Corona Virus:
Emission-Transmission-Immission model based on the Mollier diagram

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Infection Risk Model: Emission-Transmission-Imission

To determine whether an infection risk is high or low, scientists use a so-called Dose-Response models. These basically say:

Infection risk = (virus concentration) x (residence time)

A scientific form that is regularly used to describe e.g. influenza risk is the Wells-Riley model.

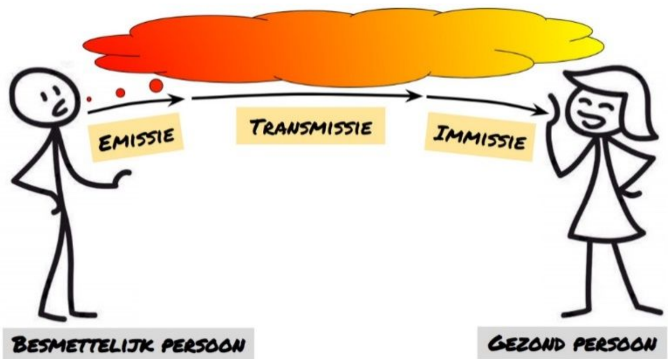
Pr (infection) = C / S = 1 - e (-Iqpt / Q)

It mainly shows that the effective concentration is the balance between the number of virus particles (q) x (p) (emission) and the ventilation that tries to eliminate the number of virus particles.

Emission
However, in every scientific piece, the (q) is the most difficult to find out because it is not known how many virus particles are emitted per breath during talking, coughing or sneezing and it is not really known how many virus particles are needed to actually infect someone. Depending on the activity (rest: 2q / h, quietly singing 65 q / h to dancing singing 408q / h), the source emits more or less.

Immission
The first studies (Miller et Al, Buonanno et Al) have meanwhile shown that approximately 970 q / h is required for effective contamination. Depending on his activity, the victim will also breathe more or less (rest 0.49 m3 / h, dancing 3.3 m3 / h) - so the activity determines the emission-immission relationship to a very large extent.

However, these models assume a reasonable 1 to 1 **transmission** of the virus load, but a lot of infections don't happen this way.



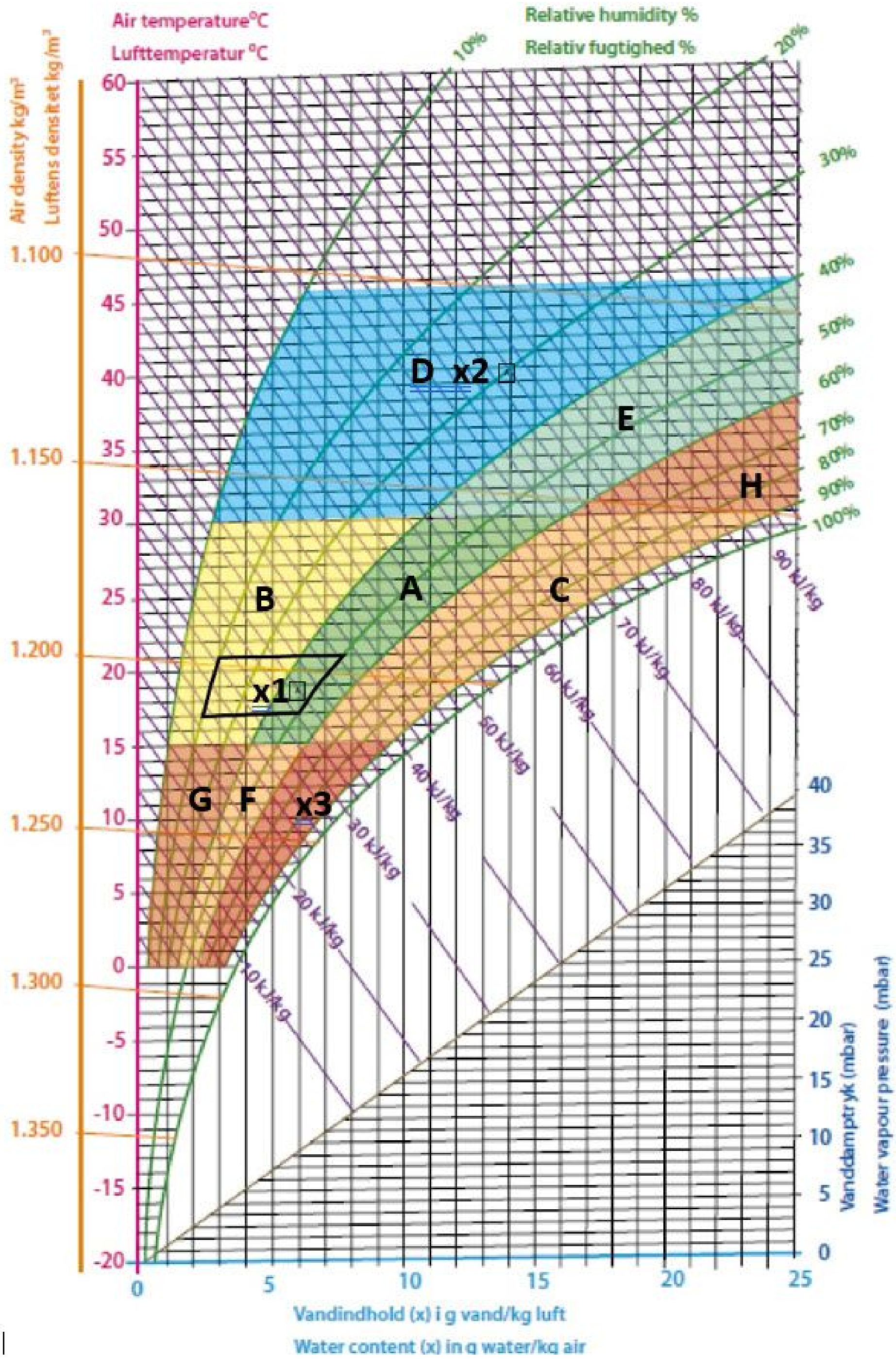
(courtesy: Frank Ploegman)

Transmission
The transmission of the virus therefore plays an essential role in determining the infection risk: some determining factors are:
1. What are the physical conditions of the virus particle? (droplet or aerosol). A droplet usually contains more virus particles, so it takes less to get infected than in the case of an aerosol.
2. How stable is the virus in the given (physical) circumstances?
3. Is there also an active driving force (e.g. a ventilation system / fan) that could drive an aerosol (“forced convection”)?

In short, it must be known which circumstances apply. Practice has shown that both temperature (° C) and humidity (RH%) play a major role in the stability of the virus and also whether we are dealing with droplets or aerosols.

The Mollier Diagram
Surely there must be a certain logic behind this and can this logic help us to place every situation in a certain risk category?

The **Mollier diagram** is invaluable here (also called enthalpy entropy diagram or psychometric diagram).

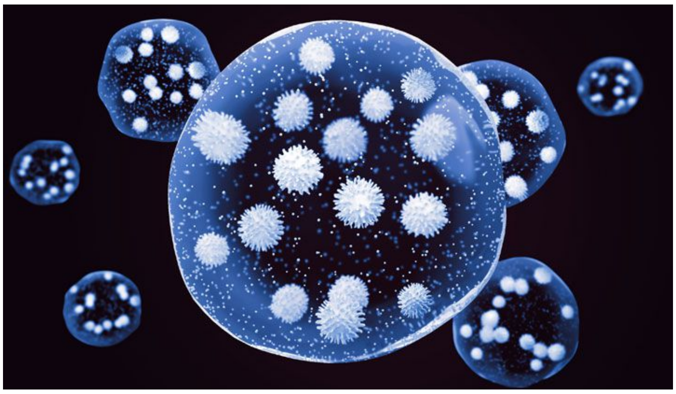


The Mollier diagram shows the relationship between temperature and humidity in all possible states (cold and dry as on winter sports or wet and warm as in the tropics). Here the complete overview with examples:

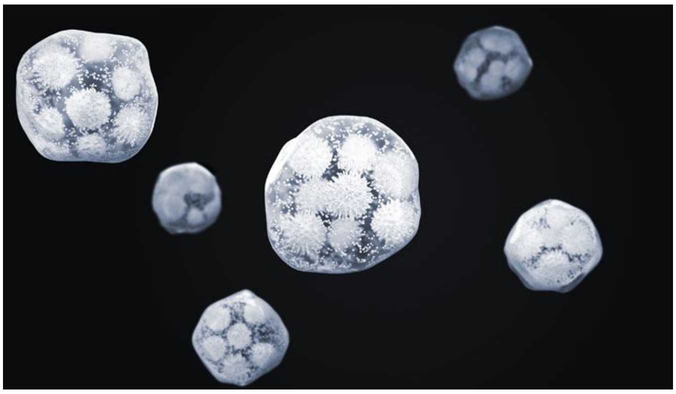
INSIDE:	A. Inside in Spring	(15-30°C en 40-60% RH%)
	B. Inside in (dry) Winter	(15-30°C en 10-40% RH%)
	C. Inside in (wet) Summer	(15-30°C en 60-90% RH%)
Examples	x1 Inside and airco "ON"	(17-22°C en 20-50% RH%)
	x2 Inside at sauna	(>30°C en 10-40% RH%)
	x3 Meat Processing Plant	(0-15°C en 60-90% RH%)
OUTSIDE:	D. Outside in Desert	(>30°C en 10-40% RH%)
	E. Outside, hot Summer	(>30°C en 40-60% RH%)
	F. Outside in Autumn	(0-15°C en 40-60% RH%)
	G. Outside in (dry) Winter	(0-15°C en 10-40% RH%)
	H. Outside in Tropics	(>30°C en 60-90% RH%)

For these areas it is also possible to make a statement in what viability the virus is a) and b) over a longer period of time.

The virus is initially exhaled as a droplet and depending on the condition (A-) it will remain a droplet or dry out to an aerosol.



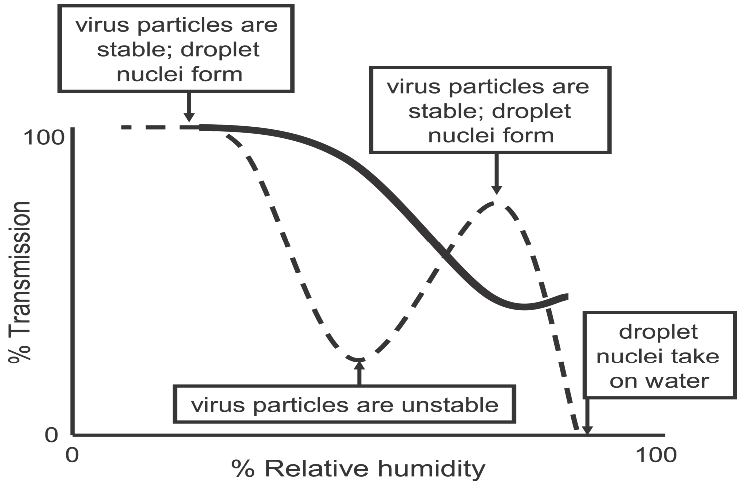
(droplet after breathing out) (www.condair.com)



(droplet dried out to an aer0sol) (www.condair.com)

In states A, C, F, and H it will remain a droplet because the air around the droplet is too humid to dry it out and in states B, D, E and G aerosols will certainly form because the droplet loses its moisture very quickly and goes to aerosol status.

It is now known that a droplet is more stable and contains more active virus particles (viability) than an aerosol, so you can also make a statement about which areas are at greater risk. This is the graph of this study from 2007 (A. Lowen e.o.)



Based on this we can now make the following table. In doing so, we make an estimate of the transmission factor.

		°C	RH%	Droplet	Aerosol	Tf
	INSIDE					
A	Inside in Spring	15-30	40-60	√ ↓	-	0,1
B	Inside in (dry) Winter	0-15	10-40	-	√→	0,3
C	Inside in (wet) Summer	15-30	60-90	√→	-	0,3
	OUTSIDE					
D	Outside in Desert	>30	10-40	-	√↓	0,05
E	Outside, hot Summer	>30	40-60	√ ↓	-	0,1
F	Outside in Autumn	0-15	40-60	√↓	-	0,2
G	Outside in (dry) Winter	0-15	10-40	-	√→	0,6
H	Outside in Tropics	>30	60-90	√→	-	0,6
		Virus Stability	Droplet Stability	Droplet movement	Aerosol movement	Transmis— sionfactor

Because there is natural ventilation outside, the risk of inhaling the virus to a sufficient extent will be very small, even if the transmission factor is -somewhat- higher. So we only focus on the situations inside.

		°C	RH%	Droplet	Aerosol	Tf
	INSIDE					
A	Inside in Spring	15-30	40-60	√ ↓	-	0,1
B	Inside in (dry) Winter	15-30	10-40	-	√→	0,3
C	Inside in (wet) Summer	15-30	60-90	√→	-	0,3
X1	Inside and airco "ON"	17-22	20-50	-	√℗↓↑	0,6
X2	Inside in sauna	>30	10-40	-	√↓	0,05
X3	Meat processing Plant	0-15	60-90	√℗↓↑	-	0,8
		Virus Stability	Droplet Stability	Droplet movement	Aerosol movement	Transmis— sionfactor

"Inside in Spring" is not a problematic situation. The conditions are unfavorable for floating aerosols. Because of the humidity the larger drops will fall directly to the ground.

But in winter when the humidity is low or in summer when the humidity is high there is a clear risk.

Some examples first

We will first discuss the three specific situations indicated to get a better understanding and then go deeper into how to deal with those risk situations in winter and summer.

Example x1: Inside and airco "ON". The air conditioning does two things. 1) it stabilizes the virus by making the air colder and drier and it ensures active air movements so that the aerosols formed can be carried along the winds created (forced convection)

You can clearly see in graph on page 3 that an air conditioner increases the risk because the virus offers more stable conditions and better transmission.

Example x2: The Sauna: The temperature is very high (80-95 ° C) (even outside the Mollier graph) and the humidity is 1-2%, so far top left in the graph. The large temperature differences at the bottom (80 ° C) and 2 benches higher (95 ° C) ensure an extreme upward thermal flow.
Risk analysis: An exhaled droplet may very quickly become an aerosol, but due to the thermals it will also rise up very quickly and most likely hit the ceiling as dried out salt crystal. Due to the high temperatures, the virus will also be destroyed within seconds or minutes.

Example x3: The meat processing industry is most at risk because everything that can go wrong actually goes wrong:

- The virus is exhaled, coughed or sneezed as a droplet because people already have lower resistance due to the cold circumstances.
- The virus remains very healthy and stable as a droplet because the air is cold and moist.
- A droplet contains the maximum virus load.
- Because it is cold and humid, the air is also fairly “heavy” (1,250kg / m3 against 1,100kg / m3 in warm air) and the droplets cannot fall to the ground as easily as in drier air would be the case.
- The cold air installation pumps the air in the room around by means of strong fans, so that the droplets are also actively carried along with the air movement
- People are close together so it is a small step to inhale a droplet.

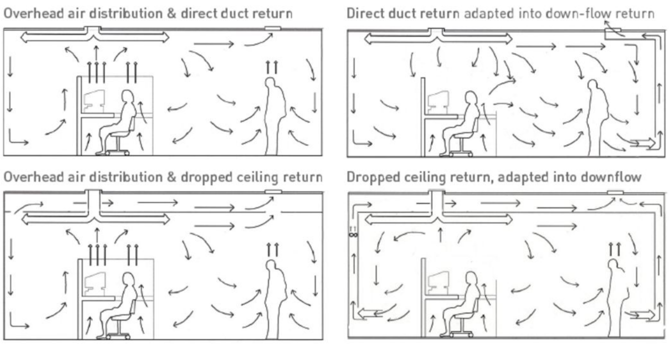
<u>What to do Inside in the dry Winter or in the wet Summer?</u>

If you are in public indoor spaces with people you normally don't meet or rarely meet, there are therefore risks of contamination if one or more people are present who are contagious at the time.

This risk can be greatly reduced by means of proper ventilation. But it's not just about ventilation, it's about the way it's done.

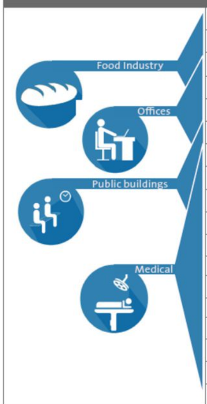
A DeltaPlan Ventilation should therefore contain the following positions (by priority)

1) AIR HIERARCHIE:
The correct air direction, for example to push the aerosols or small droplets to the ground and extract them there



2) AIR CAPACITY:
Supply the correct amount of air (ACH) so that any aerosols can be extracted within minutes.

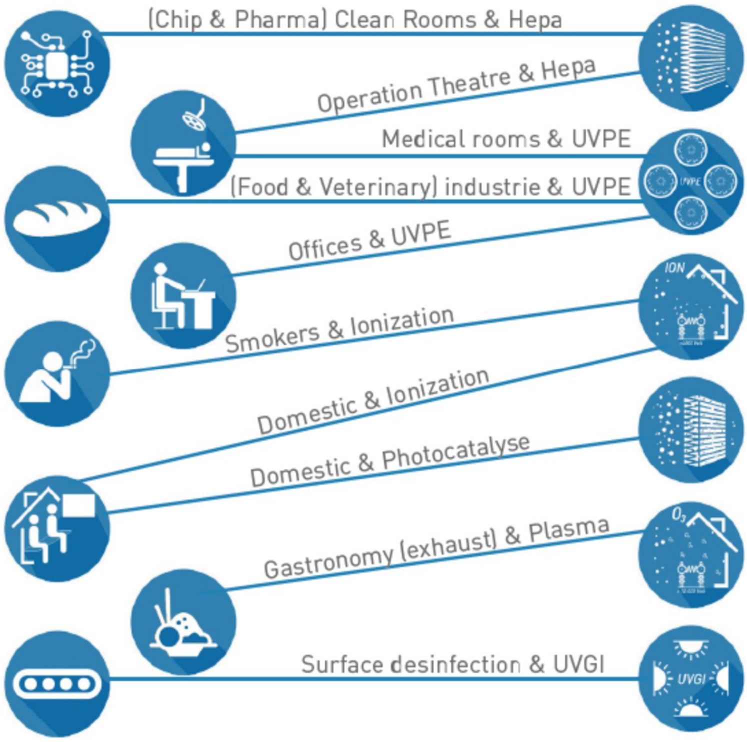
Average Air Changes per Hour (ACH) and minutes according to regulations



ACH	Description	(av.) initial CFU	Minutes -90%
1	cold storage, warehouse, lockerroom,	250-500	138
2	Production hall	750 -1250	69
3	Indoor Swimmingpool (VDI 2089)	250 - 500	46
4	conference room, library, Gym (DIN 1946-2)	125 -250	35
5	Shopping mall & Retail stores (VDI 2082)	250 -500	28
6	Classroom (DIN 1946-2), Isolation room (DIN 1946-1)	250 -500	23
7	Theatre, Cinema, churches (DIN 1946-2)	250 - 500	20
8	Open plan office (DIN 1946-1)	125 - 250	17
9	Laboratories (VDI 2051)	100 - 250	15
10	Restaurants (DIN 1946-1), Casino (VDI 2082)	250 - 500	14
11	Minor surgery room (DIN 1946-1)	100 - 250	13
12	Intensive Care (DIN 1946-1)	10 - 100	12
13			11
14			10
15	Professional Kitchen (VDI 2052)	500 -750	9
16	Bars (DIN 1946-1)	250 - 500	9
17			8
18	Operation Theatre (DIN 1946-1)	<10	8

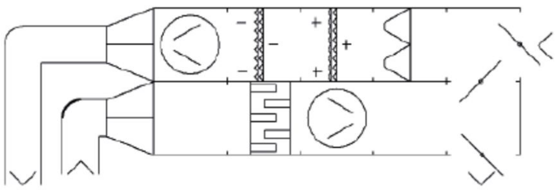
3) AIR QUALITY:

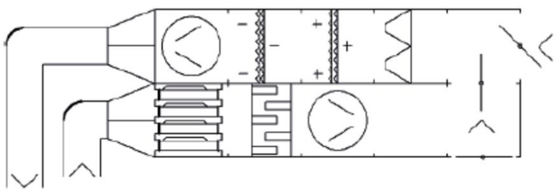
Use the correct air quality technology if the air is recirculated
(note: 100% fresh air in combination with heat-recovery-wheels gives carry-over effect and another risk is even possible short circuit of exhaust and supply air outside, next to the air handling unit.)



4) AIR INSTALLATION:

The right upgrade for the (existing) HVAC installation with regards to filter classes or UV systems and to keep the humidity between 40-60%.





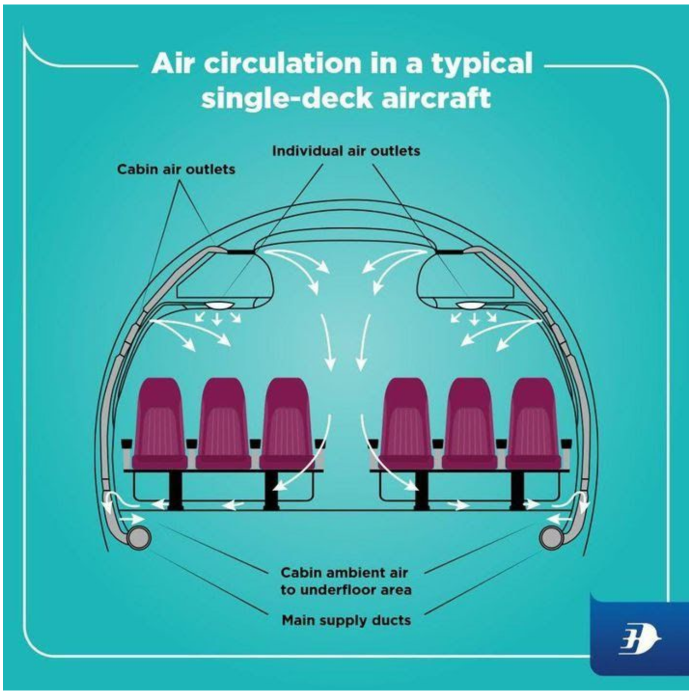
5) AIR MAINTENANCE:

Draw up a validation and maintenance plan so that everything always works properly.

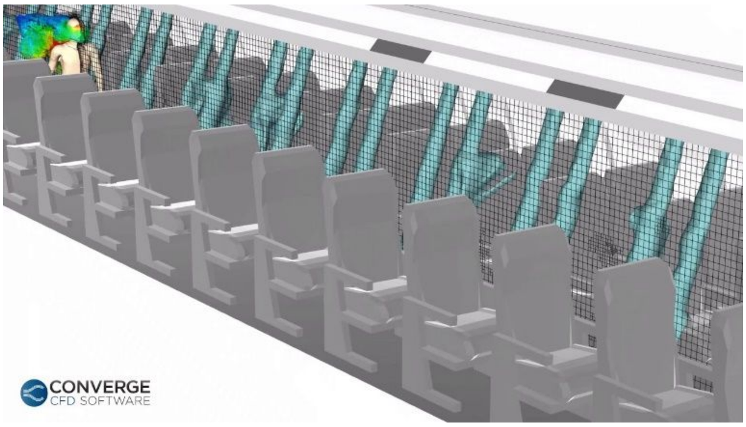
<u>Some practical example for a risk analysis: Airplane</u>

Flying is seen as a risk by many people, however an analysis based on our DeltaPlan Ventilation shows that it can sometimes be safer on an airplane than on public transport.

In an airplane, there is a downflow **air hierarchy** with extremely **high air capacities** and the regulated air is returned through **HEPA Filters**, which makes the **air quality** good.



The Air installation is also designed in such a way that almost every passenger stays in their own “air balloon” and can therefore spread a maximum of 1-2 rows to the front or rear.



Measures such as an FFP3 mask, few people walking around or cabin crew also further reduce the risk of such infections.

Appendix: Mathematical model

In life on earth there is actually no hocus-pocus, after all, almost everything can be explained scientifically, provided the inputs are known. Depending on the situation and circumstances, there is a decision to be made whether there is an increased risk of infections

Abstract model:

Emission	Transmission	Immission
Activity (Eq) Moundmask (E_M)	(Mollier) area (T_F) Distancing (T_D)	Ventilation (L_F) Inactivation (I_F) Moundmask (I_M)

with:

(E_q)

breathing:	6.5q
Talking:	12q
Coughing:	25q
Sneezing:	200q
Sporting:	35q
Singing:	30q

(E_M)

N95:	0,6
Chirurgical	0,8
FFP3	0,3

(T_F)

A (0,1), B (0,3), C(0,3), D (0,05), E (0,1), F (0,2), G (0,6). H (0,6.

(L_F) = (1 – L – A – F) If applied

(L) Air Hierarchy:	0,4
(A) ACH >5	0,3
(F) HEPA/UVC	0,2

(I_F)

(100 - % reduction within 1 hour) / 100

(example: device dilutes 70% of the concentration within 1 hour: (100-70) / 100 = 0.3 factor over.

(I_M)

N95:	0,6
Chirurgical	0,8
FFP3	0,3

Safe Time = 960q / (Eq * Em * TF * LF * IF * IM)

Example:

Meeting room with DeltaPlan compliant measures, and air conditioning on.

T = 960q / (6.5 * 1 * 0.6 * 0.2 * 1 * 1) = 1,200 min

Without DeltaPlan Ventilation

T = 960q / (6.5 * 1 * 0.6 * 1 * 1 * 1) = 246 min

Note: the values used here are relative and sometimes estimated, and the model is suggestive because it assumes linear behaviour. Nevertheless, it gives a relatively good difference in the different states in which one can be compared to other states and the influence of measures on them.

This model therefore needs to be further developed and fed with more data so that it can be placed as a dynamic value in a Wells-Riley or Dose-Response model.

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