



Ventilatsiooni lahendused viiruse leviku tõkestamiseks

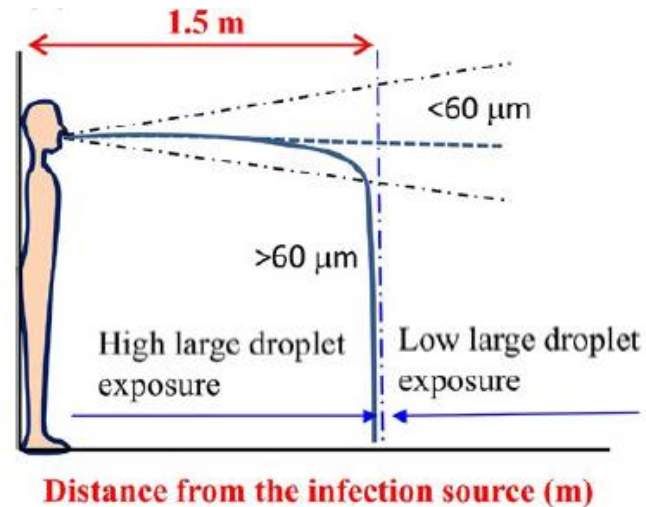
Jarek Kurnitski
REHVA COVID-19 Task Force

REHVA guidance for building services

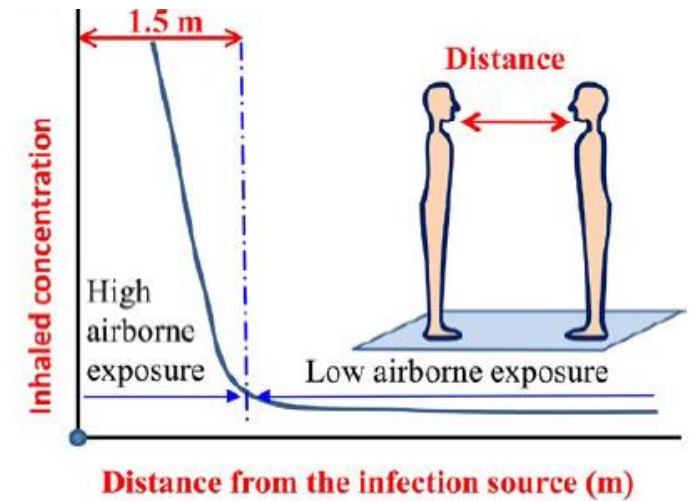
- <https://www.rehva.eu/activities/covid-19-guidance>
- An addition to the general guidance for employers and building owners that is presented in the WHO document [‘Getting workplaces ready for COVID-19’](#).
- First version March 17, 2020 that has been updated April 3 and August 3
- Targeted to HVAC professionals and facility managers but may be useful for occupational and public health specialists deciding how to use buildings
- The scope is limited to commercial and public buildings
- Practical guidance on temporary, easy-to-organize measures that can be implemented in existing buildings
- Some discussion how to conduct a risk assessment and what would be more far-reaching actions to further reduce the spread of viral diseases in future in buildings with improved ventilation systems

Viiruse levikuteed

1. Close contact droplet and aerosol transmission (<1.5 m distance)
2. Long range airborne (aerosol based) transmission (> 1.5 m, droplet nuclei of 5-10 μm stay airborne for long time)
3. Surface (fomite) contact
4. Faecal-oral route
5. Resuspension



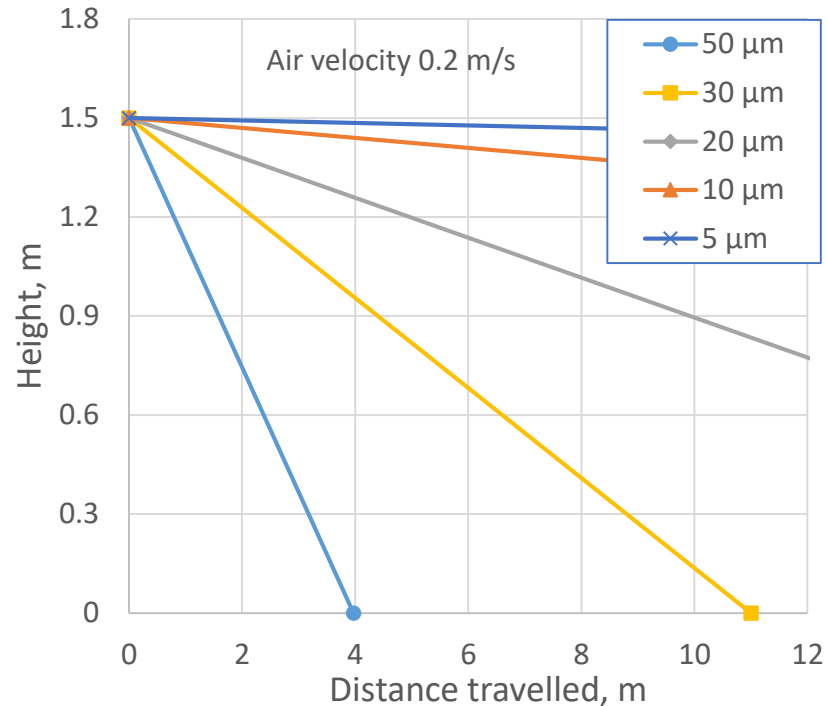
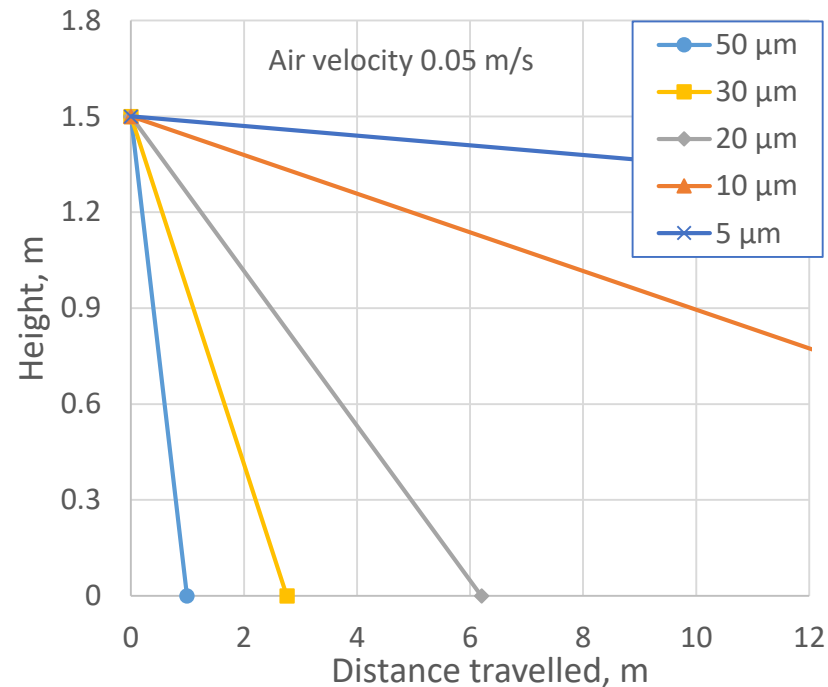
Close contact: combined exposure from droplets and droplet nuclei (aerosols)



Long range: exposure from droplet nuclei (aerosols) can be controlled with sufficient ventilation

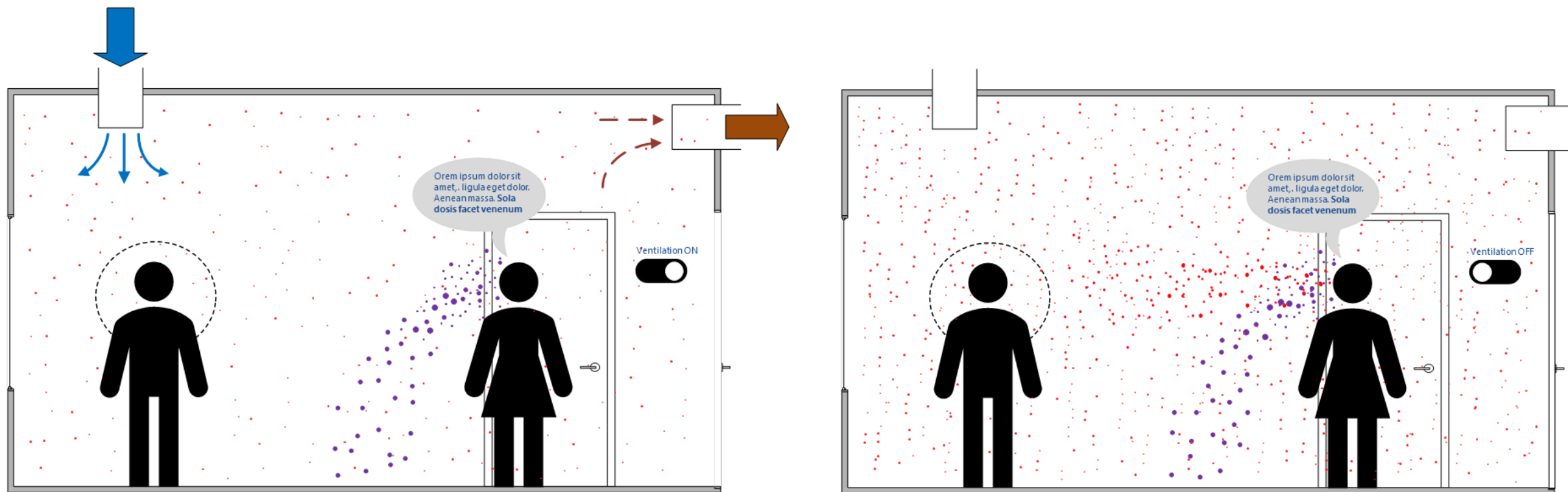
The means to deal with these routes are physical distance to avoid the close contact, **ventilation to avoid (long range) airborne transmission** and hand hygiene to avoid surface contact

Kui kaugele piisad kanduvad?



- Traveling distance estimates (after the initial jet has relaxed) for different sizes of droplets to be carried by room air velocities of 0.05 and 0.2 m/s before settling 1.5 m under the influence of gravity. (μm values in the figure refer to equilibrium diameters of desiccated respiratory droplets)
- An airborne virus is contained inside expelled respiratory fluid droplets that are suspended in air, ranging from less than 1 μm to more than 100 μm in diameter, which is the largest particle size that can be inhaled

Ventilatsiooni mõju



- Ventilatsioon sees/väljas
- Doos (võrdeline nakkuse tõenäosusega) võrdub kontsentratsiooni ja aja korrutisega
- Ventilatsiooni lisaks viiruseosakesi võib eemaldada filtritega või deaktiveerida UV-C-ga

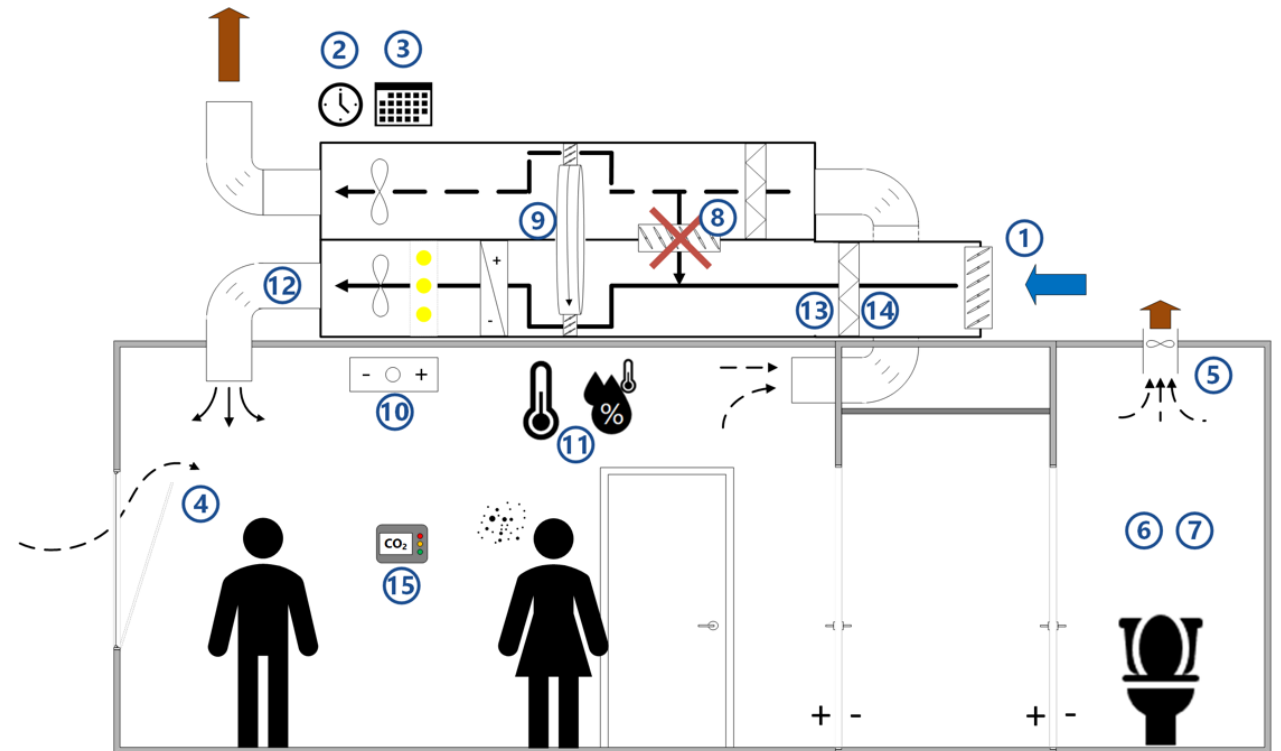
Ventilatsioonilahendused nakkusriski maandamise hierarhias



- Nakkuse haldamise püramiid US CDC järgi (CDC 2015)
- Ventilatsioonilahendused on põhiline inseneritehniline meede õhu teel leviva viiruse tõkestamiseks

15 REHVA soovitud olemasolevatele hoonetele

1. Ventilation rates
2. Ventilation operation times
3. Continuous operation of ventilation
4. Window opening
5. Toilet ventilation
6. Windows in toilets
7. Flushing toilets
8. Recirculation
9. Heat recovery equipment
10. Fan coils and induction units
11. Heating, cooling and possible humidification setpoints
12. Duct cleaning
13. Outdoor air and extract air filters
14. Maintenance works
15. IAQ monitoring



Põhilised soovitusused

- Pikendada ventilatsiooni käiduaegasid (2 tundi enne ja pärast kasutusaega)
 - Vältida tagastusõhu (retrsirkulatsiooni) kasutamist
 - Kui tagastusõhku ei ole võimalik vältida, siis paigaldada F8 filtrid (ca 80% eraldusaste, sest viirus ei ole paljas)
 - Rootorsoojusvahetite tehniline ülevaatus
 - Sisekliima tagamiseta hoonetes paigaldada CO₂ andurid
-
- Eesti eriolukorra määrus ventileerimise ja tuulutamise täiendavatest nõuetest:
<https://www.riigiteataja.ee/akt/104042020003>
 - TTJA juhend:
https://www.ttja.ee/sites/default/files/content-editors/Ehitus/ventilatsioonisusteemide_too_eriolukorras.pdf



Fundamental issues

Addressed by scientist in the petition to WHO (Morawska et al. 2020) :

1. Ventilation rates should be increased;
2. Air should not be recirculated;
3. Individuals should avoid staying directly in the flow of air from another person;
4. The number of people sharing the same indoor environment should be minimized;

No 3 addresses air distribution - not easy to change in existing buildings

Many research needs for future - ventilation rates, air cleaners, air distribution, hygiene of components, maintenance of systems ...

Aerosoolse leviku nakkusriski hindamine

- COVID-19 haigus seostub lähikontaktiga (mille jaoks ventilatsioon ei ole lahendus) ja ruumidega, mis on puudulikult ventileeritud
- Superlevikuga juhtumite puhul välisõhu ventilatsioon on olnud kõigest 1-2 L/s inimese kohta (Guangzhou restoran, Skagit Valley koorilaulmine)
- Kas tavapärane 10 L/s inimese kohta on piisav - tõendus puudub
- Mõningane tõendus nakkuste puudumisest haiglates (u 40 L/s patsiendi kohta, 6-12 1/h)
- Tavapärane projekteerimine ISO 17772-1:2017 ja EN 16798-1:2019 annab tulemuseks II kategoorias 1.5 - 2 L/s m² (10-15 L/s inimene) büroodes ja umbes 4 L/s m² (8-10 L/s inimene) klassiruumides ja nõupidamiste ruumides
- 4 L/s m² nõupidamiste ruumides ja klassiruumides vastab 5 1/h

Standard airborne disease transmission Wells-Riley model

- The probability of infection (p) is related to the number of quanta inhaled (n):

$$p = 1 - e^{-n}$$

- n (quanta) depends on the time-average quanta concentration (C_{avg} , quanta/m³), the volumetric breathing rate of an occupant (Q_b , m³/h) and the duration of the occupancy (D , h)

$$n = C_{avg} Q_b D$$

- A fully mixed material balance model for the room:

$$\frac{dC}{dt} = \frac{E}{V} - \lambda C$$

where

E	quanta emission rate (quanta/h);
V	volume of the room (m ³);
λ	first-order loss rate coefficient for quanta/h due to the summed effects of ventilation (λ_v , 1/h), deposition onto surfaces (λ_{dep} , 1/h) and virus decay (k , 1/h);
C	time-dependent airborne concentration of infectious quanta (quanta/m ³).

- (Concentration in larger rooms is not fully mixed - air distribution issues)

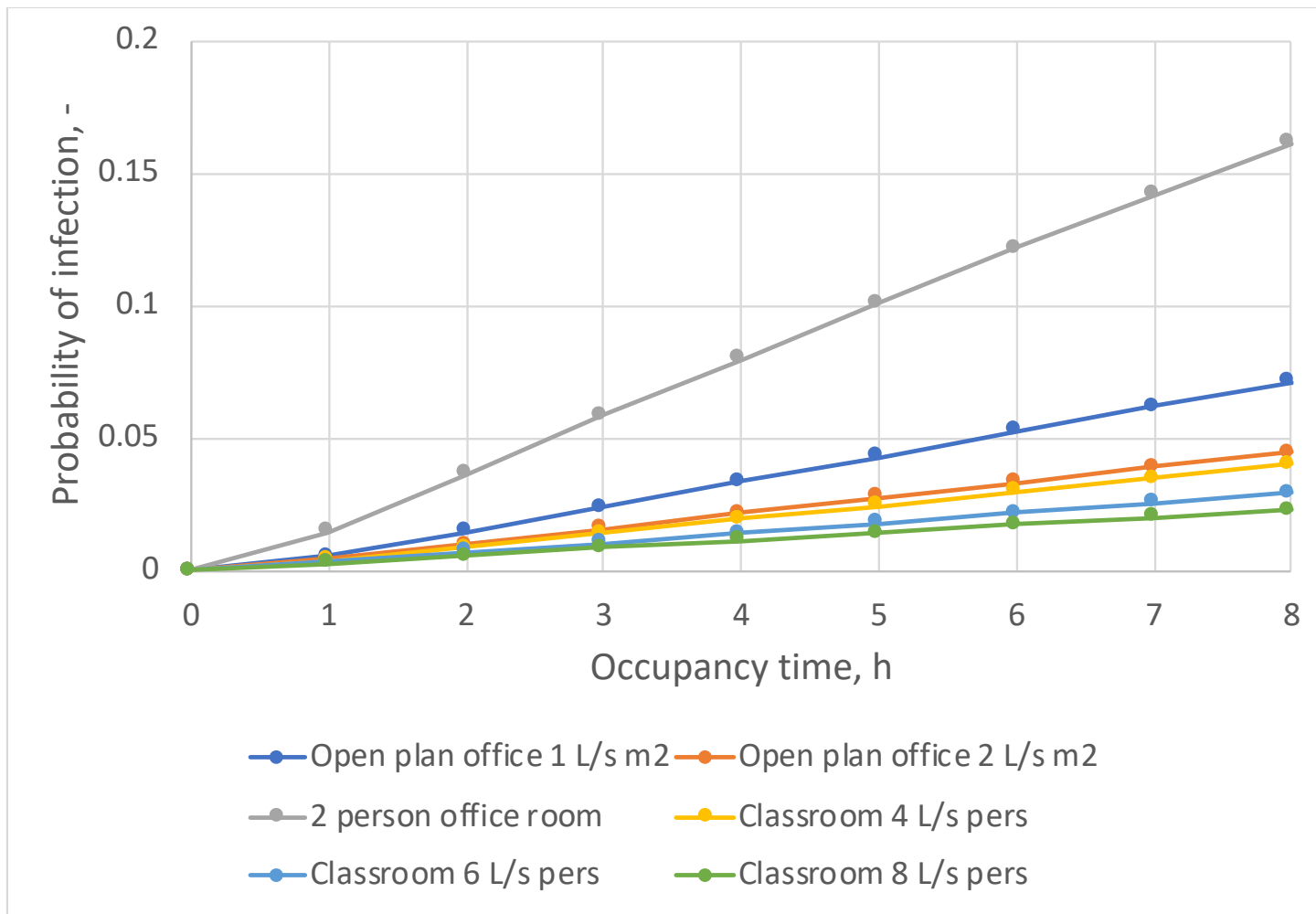
SARS-CoV-2 nakatumine on võrreldav külmetushaigusega (rinoviirus)

- Common cold/rhinovirus (Yuexia Sun et al. 2011) 1-10 quanta/h
- Influenza (Mesquita, Noakes and Milton 2020) 0.1-0.2 q/h in average, but 630 q/h max daily rate
- SARS-CoV-2 (Buonanno G, Morawska L, Stabile L, 2020):

Activity	Quanta emission rate, quanta/h
Resting – Oral breathing	2.0
Resting – Speaking	9.4
Resting – Loudly speaking	60.5
Standing – Oral breathing	2.3
Standing – Speaking	11.4
Standing – Loudly speaking	65.1
Light exercise – Oral breathing	5.6
Light exercise – Speaking	26.3
Light exercise – Loudly speaking	170
Heavy exercise – Oral breathing	13.5
Heavy exercise – Speaking	63.1
Heavy exercise – Loudly speaking	408

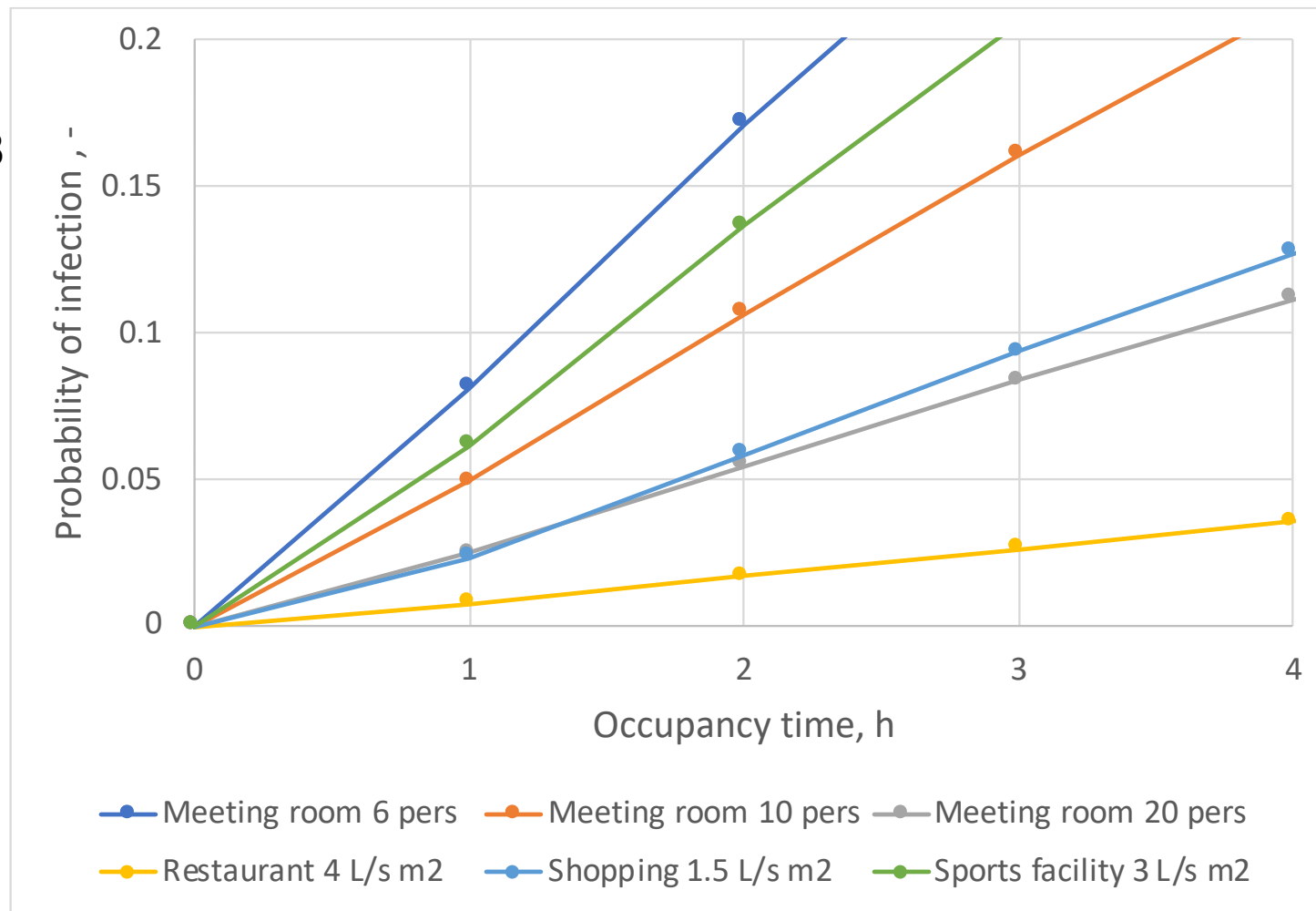
Arvutusnäited

- Oletusena 1 nakatunud inimene kõikides ruumides
- 5 quanta/h büroodes ja klassiruumides
- 1.5 L/s m² ventilatsioon 2 inimese 16 m² tööruumis
- 50 m² avatud kontor
- 56 m² klassiruum



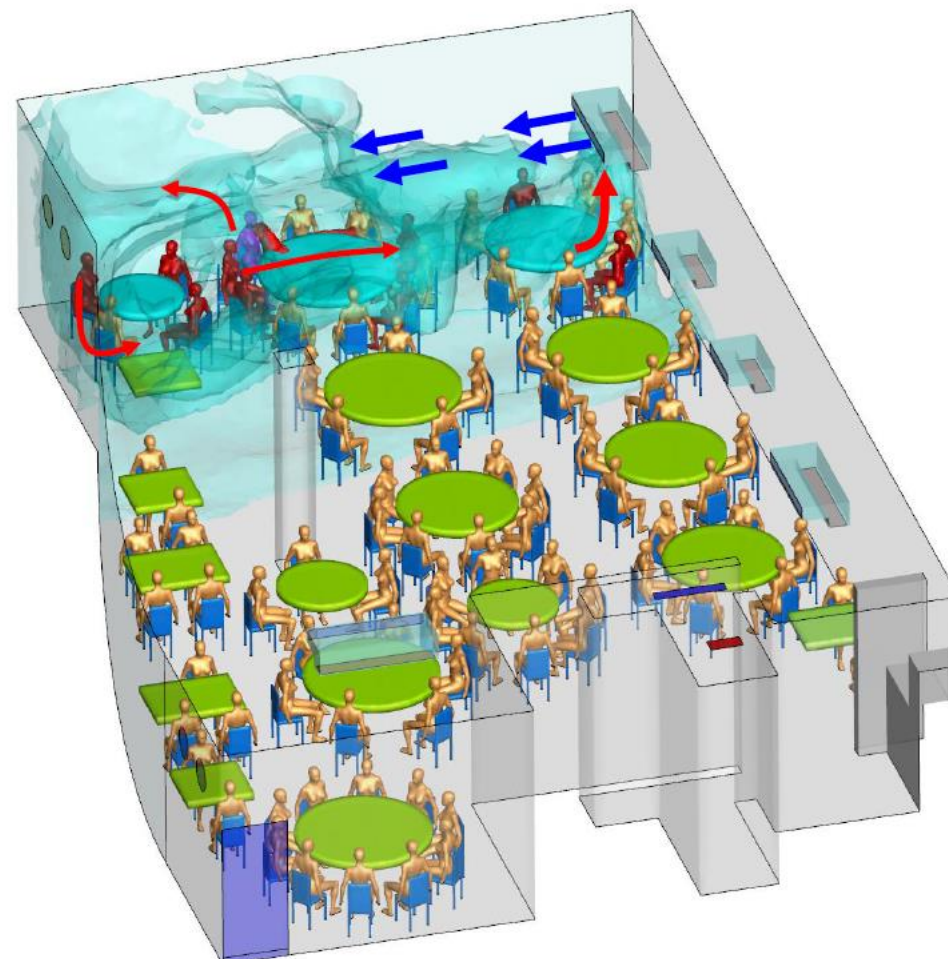
Calculation examples

- 7 q/h for a restaurant, 10 q/h for shopping, 16 q/h for sports and 23 q/h for meeting rooms
- 4 L/s m² in meeting rooms of 15, 25 and 50 m²
- 50 m² for other rooms
- The total airflow rate in L/s per infected person matters
- Common cold (5 q/h) design criterion of $p=0.05$ at 8 h occupancy possible in most of rooms (not in small 2-3 person rooms)



Propagation and spread by air currents directed to a person

- New meaning for air movement/distribution
- ECDC addresses in their HVAC paper "Air flow generated by air-conditioning units may facilitate the spread of droplets excreted by infected people longer distances within indoor spaces."
- In reality, combined effect of directed air flow of the split unit and the poor ventilation (1 L/s per person) known in the Guangzhou restaurant
- Unfavorable airflow patterns may increase the concentration in the breathing zone for instance in some displacement and underfloor systems (Pantelic & Tham 2013, Bolashikov et al. 2012)



Kokkuvõte

- Nn piisknakkushaigus levib väljahingatavate suuremate piiskade ja väiksemate aerosoolide vahendusel milles sisalduvad viirused püsivad õhus aktiivsed kuni 3 tundi
- Aerosoolid hõljuvad õhus ja kanduvad koos õhu liikumisega kümnete meetrite kaugusele
- Nakkuskandja vahetus läheduses on kõrge viiruseosakeste kontsentratsioon
- Alates 1,5 m kauguselt saab viiruse levikut tõkestada korraliku ventilatsiooniga
- Kõige ohutumad on suured ruumid (klassiruumid jne) kus nakkuskandja kohta on suur õhuvooluhulk - praegused ventilatsiooni määrad piisavad mõistlikel riskitasemetel
- Väikestes ruumides suur risk - ohutu kasutada ainult ühe inimese poolt
- Doos sõltub kontsentratsiooni ja aja korrutisest, mistõttu lühiajalised viibimised ohutumad
- Sisekliima tagamiseta ruumidesse soovitav paigaldada CO₂ andurid, >1000 ppm puhul vajalik tuulutada või lahkuda ruumist
- Pikemas perspektiivis kontsentratsiooni alandamine õhujaotuse ja personaalse ventilatsiooni lahendustega