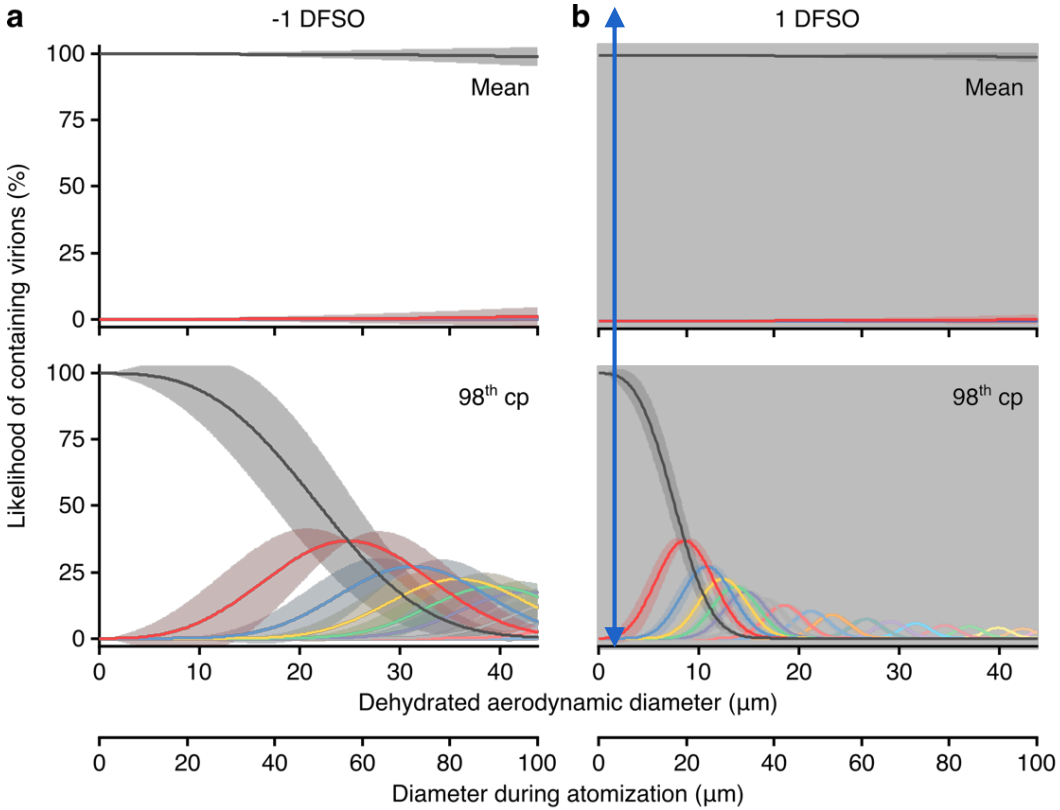


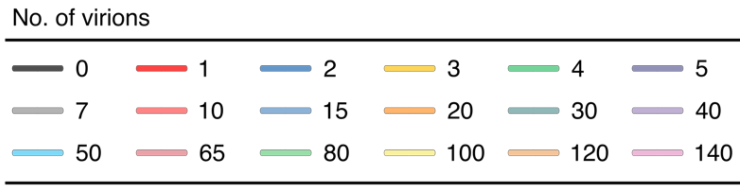
GHENT UNIVERSITY

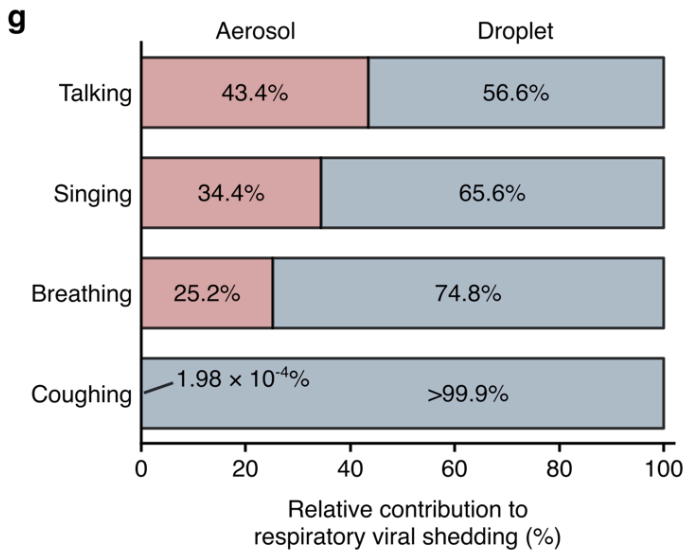
Atic for HVAC professionals

Gameiro Da Silva, 2020
DOI: 10.13140/RG.2.2.28663.78240

PROBABILITÉ DE GOUTTELETTE AVEC VIRUS







GHENT UNIVERSITY

Atic for HVAC professionals

Chen et al, 2020, https://doi.org/10.1101/2020.10.13.20212233

EVAPORATION

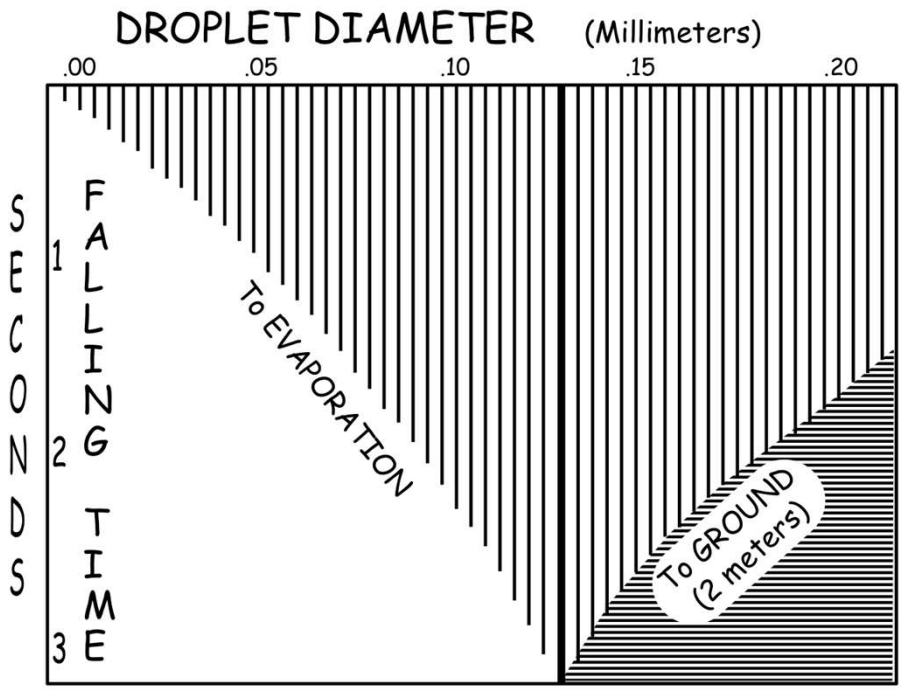


CHART 1. Falling and evaporation times for droplets of varying diameter.

Redrawn from Wells, W. F. 1934.

AIRBORNE SPREAD OF MEASLES IN A SUBURBAN ELEMENTARY SCHOOL

E. C. RILEY ✉, G. MURPHY, R. L. RILEY

American Journal of Epidemiology, Volume 107, Issue 5, May 1978, Pages 421–432,
https://doi.org/10.1093/oxfordjournals.aje.a112560
Published: 01 May 1978 **Article history** ▾

❝ Cite 🔑 Permissions 🔗 Share ▾

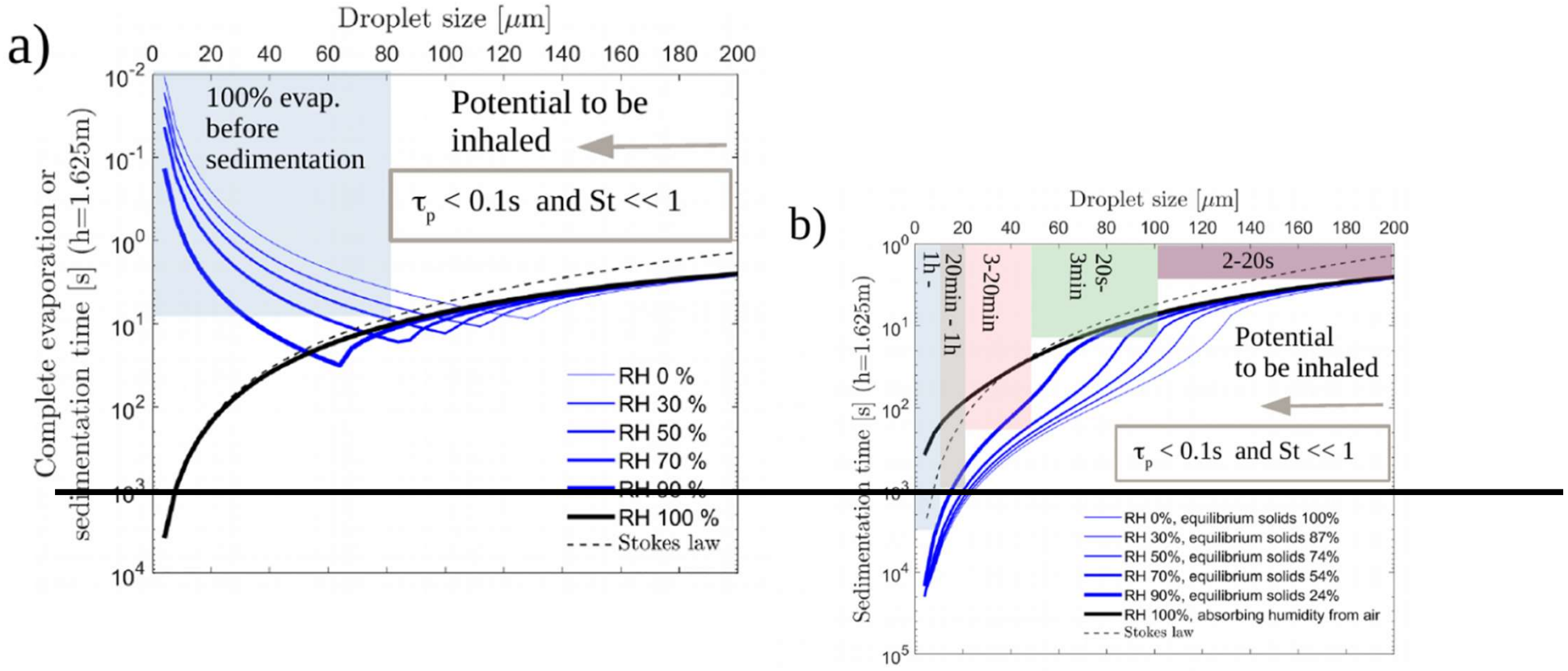
Abstract

A measles epidemic in a modern suburban elementary school In upstate New York In spring, 1974, is analyzed in terms of a model which provides a basis for apportioning the chance of infection from classmates sharing the same home room, from airborne organisms reclrculated by the ventilating system, and from exposure In school buses. The epidemic was notable because of lts explosive nature and lts occurrence In a school where 97% of the children had been vaccinated. Many had been vaccinated at less than one year of age. The Index case was a girl In second grade who produced 28 secondary cases in 14 different classrooms. Organisms reclrculated by the ventilating system were strongly Implicated. After two subsequent generations, 60 children had been Infected, and the epidemic subsided. From estimates of major physical and biologic factors, It was possible to calculate that the lndex case produced approximately 93 units of airborne lnfection (quanta) per minute. The epidemic pattern suggested that the secondaries were less Infectious by an order of magnitude. The exceptional Infectiousness of the Index case, lnadequate Immunization of many of the children, and the high percentage of air reclrculated throughout the school, are believed to account for the extent and sharpness of the outbreak.

GHENT UNIVERSITY

Atic for HVAC professionals

NUCLEIDES



GHENT UNIVERSITY

Atic for HVAC professionals

Vuorinen, 2020, https://doi.org/10.1016/j.ssci.2020.104866

WIRED 2021

PHOTOGRAPH: NAILA RUECHEL

MEGAN MOLTENI BACKCHANNEL 05.13.2021 06:00 AM

The 60-Year-Old Scientific Screwup That Helped Covid Kill

All pandemic long, scientists brawled over how the virus spreads. *Droplets! No, aerosols!* At the heart of the fight was a teensy error with huge consequences.

GHENT UNIVERSITY

Atic for HVAC professionals

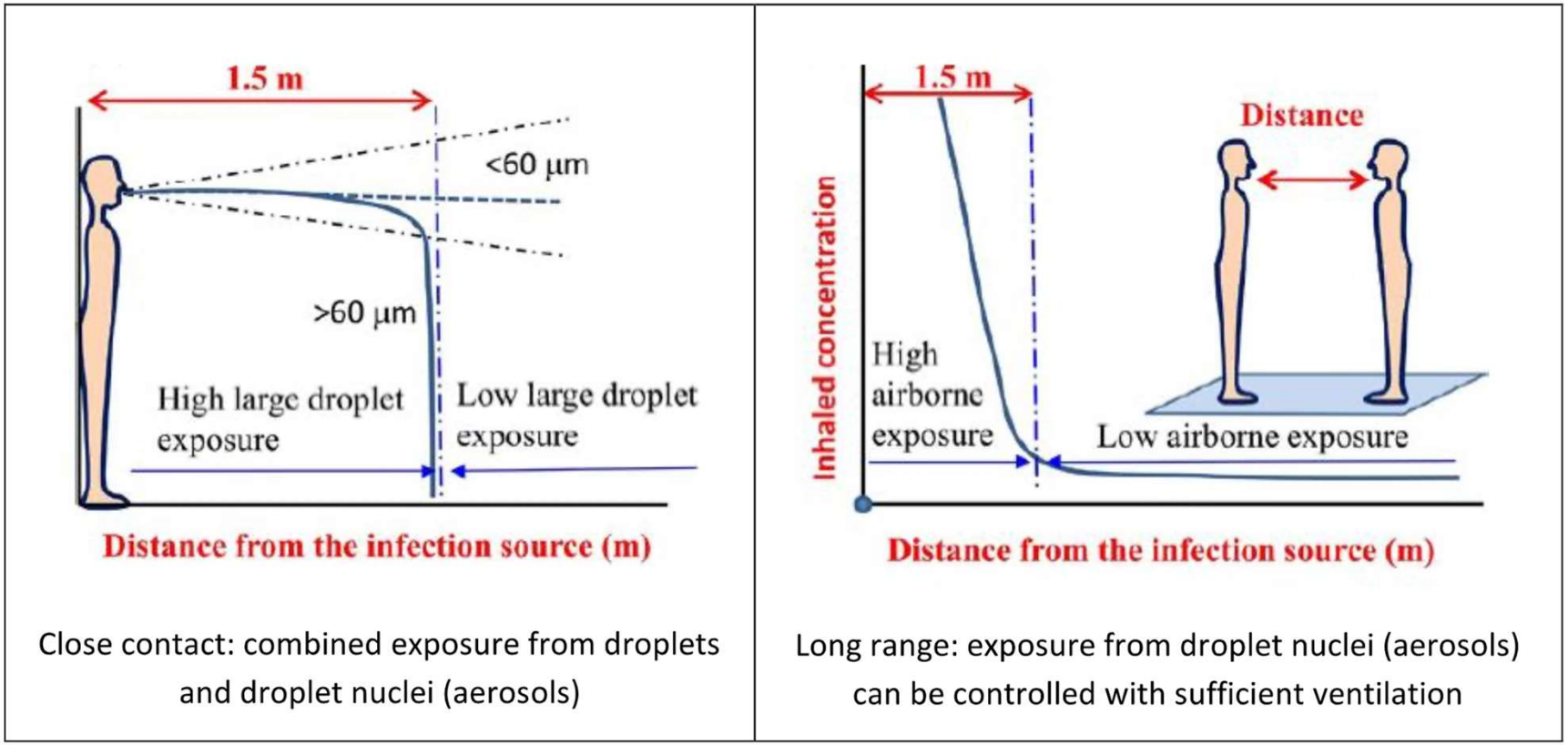


Figure 1. The distinction between close contact combined droplet and aerosol transmission (left) and long-range aerosol transmission (right) which can be controlled with ventilation diluting the virus concentration to a low level. (Figure: courtesy L. Liu, Y. Li, P. V. Nielsen et al.[xii])

GHENT UNIVERSITY

REHVA_COVID-19_guidance_document_V3_03082020.pdf

VENTILEREN EN SARS-COV-2

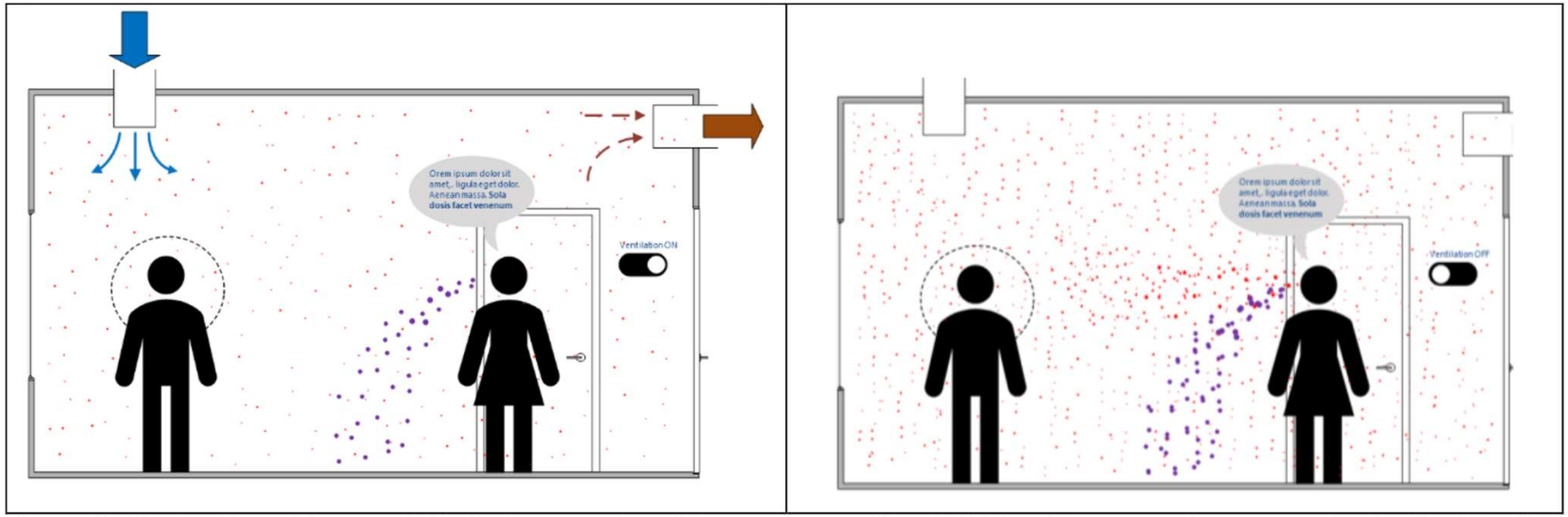


Figure 2. Illustration of how an infected person (speaking woman on the right) leads to aerosol exposure (red spikes) in the breathing zone of another person (man on the left in this case). Large droplet exhalation is marked with purple spikes. When the room is ventilated with mixing ventilation system, the amount of virus-laden particles in the breathing zone is much lower than when the ventilation system is off. Left figure: ventilation system on, right figure: ventilation system off.

GHENT UNIVERSITY

Atic for HVAC professionals

REHVA_COVID-19_guidance_document_V3_03082020.pdf

VENTILEREN EN SARS-COV-2: HOEVEEL??

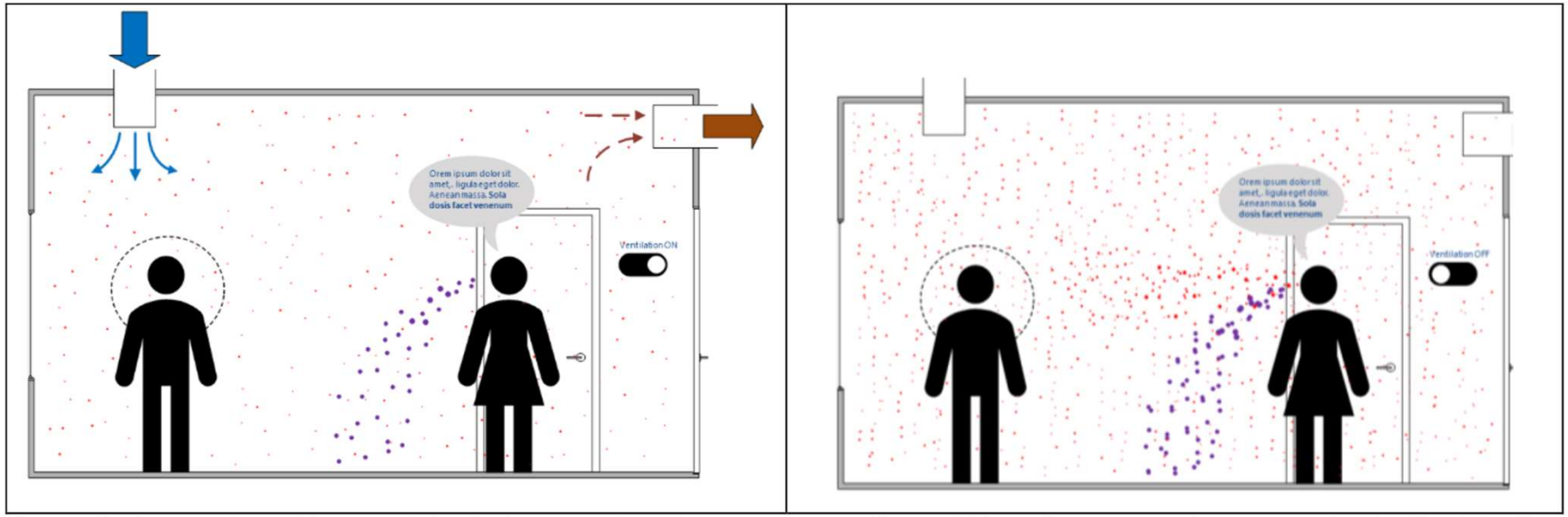


Figure 2. Illustration of how an infected person (speaking woman on the right) leads to aerosol exposure (red spikes) in the breathing zone of another person (man on the left in this case). Large droplet exhalation is marked with purple spikes. When the room is ventilated with mixing ventilation system, the amount of virus-laden particles in the breathing zone is much lower than when the ventilation system is off. Left figure: ventilation system on, right figure: ventilation system off.

GHENT UNIVERSITY

Atic for HVAC professionals

REHVA_COVID-19_guidance_document_V3_03082020.pdf

VENTILEREN EN SARS-COV-2

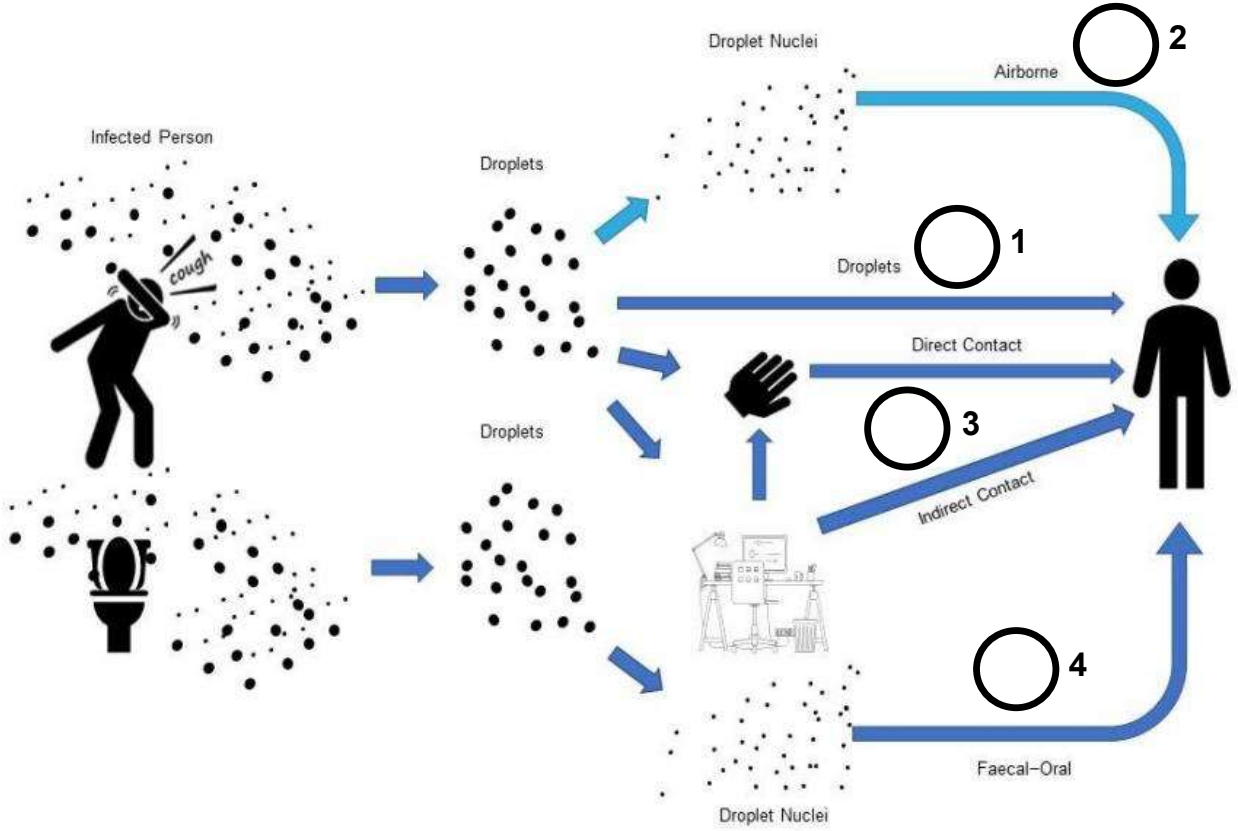
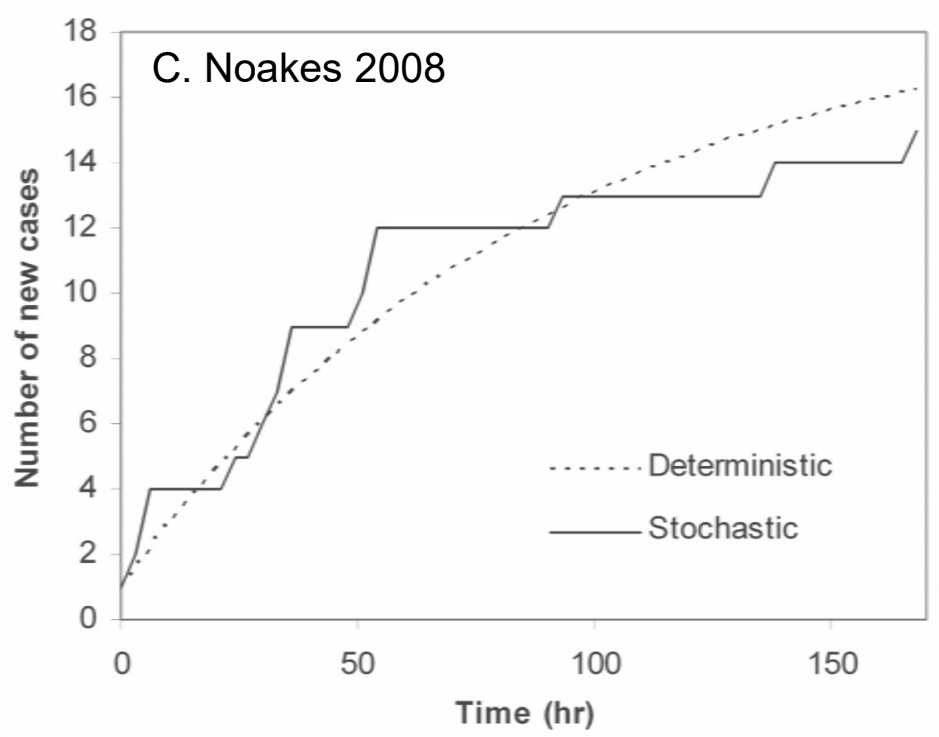


Figure 1. Exposure mechanisms of COVID-19 SARS-CoV-2 droplets. (figure: courtesy Francesco Franchimon).

GHENT UNIVERSITY

Atic for HVAC professionals

INFECTION RISK



Wells-Riley Equation:

$$P = \frac{D}{S} = 1 - e^{-\frac{Ipqt}{Q}}$$

And:

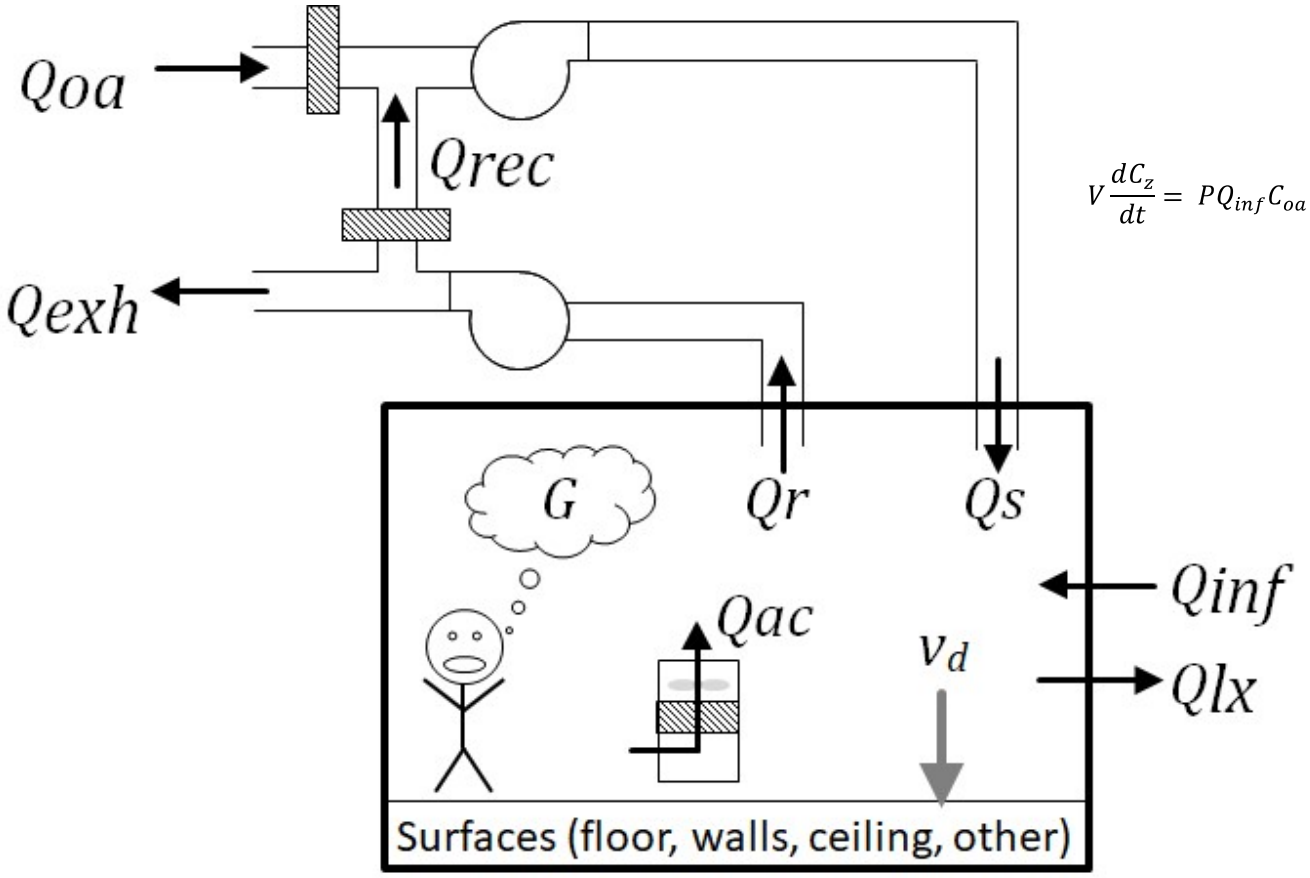
$$P = 1 - e^{-\mu}$$

Poison's probability of rare discrete events

GHENT UNIVERSITY

Atic for HVAC professionals

HOEVEEL VENTILATIE: MASSABALANS



$$V\frac{dC_z}{dt} = PQ_{inf}C_{oa}(t) + Q_sC_s(t) + G(t) - (Q_r + Q_{lx} + \eta_{ac}Q_{ac})C_z(t) - \sum_{i=1}^{N_s} v_{di}A_{si}C_z(t)$$

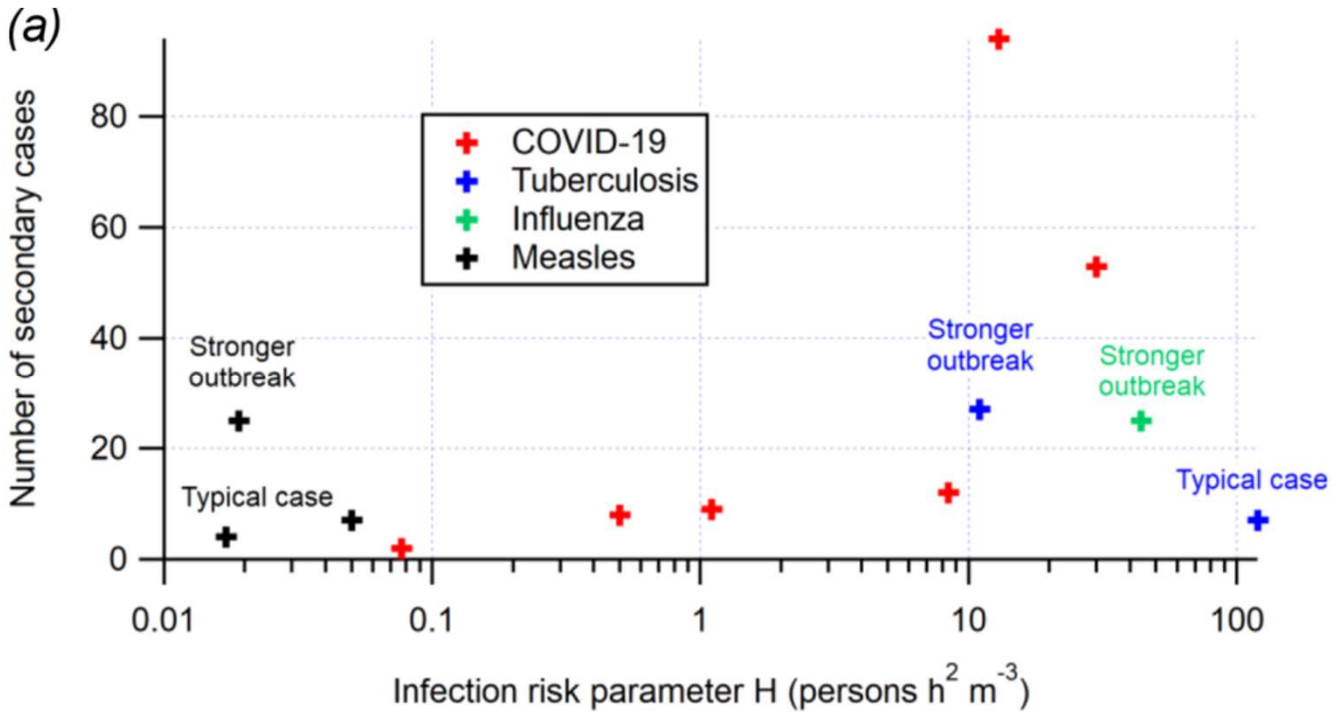
$$A_{si}\frac{dL_{si}}{dt} = v_{di}A_{si}C_z(t)$$

GHENT UNIVERSITY

Atic for HVAC professionals

Dols, 2020, https://doi.org/10.6028/NIST.TN.2095

IMPLICATIES VOOR ONTWERP?



GHENT UNIVERSITY

Atic for HVAC professionals

Peng et al. Environ. Sci. Technol. 2022, 56, 1125−1137

FACULTY OF ENGINEERING AND ARCHITECTURE

Jelle Laverge

Associate professor

ARCHITECTURE & URBAN PLANNING

E jelle.laverge@ugent.be
T +32 9 264 37 49

architecture.ugent.be

Ghent University
@Jlaverge
Jelle Laverge

GHENT UNIVERSITY

Atic for HVAC professionals