2025 ASHRAE WINTER CONFERENCE

ORLANDO, FEB 8-12 | AHR EXPO, FEB 10-12

Seminar 14: New Standards, Guidelines or Regulations for Ventilation due to COVID-19

Revision of European Standard EN 16798-1: Ventilation Design for Airborne Transmission

Jarek Kurnitski, Tallinn University of Technology
jarek.kurnitski@taltech.ee

Learning Objectives

1. Explain the importance of ventilation during a pandemic
2. Design a ventilation rate for reducing cross contamination during a pandemic
3. Provide an overview of actions taking in different parts of the world to reduce the risk of cross contamination during a pandemic.
4. Understand how important air cleaning and peoples density are during a pandemic

Design criteria for health vs. comfort

Comfort – perceived air quality – odours/bioeffluents/material emissions – existing:

- EN 16798-1:2019 ventilation rates are based on PAQ by the visitors (unadapted) in non-residential and occupants (adapted persons) in residential buildings
- Depend on the emissions from humans and building materials

Health and airborne transmission – proposed to be added:

- Specify minimum ventilation rate based on epidemiological studies
- Keep the likelihood of infecting others on the reasonable level to avoid the rapid spread of epidemic (one infector will cause no more than one new disease case)
- The infection risk should be considerably reduced but not eliminated (R_0 = 1)
- Relevant for shared indoor spaces (mostly non-residential), but not for health care with much more strict criteria

Design for airborne transmission

- New method intended to be used in combination with one of existing methods (PAQ, specific pollutant or fixed ventilation rates) so that the highest value of the ventilation rate shall be used as the design ventilation rate
- **Wells-Riley quanta method** (long range transmission) with one infector and the risk model that provides the same number of new disease cases for all spaces and occupant densities – sensitive to selected quanta values
- Calculates the ventilation rate reducing the expected number of **secondary infections from an infected person to 1.0 over the sequence of interactions the infected person has with susceptible persons during the whole pre-symptomatic infectious period**
- **Relative risk reduction method** included as an informative annex – may be useful for existing buildings but not preferred for the design of ventilation

Generic equation proposed to EN 16798-1

Infection risk-based ventilation rate for the breathing zone:

$$Q = q_q(N-1) - q_r V$$

Q target ventilation rate (L/s)
q_q quanta specific parameter
q_r removal rate of virus decay, deposition and filtration,
N **the number of persons in the room**
V **volume of the room, m^3**

Tabulated values for virus specific parameters q_q and q_r

Space category	q_q, L/(s person)	q_r, L/(s m^3)
Classroom	10	0.24 + k_f/3.6
Office	23	0.24 + k_f/3.6
Assembly hall	30	0.24 + k_f/3.6
Meeting room	40	0.24 + k_f/3.6
Restaurant	40	0.24 + k_f/3.6
Gym	70	0.24 + k_f/3.6

In the case of no air cleaner, filtration removal rate (1/h) k_f = 0

$$k_f = \frac{Q_f \eta_f}{V}$$

Tabulated values are informative (Annex B) and may be changed in the national annex

Generic equation proposed to EN 16798-1

Infection risk-based ventilation rate for the breathing zone:

$$Q = q_q(N-1) - q_r V$$

Virus specific parameters q_q and q_r:

$$q_q = \frac{q Q_b D}{R}$$

$$q_r = \lambda_{dep} + k + k_f + k_{UV}$$

- Target ventilation rate equation may be applied to calculate allowed occupancy at given ventilation rate
- Default values given for q_q and q_r
- In addition to quanta, q_q can be derived from relative risk reduction

Q target ventilation rate, L/s
q_q quanta specific parameter
q_r removal rate of virus decay, deposition and filtration
N **the number of persons in the room**
V **volume of the room, m³**
q quanta emission rate, quanta/(h pers)
Q_b breathing rate, m^3/h
D room occupancy period, h
R event reproduction number
λ_{dep} deposition onto surfaces, 1/h
k virus decay, 1/h
k_f filtration by an air cleaner, 1/h
k_{UV} disinfection by UVGI, 1/h

Calculation example

Model classroom:

- 26 persons
- 56 m^2 floor area
- 3,0 m height

Model open office:

- 12 persons
- 100 m^2 floor area
- 2.7 m height

+ varying occupant density

Airborne transmissin calculation methods:

- EN Health, new proposed method for airborne transmission to EN 16798-1
- ASHRAE 241

Perceived air quality calculation methods:

- EN 16798-1:2019, Category II, very low polluting building
- ASHRAE 62.1

Health vs. comfort, existing EN 16798-1

Airborne transmission

Target ventilation (non-infectious) rate for infection risk control = **outdoor air + particle filtered air + disinfected air:**

$$Q = q_q(N-1) - q_r V$$

Q = total ventilation rate for the breathing zone, L/s
N = design value for the number of the persons in the room
V = room volume, m^3
q_q = quanta specific ventilation rate, L/s person
q_r = removal rate of virus L/(s m^3)

Perceived air quality

Target ventilation rate = **outdoor air** (if no gas phase air cleaning):

$$q_{tot} = nq_p + A_R q_B$$

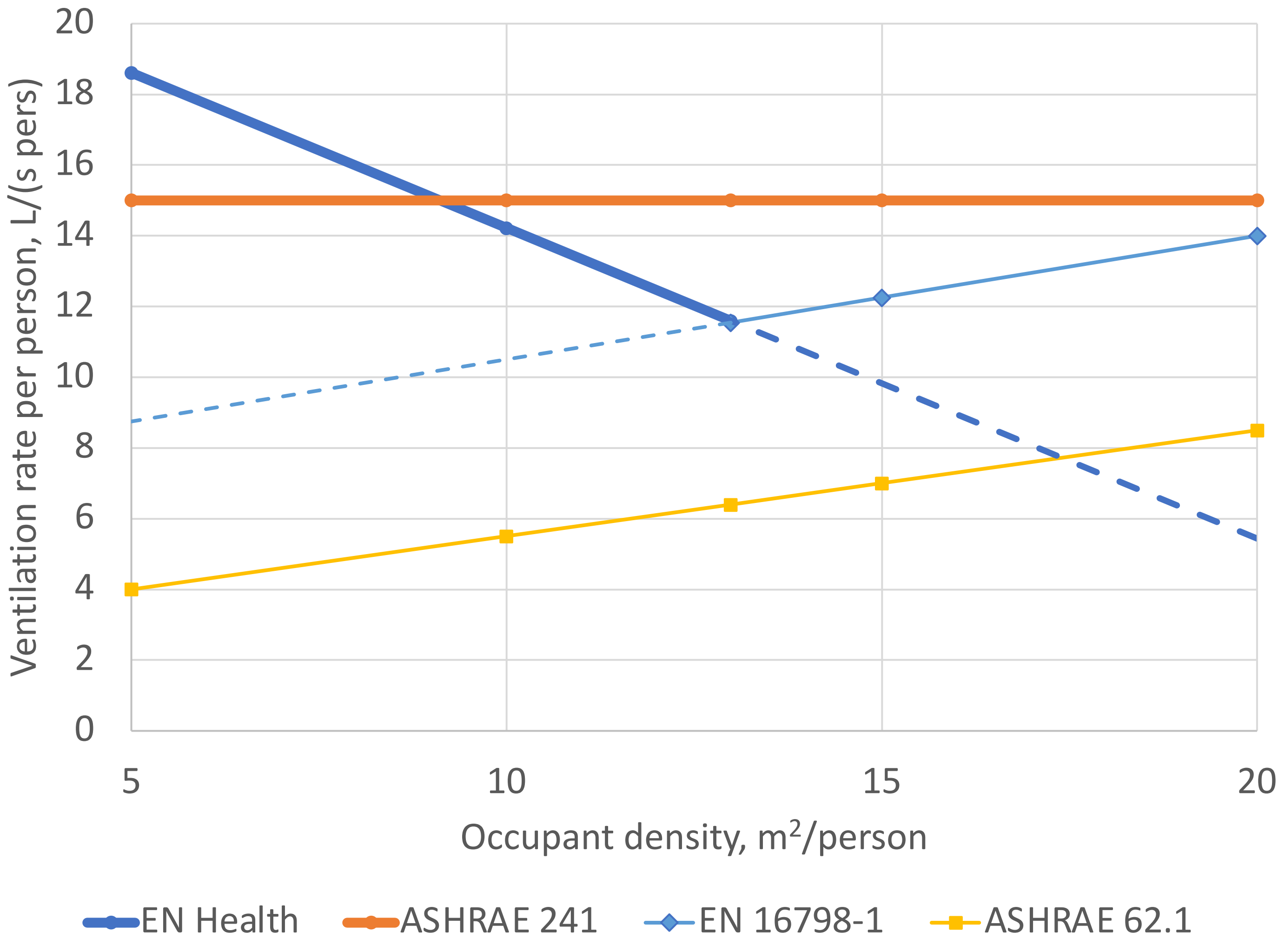
q_{tot} = total ventilation rate for the breathing zone, L/s
n = design value for the number of the persons in the room
A_R = room floor area, m^2

	Classroom		Office	
	L/s pers.	1/h	L/s pers.	1/h
EN 16798-1, Cat II VLPB	**7.8**	4.3	**9.9**	1.6
ASHRAE 62.1	**6.3**	3.5	**5.0**	0.8
EN Health proposal	**8.1**	4.5	**15.7**	2.5
ASHRAE 241	**20**	11.1	**15.0**	2.4

Higher ventilation rates will be in meeting rooms, restaurants and gyms – reduce occupancy

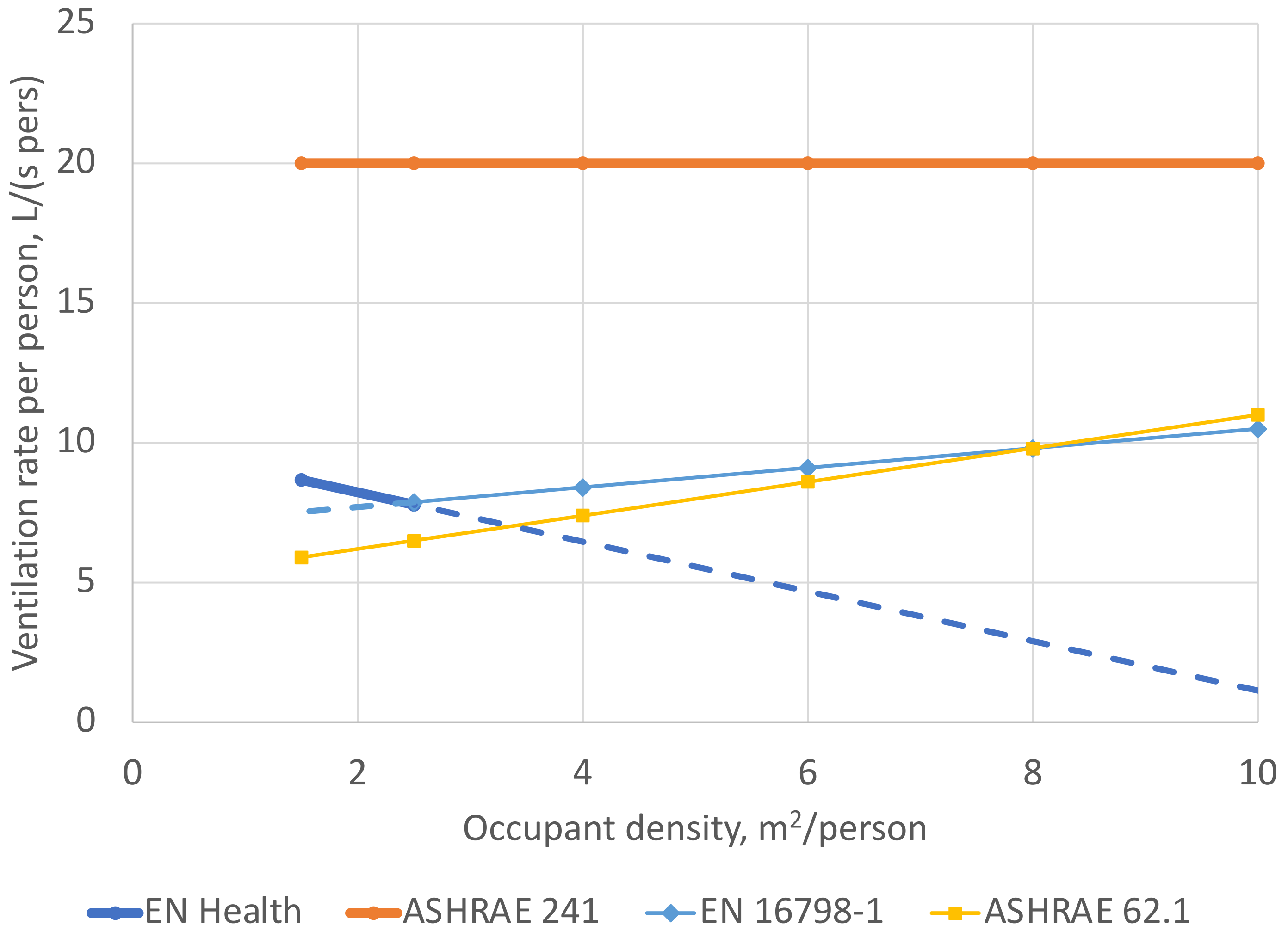
Office: higher or lower occupant density

- EN Health should be used in combination with EN-16798-1 PAQ that provides higher ventilation rate at low occupant densities (solid line in the figure)
- ASHRAE 241 fixed value is relatively close
- ASHRAE 62.1 provides the lowest ventilation rate



Classroom: higher or lower occupant density

- EN Health is close to EN 16798-1 at common occupant densities
- ASHRAE 241 is excessively high resulting in 11 1/h
- High quanta emission at speaking may explain the difference: EN Health assumes infected student speaking 5% of the time



Relative risk reduction

- Calculates the risk reduction from the initial/reference case conditions without any uncertainty related to the viral load (proposal for informative annex)
- Possible to calculate how infections in known disease case could have been reduced
- Example: relative risk reduction by 80% $\frac{R_1 - R_2}{R_1} = 0.8$ or **relative risk** $\frac{R_2}{R_1} = 0.2$
- Number of occupants and removal mechanisms can be changed to calculate relative risk:

$$\frac{R_2}{R_1} = \frac{\lambda_1 N_{s2}}{\lambda_2 N_{s1}}$$

where

λ_2 total removal rate in case 2, m^3/h

λ_1 total removal rate in the reference case 1, m^3/h

N_{s2} number of susceptible persons in case 2, -

N_{s1} number of susceptible persons in the reference case 1, -

r relative risk $r = \frac{R_2}{R_1}$ where R_1 and R_2 are number of new disease cases in the reference and target cases 1 and 2, -

Relative risk reduction

Total removal rate is defined as:

$$\lambda = \frac{Q}{V} + \lambda_{dep} + k + k_f + k_{UV}$$

where

Q	ventilation rate (m^3/h)
λ_{dep}	deposition onto surfaces (1/h)
k	biological decay rate (1/h)
k_f	filtration by a portable air cleaner (1/h)
k_{UV}	disinfection by UVGI (1/h)
V	volume of the room (m^3)

Relative risk reduction from the reference case can be achieved by changing the number of occupants, ventilation rate and removal rates by room air cleaner and UV. New ventilation rate Q_2 in case 2:

$$Q_2 = \frac{N_{s2}}{rN_{s1}}\left(Q_1 + V\left(\lambda_{dep} + k + k_{f1} + k_{UV1}\right)\right) - \left(\lambda_{dep} + k + k_{f2} + k_{UV2}\right)V$$

In the case of no air cleaner and no UVGI, with one infectious person assumption:

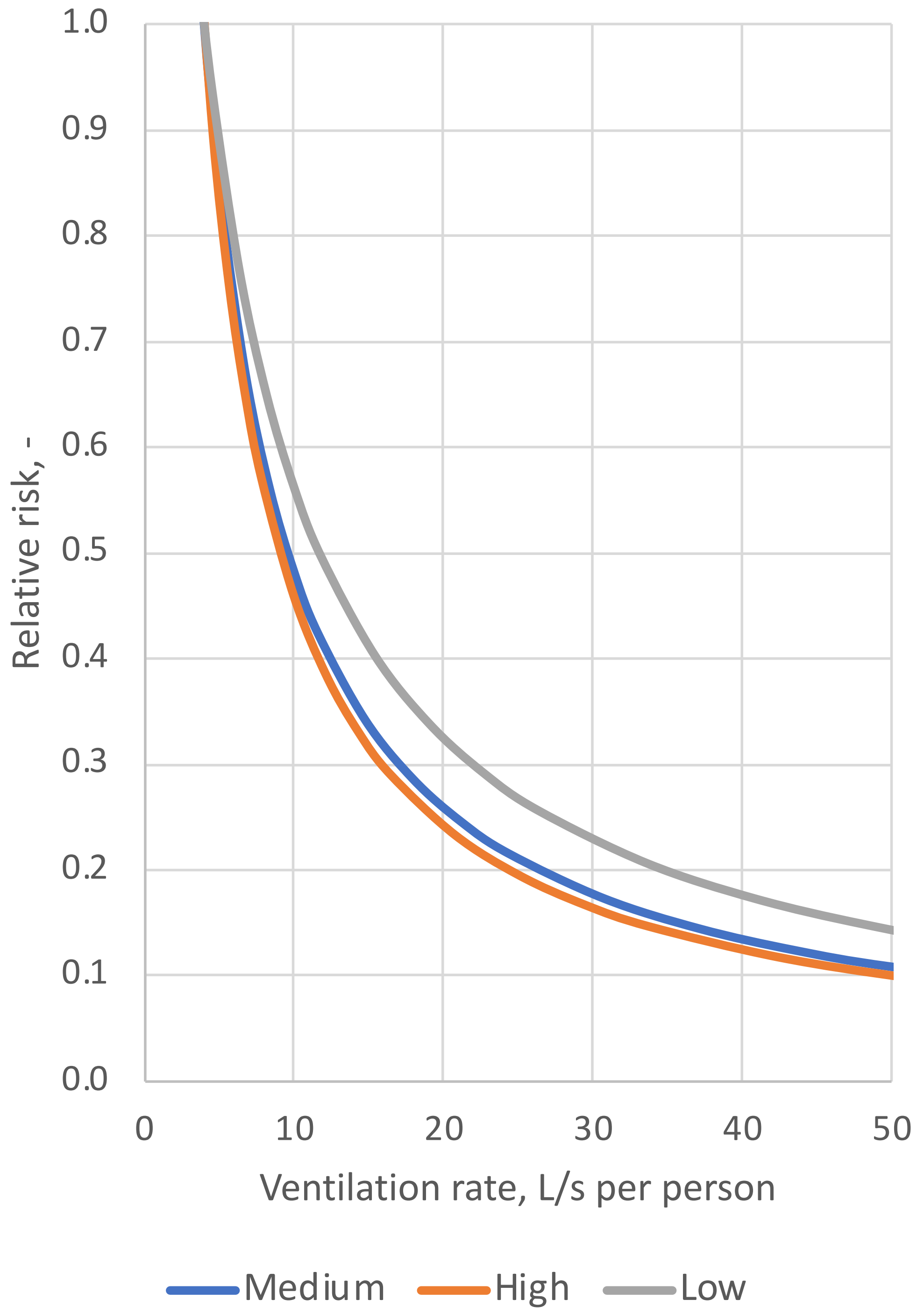
$$Q_2 = \frac{N_2 - 1}{r(N_1 - 1)}(Q_1 + 0.24V) - 0.24V$$

where

N_2	number of persons in case 2, -
N_1	number of persons in the reference case 1, -
r	relative risk compared to reference case 1, -

Classroom example

- Category IV 4.0 L/s-p is used as the reference ventilation rate Q_1
- *r* with 25, 37 and 11 persons (2.2, 1.5 and 5.1 m^2 per person)
- *r* is sensitive to occupant density
- Changes close to a typical occupancy of 2 m^2 per person had a small impact as 1.5 m^2 and 2.2 m^2 per person curves are close to each other and infection risk-based ventilation rates for medium and high occupancy of 8.0 and 8.6 L/s per person correspond to relative risk of 0.58 and 0.52
- Low occupant density is an outlier
- Similar results in the meeting room, restaurant and fitness, but higher differences in the office



From target to design ventilation rate

Design ventilation rate supplied by the **actual air distribution system** Q_s

$$Q_s = \frac{Q}{\varepsilon_b}$$

ε_b ventilation effectiveness for the breathing zone, contaminant removal effectiveness in REHVA Guidebook No 2

ε_b can be calculated from **local air quality index** ε_P values:

$$\varepsilon_{P,i} = \frac{C_e - C_o}{C_i - C_o}$$

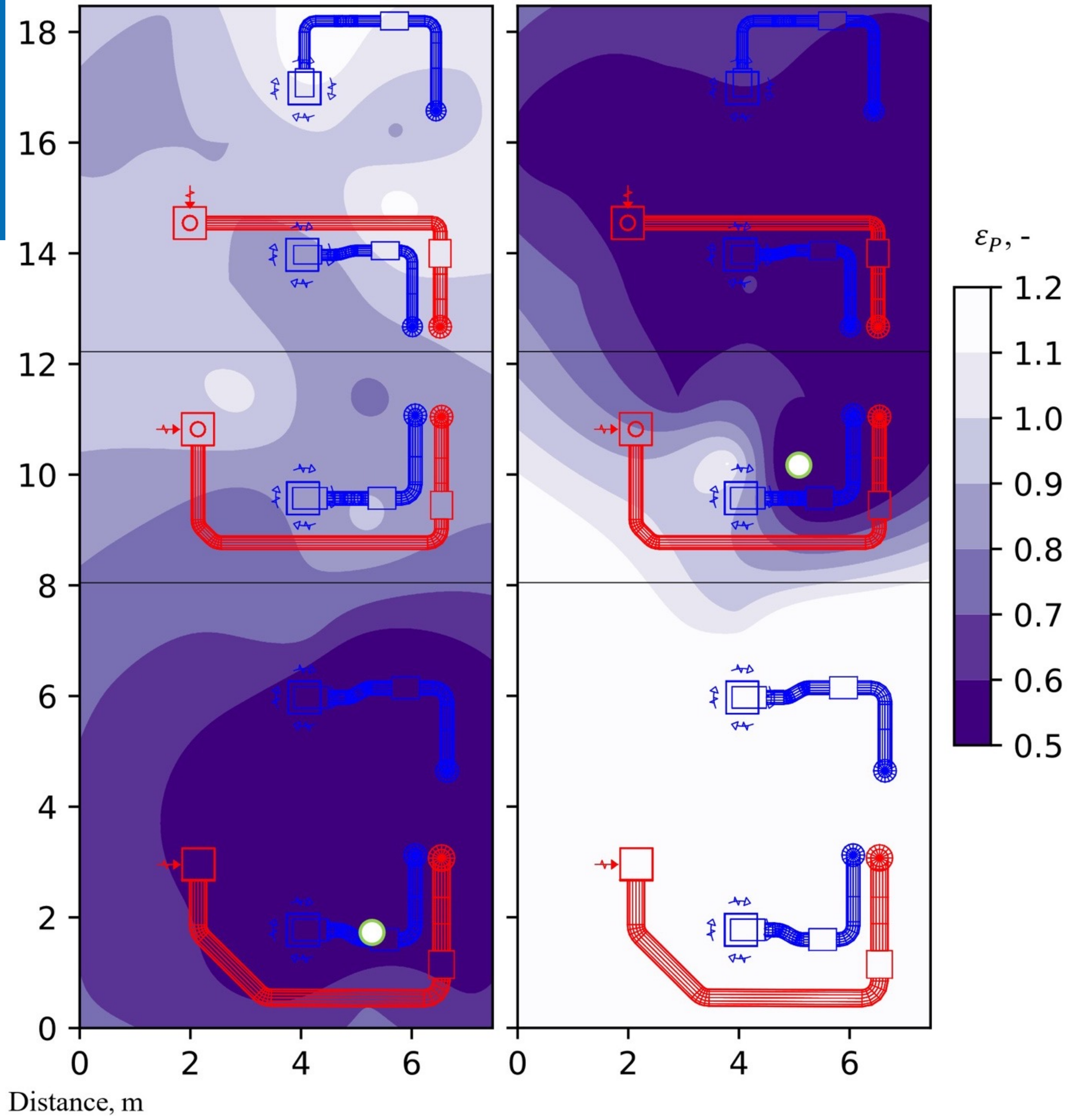
$$\varepsilon_b^j = \frac{1}{\frac{\sum_{i=1}^{k}\left(\frac{1}{\varepsilon_{P,i}}\right)}{k}}$$

where

C_e concentration in the extract air duct

C_i concentration at the breathing level

C_o concentration in the supply air



Large teaching space of 130 m² with 4 L/(s m²) ventilation: ε_b^1=0.76 (left) and ε_b^2=0.77 (right), the average value of two measurements ε_b=0.76

Conclusion

- Quanta method for long range airborne transmission with one infector and the risk model that provides the same number of new disease cases for all spaces and occupant densities proposed to EN 16798-1
- Includes new dose-response model, Wells-Riley modification using quanta at median viral load
- Scenario of exposure (one infector) and risk assessment model aiming to $R_0 = 1$, using constant likelihood of infecting others over the pre-symptomatic infectious period
- Provides space category specific target ventilation rates for fully mixing, limited to non-residential buildings (health care settings excluded)
- From fully mixing to actual air distribution method – introduces point source ventilation effectiveness (contaminant removal effectiveness)
- Relative risk reduction method proposed as informative annex for existing buildings

Bibliography

Scientific background of the model:

- New dose-response model, Wells-Riley modification using quanta at median viral load
Amar Aganovic, Guangyu Cao, Jarek Kurnitski, Pawel Wargocki, New dose-response model and SARS-CoV-2 quanta emission rates for calculating the long-range airborne infection risk, *Building and Environment*, 2022 https://doi.org/10.1016/j.buildenv.2022.109924
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- From fully mixing to actual air distribution method – introduces point source ventilation effectiveness (contaminant removal effectiveness)
Martin Kiil, Alo Mikola, Karl-Villem Võsa, Raimo Simson, Jarek Kurnitski, Ventilation effectiveness and incomplete mixing in air distribution design for airborne transmission, *Building and Environment*, 2025, https://doi.org/10.1016/j.buildenv.2024.112207

Questions

Jarek Kurnitski

jarek.kurnitski@taltech.ee