

Ventilatsiooni lahendused viiruse leviku tõkestamiseks

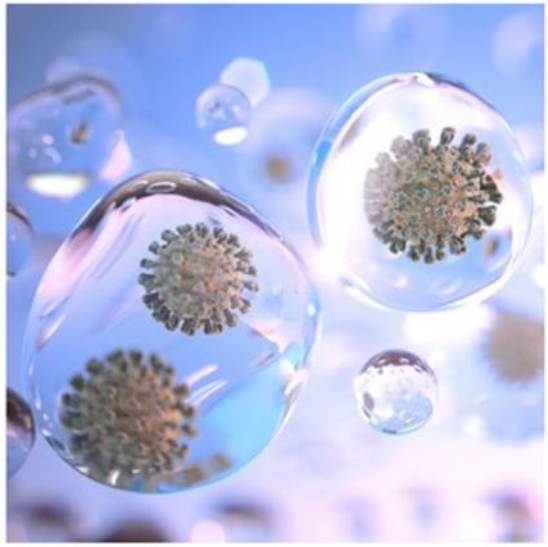
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Viruses in the air

- The size of a coronavirus particle is 80-160 nanometer (100 nm = 0.1 μm)
- **An airborne virus is not naked but is contained inside expelled respiratory fluid droplets**
- In indoor air SARS-CoV-2 can remain active up to 3 hours and up to 2-3 days on room surfaces at common indoor conditions

Incorrect

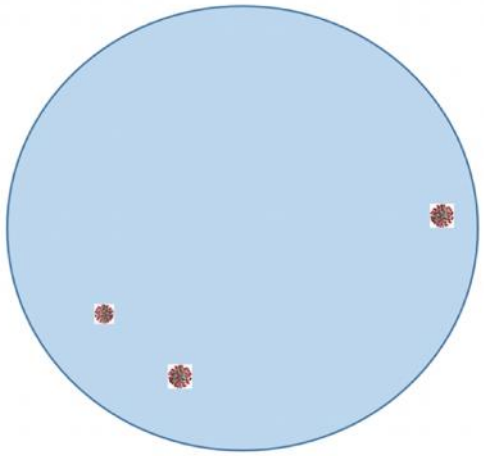
- Aerosols too small relative to the virus (look like 0.2-0.3 um)
- Looks like water + virus only
- Mass fraction of virus very high



From Klompas et al., JAMA (2020)
https://jamanetwork.com/journals/jama/fullarticle/2768396

More correct

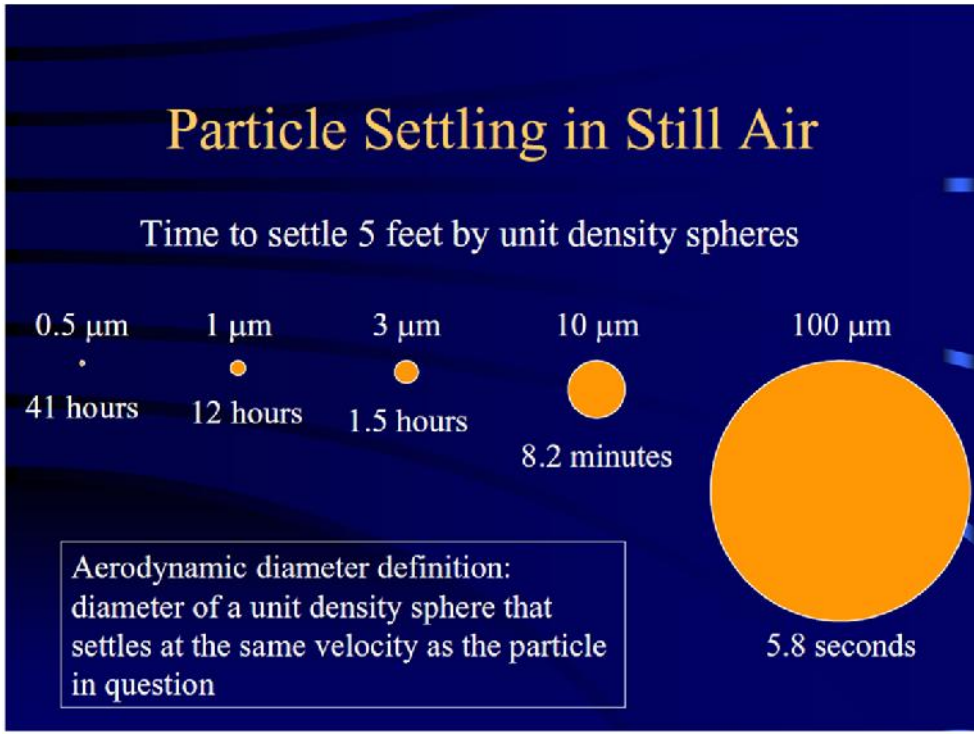
- More typical: few micron aerosol
- Mucin, NaCl, water + sprinkle of virus
- Mass fraction of virus very low



https://tinyurl.com/aerosol-pros-cons

Aerosol physics

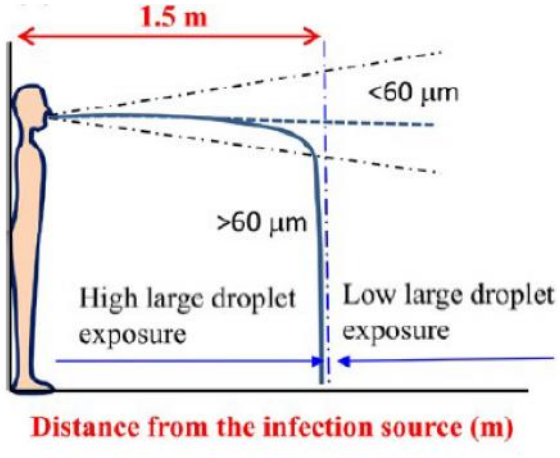
- Expelled respiratory droplets that are suspended in air (which means airborne) range from **less than 1 ㎛ (micrometer = micron) to more than 100 ㎛** in diameter, which is the largest particle size that can be inhaled
- They are also referred to as aerosols, i.e. particles suspended in air, since droplets are liquid particles
- Expelled droplets evaporate and desiccate in the air so that the final droplet nuclei shrink to roughly a half or one-third of the initial diameter
- Droplet desiccation is a fast process; 50 μm droplets desiccate in about two seconds and 10 μm droplets in 0.1 s (desiccated droplets still contain some fluid)



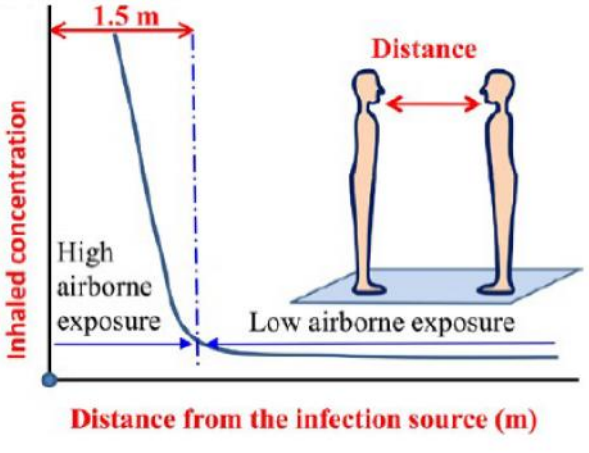
From CDC web page, “Aerosols 101” presentation: https://t.co/HXnHGnf2up?amp=1

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



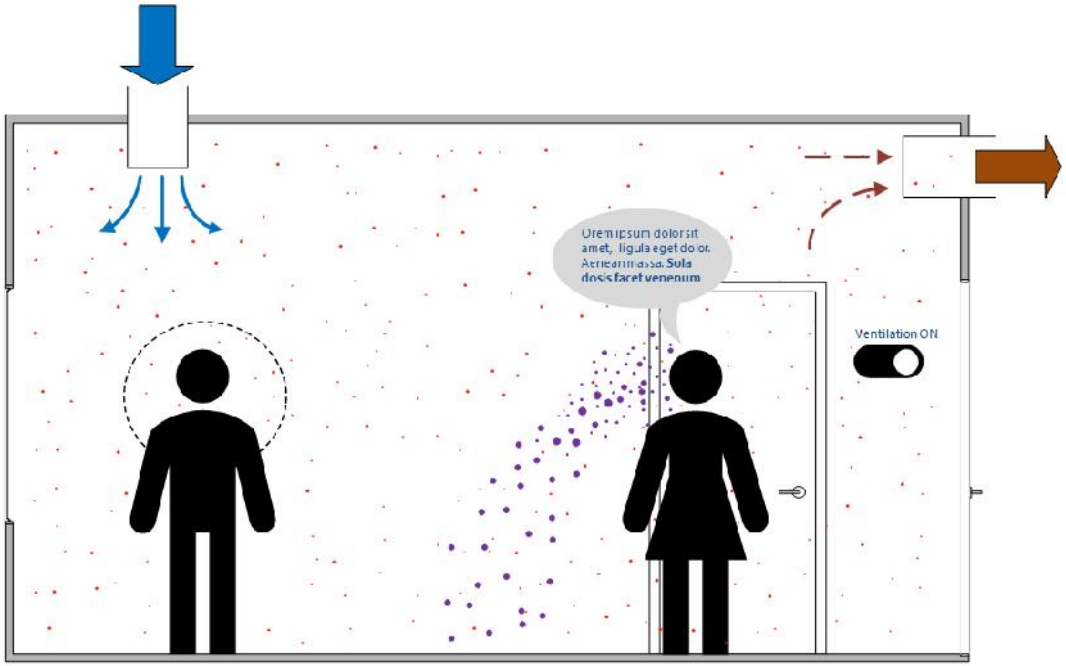
Close contact: combined exposure from droplets and droplet nuclei (aerosols)

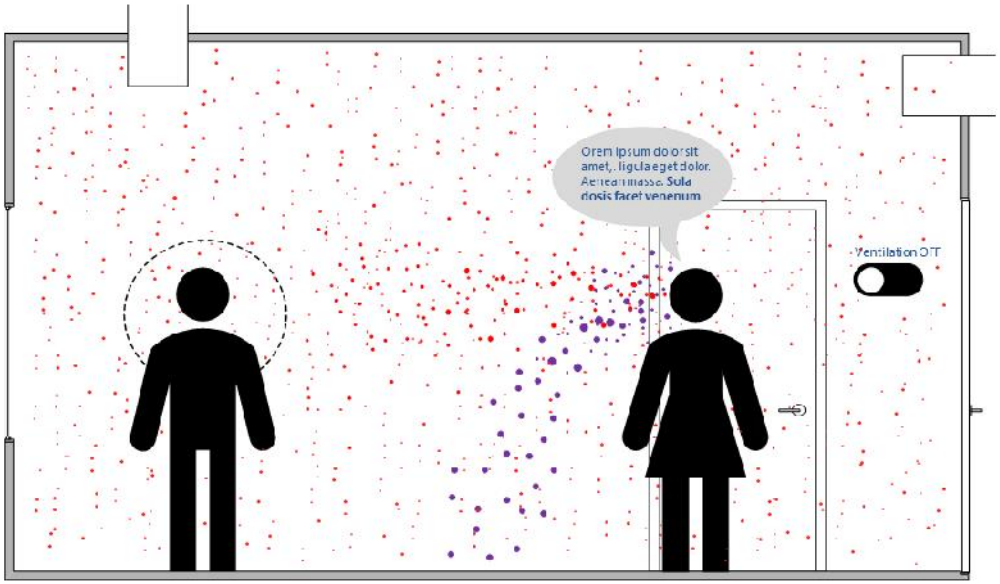


Long range: exposure from droplet nuclei (aerosols) can be controlled with sufficient ventilation

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

Ventilatsiooni mõju





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

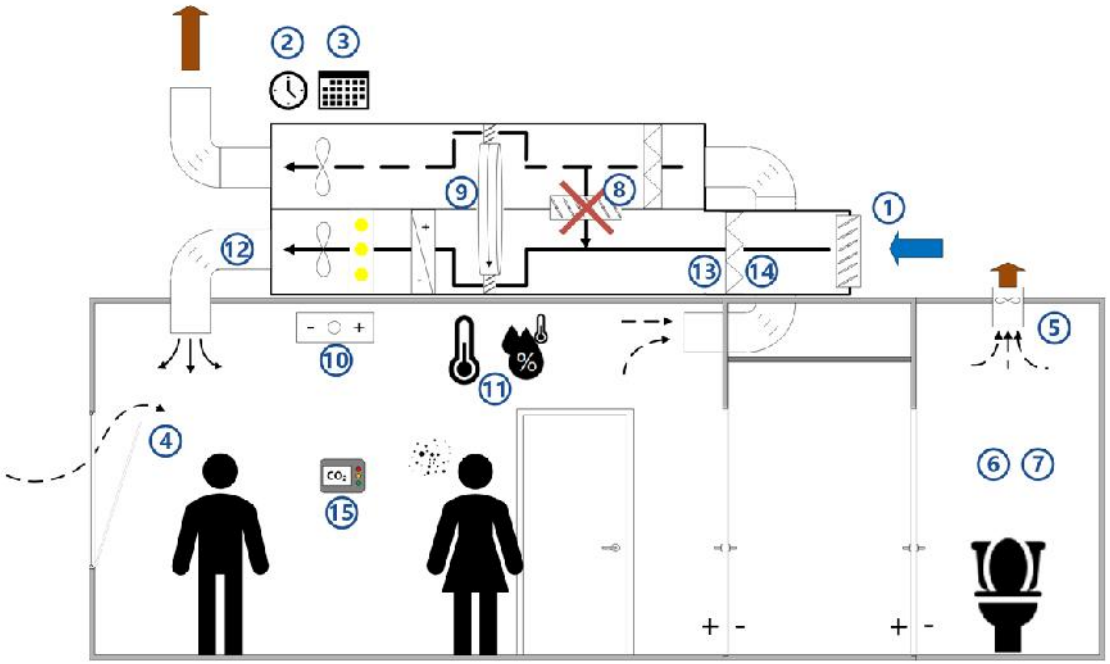
Ventilatsioonilahendused nakkusriski maandamise hierarhias



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

15 REHVA soovitust 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 soovitused

- 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 CO_2 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

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 m^2 (10–15 L/s inimene) büroodes ja umbes 4 L/s m^2 (8–10 L/s inimene) klassiruumides ja nõupidamiste ruumides
- 4 L/s m^2 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):

$$= 1 -$$

- n (quanta) depends on the time-average quanta concentration (C_{avg}, quanta/m^3), the volumetric breathing rate of an occupant (Q_b, m^3/h) and the duration of the occupancy (D, h)

$$= \qquad D$$

- A fully mixed material balance model for the room:

$$— = — —$$

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)

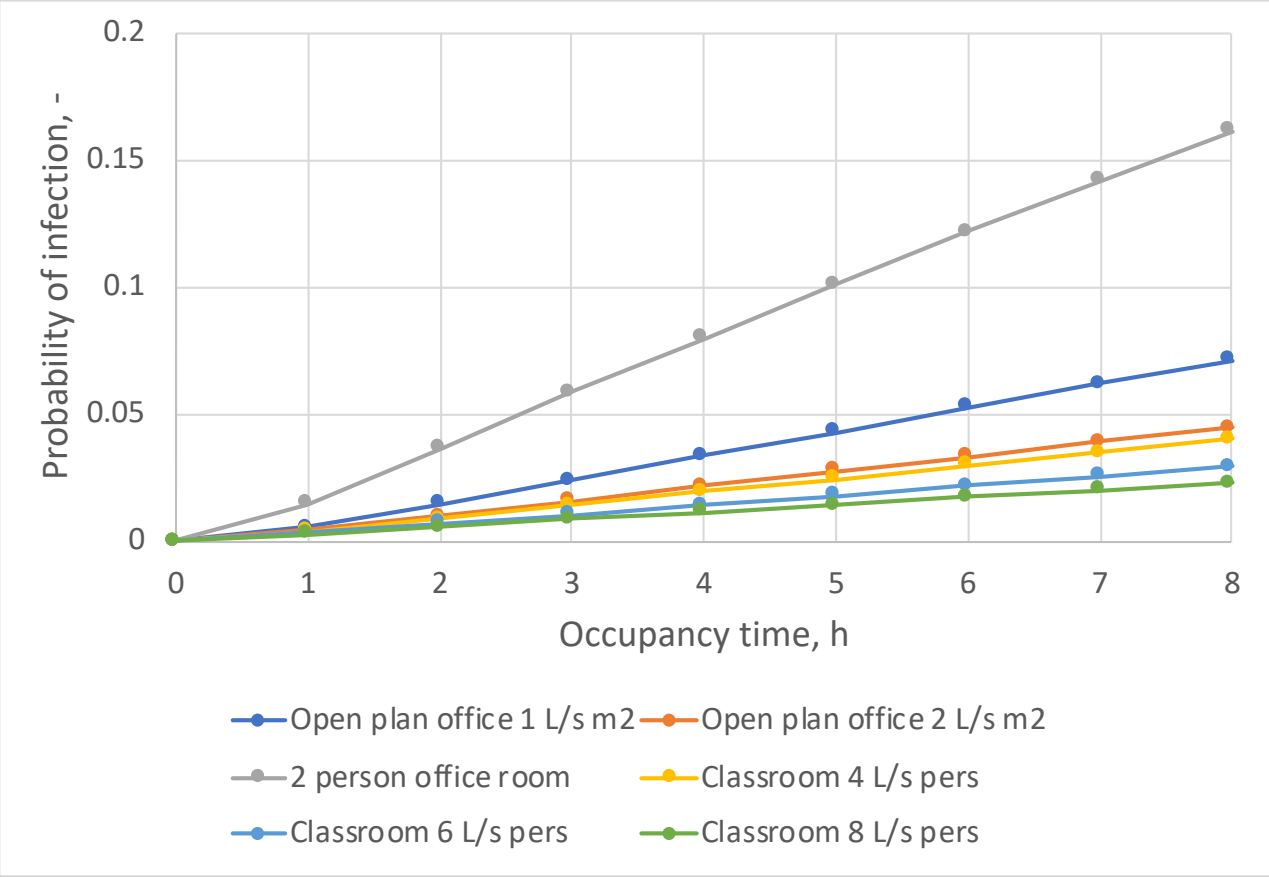
SARS-CoV-2 nakatumine on võrreldav külmetushaigusega (rinoviirus)

- 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

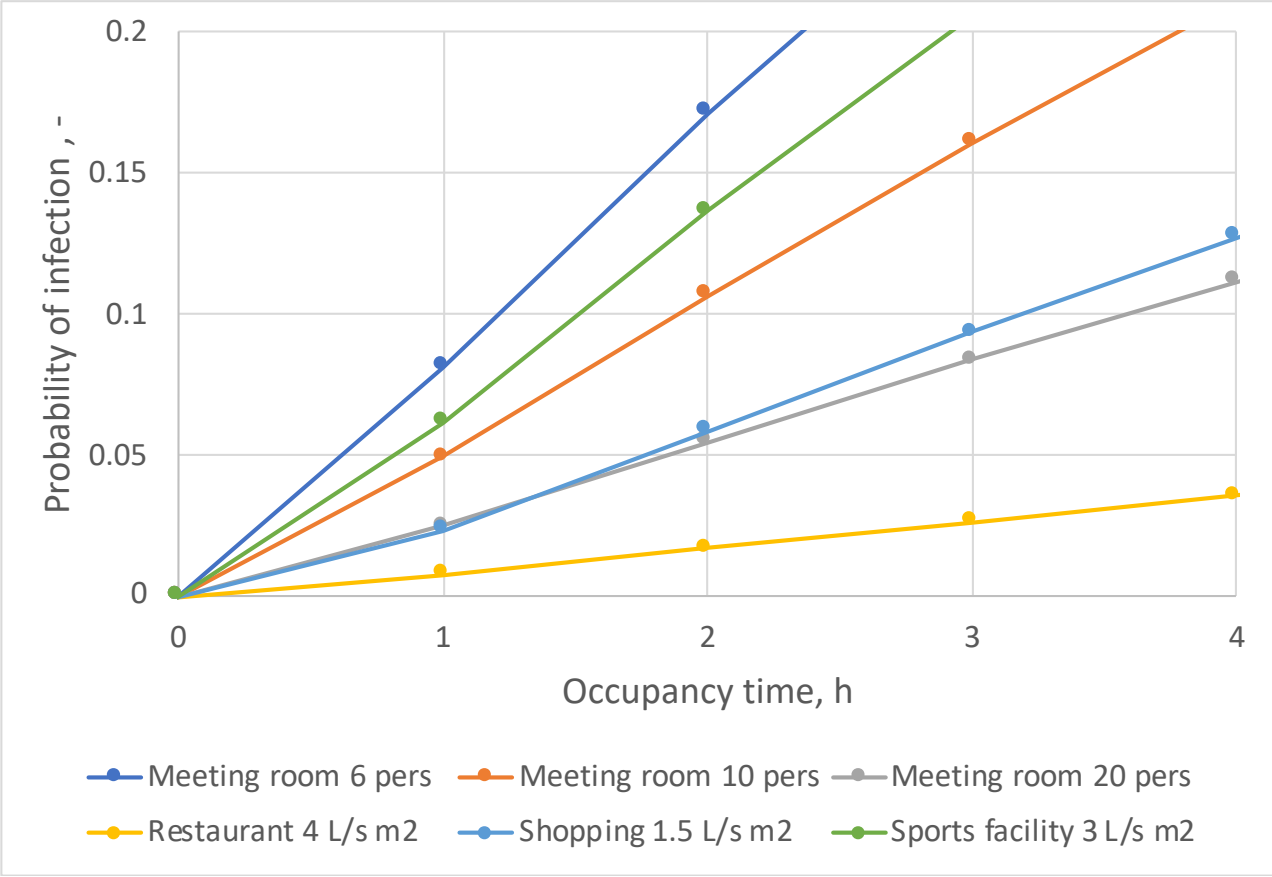
- Oletusena 1 nakatunud inimene kõikides ruumides
- 5 quanta/h büroodes ja klassiruumides
- 1.5 L/s m^2 ventilatsioon 2 inimese 16 m^2 tööruumis
- 50 m^2 avatud kontor
- 56 m^2 klassiruum



Calculation examples

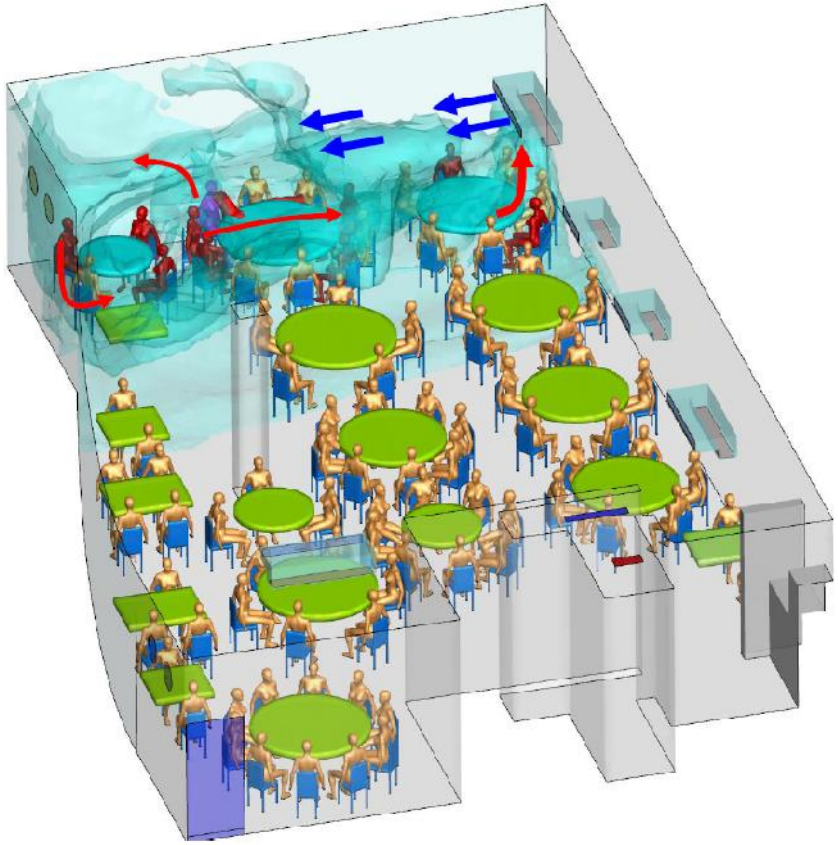
- 7 q/h for a restaurant, 10 q/h for shopping, 16 q/h for sports and 23 q/h for meeting rooms
- 4 L/s m^2 in meeting rooms of 15, 25 and 50 m^2
- 50 m^2 for other rooms

- 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 üldventilatsiooniga
- 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 CO_2 andurid, >1000 ppm puhul vajalik tuulutada või lahkuda ruumist
- Pikemas perspektiivis kontsentratsiooni alandamine õhujaotuse ja personaalse ventilatsiooni lahendustega