How to reduce risk of Airborne infection with ventilation / Air Cleaning?

Halton
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Content of the presentation

- Different needs for Cleaning / Purification
  - Air Cleaning
    - Supply Air Cleaning
    - Supplementary Room Air Cleaning to control contamination levels
    - Room Clean Up Between Op

- Presentation of the different Air cleaning/purification techniques

- Impact of ventilation / cleaning on Airborne infection
  - Case: Safe return to Halton Pasila Office

- Design examples of Certain Air Cleaning situations
  - Room air Contamination Control
  - Room Clean-Up

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Needs for Air Cleaning in Buildings 1/2

& Additional precautions due to Covid

- Supply Air
  - Cleaning outside air from particles (and eventually gaseous contamination in some congested city areas)
  - Purpose to Protect ventilation system, building and people
  - In general no need for additional precautions due to Covid-19

- Air Recirculation systems for multiple rooms
  - Protecting system from dust collection
  - Need for Improved Air cleaning (e.g. HEPA) to avoid crosscontamination – hard to realize in existing systems

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Needs for Air Cleaning in Buildings

& Additional precautions due to Covid

- Supplementary Room Air Cleaning to control contamination levels , Often realized by mobile air cleaners
  - Cleaning of Room air from impurities, such as particles, Smells (such as VOC's)
  - Purpose to supplement insufficient ventilation, to compensate for high local emissions or to protect sensitive individuals
  - Need to diminish infection risk by reducing microbial content from room air
    - In order to make remarkable impact it is important that cleaner efficiency, air capacity and ability to influence room air movement are ensured for the purpose

- Room Clean Up between consecutive events
  - Typically used in special environments for example in hospitals etc. (poorly ventilated schools)
  - Clean Up can be used to reduce contamination risk of next event and thus enable continuation of efficient work, such as between meetings, dental practices etc.

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Air cleaning/purification techniques

- Mechanical Filtration
  - Gross/Fine filters
  - HEPA filters
- Ultraviolet Light
- Electrostatic precipitators/Ionisers
- Chemical filter medias – for gas phase contaminant removal, not applicable for microbial cleaning
- (Gassing – primarily on special rooms)

NOTE! Air cleaners may and often do utilize combination of different techniques

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Performance Evaluation

Recirculation Air Cleaning

- The Efficiency of a aircleaner is a function of the Cleaning Efficiency and airflow rate, also unit's ability to distribute air to the whole space to be cleaned is important – especially, when critical contaminants such as (Covid-19) are to be cleaned

- A commonly used Efficiency Rating is ***CADR*** (Clean Air Delivery Rate). It illustrate the unit's capability to clean the air for certain contaminant at the same rate as cleaned ventilation air:

$$\boldsymbol{CADR} = E_i \times Q_{max} ,$$

E_i is Cleaning efficiency of the unit for a contaminant of concern [*i*]

Q_{max} is maximum airflow rate [m^3/h]

- Efficiency E_i is naturally different for different particle sizes, microbes or gases, whichever is a concern. Thus it is vital to know what is the purpose for use
  - As an example for the particulate contamination it is important to ensure that unit is efficiet for the particulates that needs to be captured (For mechanical filters the measure is particle size)

  NOTE! Covid-19 particle size is 0,1 µm

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Mechanical Filtration

- Mechanical filtration removes particluate contaminants from the air – the efficiency is depending on the quality and type of filter used

- When properly used and maintained there are no adverse effects to take into account
  - Prevent water moisture penetration (fan-units, outside air,…)
  - Change regularly (easy to monitor by measuring pressure loss)
  - Mechanical filters cause pressure drop and may consume somewhat more energy than purification methods w/o filter
    - However most purification devices have also mechanical filter included
    - This need to be account, when addition/change of filter type is considered into existing system

- The efficiency in general and for Covid-19 removal is discussed in next slides

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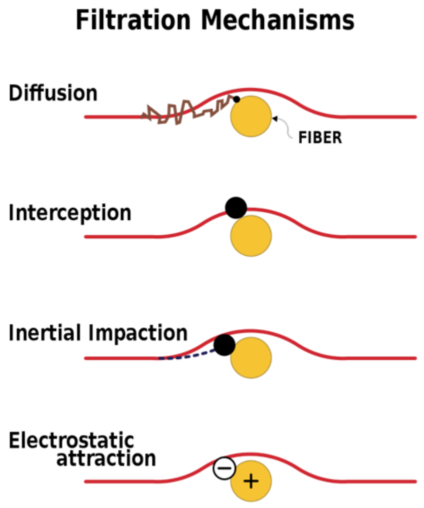
Particulate Filtration – Theory 1/2

- Different filtration mechanisms affect on the total filtration efficiency – Diffusion and Interception dominate in practise
    - Diffusion is especially important for small particles
- Each Filter has a **Most Penetrating Particle Size** (MPPS) with lowest efficiency



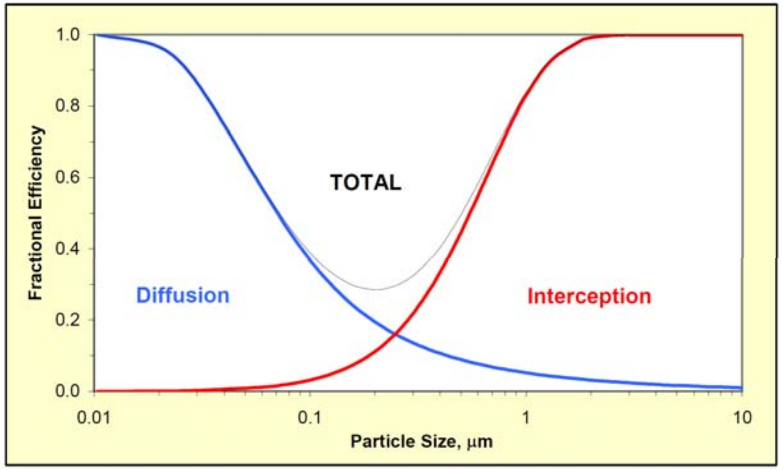


Figure 1: Generalized performance curve for a MERV 15 filter showing components.

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Particulate Filteration – Theory 2/2

- The MPPS becomes smaller and minimum efficiency increases when changing to higher filter class
- Velocity trough filter material impact on efficiency – especially impairing diffusion effect
- Figures show efficiency curves of MERV filters, ASHRAE M13 closest comparable to EN779: F7 Filter
  - The most penetrating (leaking) particle size is close to Covid-19 molecule size

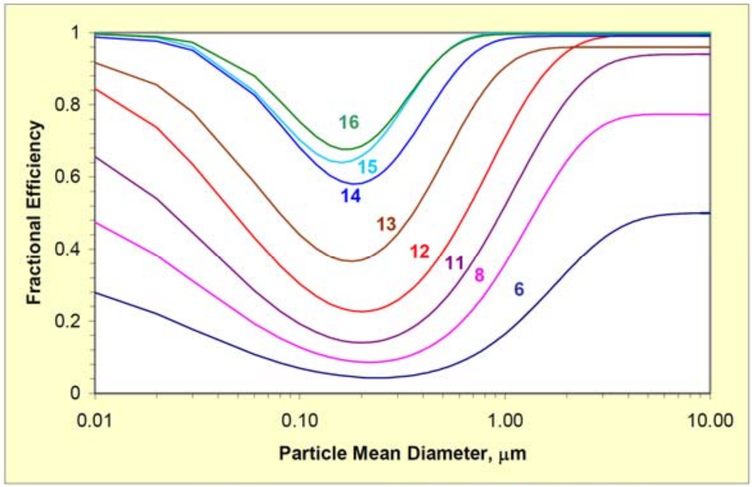

Figure 4: Composite of all MERV filter models, based on initial conditions.

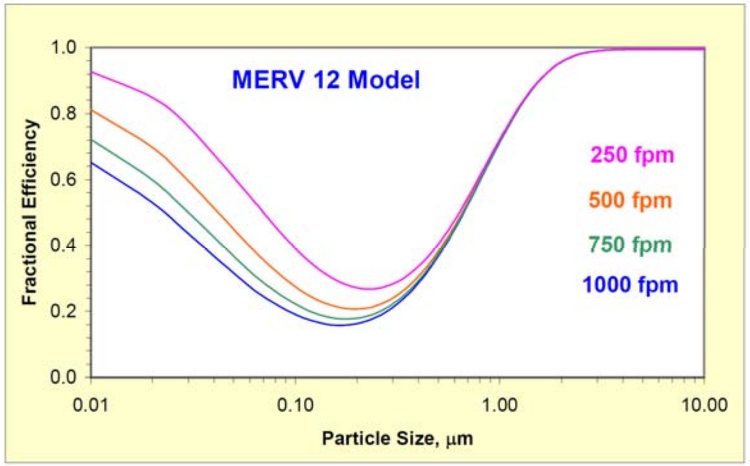

Figure 5: MERV 12 filter model at various operating velocities.

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Filtration efficiency – Fine Particulate Filters

- New Filter Classification Standard ISO 16890 is based on the average efficiency (in mass) over the range of certain particle sizes , i.e. ePM1 particle size range 0,3 – 1,0 Microns, thus it does not tell about the efficiency for certain particle size. (Old EN 779 was focusing on 0,4 micron particles)
- The MPPS for cless eMP1 40%-65% / ”E7” Filter is between 0,1 - 0,2 microns, which is the size range

EN 779:2012	ISO 16890		
Filter class	ePM 1	ePM 2,5	ePM 10
M5	5% - 35%	10% - 45%	40% - 70%
M6	10% - 40%	20% - 50%	60% - 80%
F7	40% - 65%	65% - 75%	80% - 90%
F8	65% - 90%	75% - 95%	90% - 100%
F9	80% - 90%	85% - 95%	90% - 100%

Source: Selection of EN ISO 16890 rated air filter classes for general ventilation applications (1st edition).
Eurovent 4/23 – 2017, 09 January 2018, https://eurovent.eu

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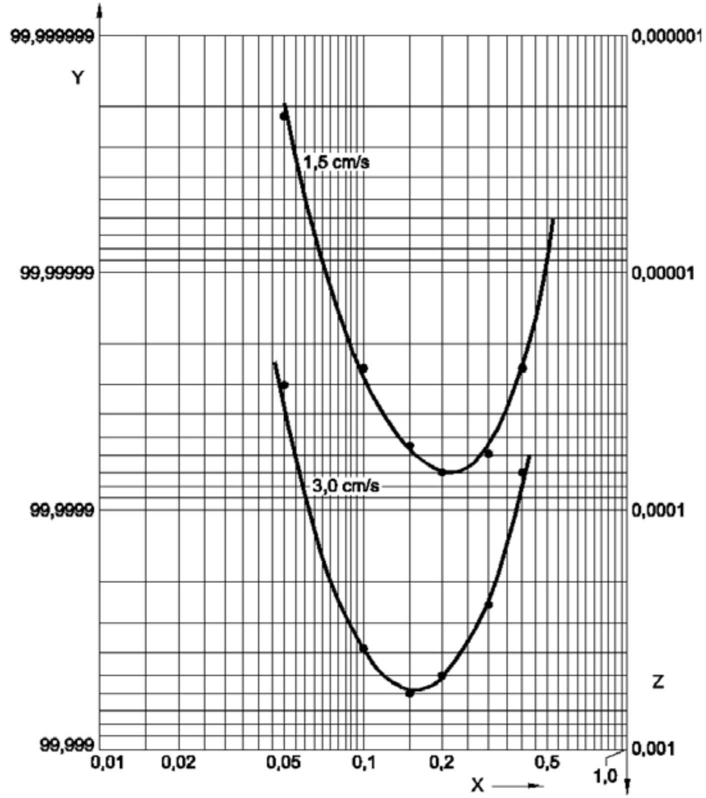
Filtration efficiency – HEPA/ULPA Filters

- HEPA/ULPA filter media involves testing of MPPS and minimum efficiency
  - MPPS for HEPA/ULPA filters is between 0,1 - 0,2 microns
  - Trough this method it is possible to know the minimum filter efficiency for a specific particle size.
- Testing of complete filters is also based on scanning the efficiency for different size of particles
  - The efficiency is defined for number of certain size particles instead of particle mass over a range of particles for cross/fine filters. (Larger particles have greater mass than smaller ones)
- For example the efficiency of H14 filter is >99,99% For Covid-19 size particles.

Figure 2 — Particle size efficiency E and penetration P of an ULPA-filter medium as function of the particle diameter d_p for two different filter medium velocities (example)



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Example or a High Capacity Mobile Air Cleaner

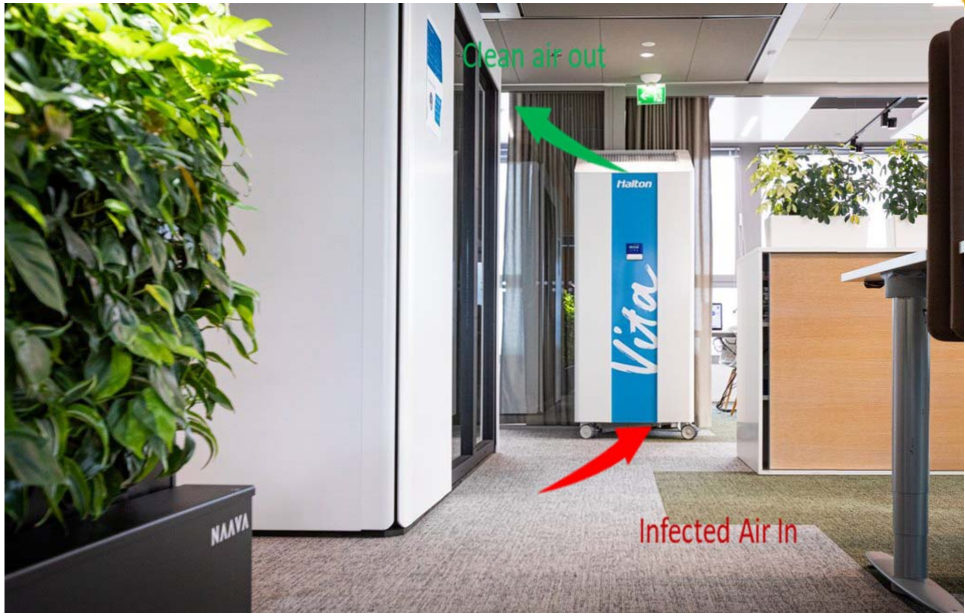
with sufficient performance to fight Covid-19

Applications, for example:

- In any rooms to supplement ventilation to reduce infection risk
- For cleaning the air in a specific space (CleanUp)
- Keeping the corridors clean

Halton VCR – All necessary features of an efficient local air purifier:

- The airflow volume is high compared to the amount of normal ventilation in the room
    - **High CADR, up to 2700 m^3/h (< 0,3 µm particles)**
- The clean air flow supplied efficiently throughout its area of influence
- Facility to integrate UV for effective inactivation of microbes collected to filter media
- Facility to integrate combi-filter for VOC reduction
- Low maintenance, designed service/filter change period 1 year



The Halton VCR is a mobile high-capacity HEPA (H14) air cleaner initially designed to enhance the cleanliness of operating room air.

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Performance Demonstration, Room Clean Up

Time with and w/o VCR Ventilation 150 m^3/h VCR 1250 m^3/h (45% Capacity)

ASSISTED WITH VCR

VENTILATION ONLY

UV-C Purification

- UVC purification is based on inactivating micro-organisms in air and surfaces.
  - Inactivation rate depends on the type of microbe, Irradiation efficiency and exposure time – **more details in next slide**
  - A proof of specific efficiency for the microbe in concern should be provided, especially when used for moving air, where it is challenging to reach sufficient dwell time and efficiency
  - UV only has no effect on particle removal – a supplementary mechanical final filter needed for capture of particles
    - Also a prefilter would be recommended to protect lamps

- UVC has following adverse effects that need to be taken take into account
  - UV light is also harmful for people
    - The system operating with people present should be shielded from direct exposure to irradiation
    - Alternatively, systems may be used during nonoccupation hours (typical practise when applied for surface cleaning)
  - Strong UV irradiation may also affect on materials and surfaces
  - UVC generate Ozone that is harmful for people – it is necessary to have proof that this is eliminated in the product to be used.
    - Ensure use of No/Low emitting UVC and sufficiently low ozone generation in relation to ventilation airflow

- There may not yet be evidence of the efficiency of the existing products for Covid-19. As a minimum there should be evidence of the product efficiency on multiple microbes to be able to asses the potential.

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UV Theoretical Background

- Ultraviolet Germicidal Irradiation (UVGI) is electromagnetic radiation that can destroy the ability of micro-organisms to reproduce by causing photochemical changes in nucleic acids. Wavelengths in the UVC range are especially damaging to cells because they are absorbed by nucleic acids.

- UV irradiation affects the DNA/RNA of pathogens by breaking the Thymine bonds of the helix and cross-linking them (also known as a Thymine Dimer)

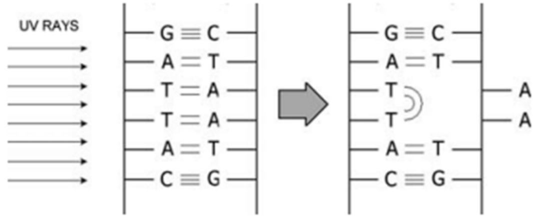
- The rate at which a pathogen is inactivated can be described by the below equation

$$S = e^{-kIt} \quad \text{Eq. 1}$$

- The k represents the individual pathogens susceptibility to the given UV Dose (D = I * t = Light Intensity * Exposure Time)

Intensity or Exposure Time ↑ Pathogen Survival Rate ↓

Fig. 2.3 Thymine dimers caused by UV absorption in adjacent nucleotides (thymine doublets)



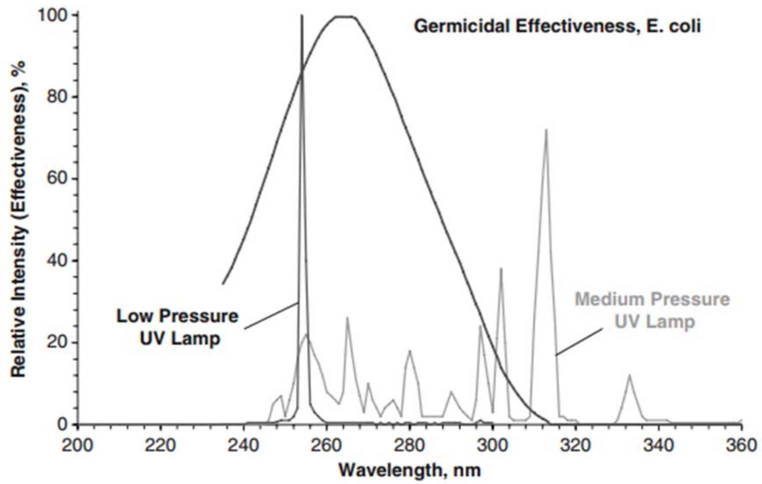


Fig. 2.1 Germicidal efficiency of UV wavelengths, comparing High (or medium) and Low pressure UV lamps with germicidal effectiveness for *E. coli*. Based on data from Luckiesh (1946) and IESNA (2000)

Impact of ventilation / cleaning on airborne infections

Airborne infections and pandemic need to be taken into account when designing and operating ventilation in new building and renovation projects.

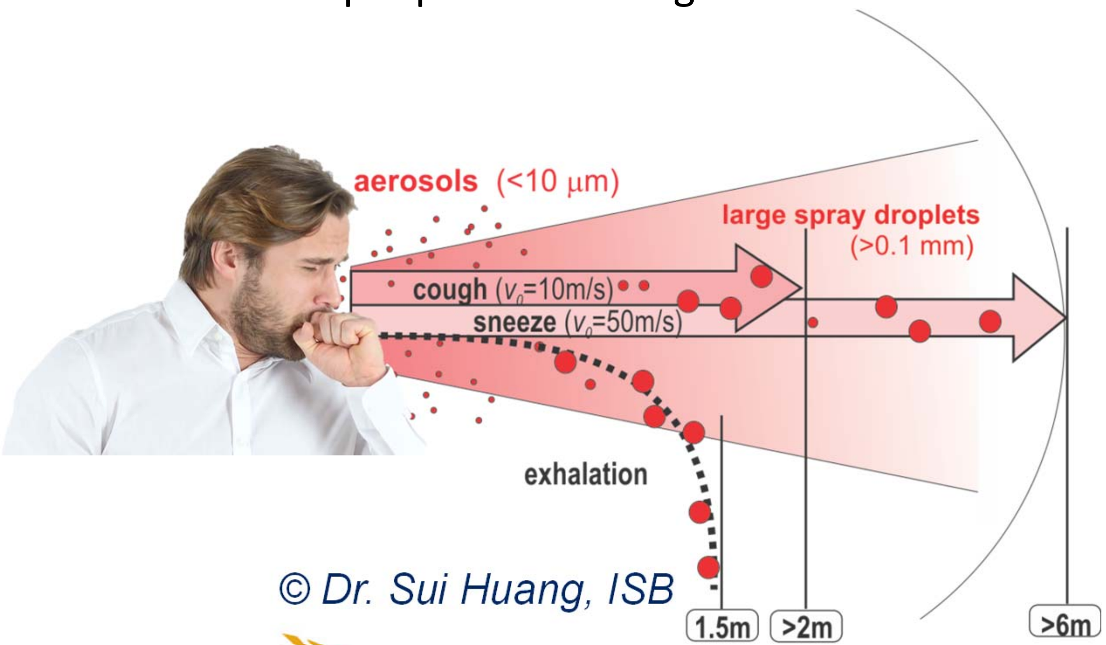
The employer must also arrange the ventilation so as to reduce the risk of infection.

There are ways to significantly reduce the risk of expose.

Exposure to disease

Direct exposure

- Droplets and aerosols travel directly into other people's breathing zones



Indirect airborne exposure

- Droplets and above all, aerosols hover with air currents in the space and into other people's breathing zones
- Ventilation reduces the amount of viruses in the air
- General air distribution aims to dilute pollutants evenly in the space

How can ventilation and directing airflows reduce the risk of infection?

Direct exposure

- Assess situations where the risk of direct exposure cannot be ruled out despite the safety distance of two meters
- Verify the situations with smoke tests and make the necessary changes
- Physical changes (plexi dividers, air curtains)
- Changes in seating arrangements

Indirect airborne exposure

- Select situations where an infected person may expose others in the same space (risk scenario)
- Calculate the risk of healthy employees being infected by airborne particles using the Wells-Riley model
- Investigate the improvement of ventilation and air distribution, and identify other measures to reduce the risk
- If the capacity of the ventilation system is not enough, efficient local air cleaners will help

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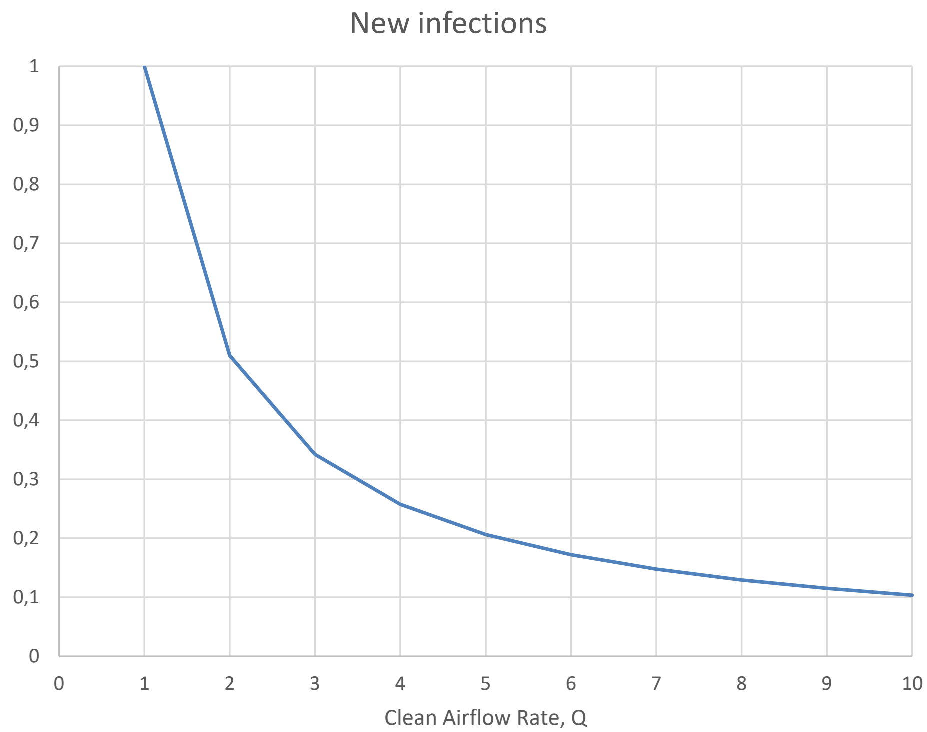
Wells-Riley model

Increasing ventilation reduces the risk of infection

Transmission – Wells–Riley Equation

$$C = S\left[1 - \exp\left(-Iqpt / Q\right)\right]$$

- C = new infections
- S = number of susceptibles
- I = number of infectors
- q = number of infectious doses
- p = pulmonary ventilation rate per susceptible
- t = exposure time
- Q = flow rate of uncontaminated air



The Wells – Riley model can be used to assess the risk of catching an airborne respiratory infection by people in a space over a period of time, when we know the total number of people in the space as well as those already infected, the amount of ventilation, and the infectivity of the disease. This can be reported as individuals (C) or as a percentage of individuals at risk (C /S).

To assess the infectivity of the disease, we must know the number of infectious particles in the exhaled air of infected people as wells as the number of particles causing the disease, the ratio of which the infectivity coefficient (q) describes.

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W-R model applicability for the assessment of airborn infection risk ?

Birthday Party, Charlton Texas, USA

- Birthday party (2 hours) was attended by 25 persons out of which one person was ill with Covid 19.
- 18 persons got ill as after the party (72%)

- Estimated airborne (indirect exposure) infection risk in this situation, when a basic dwelling ventilation is assumed: 75%

Choral practice, Mount Vernon, Washington, USA

- 61 persons were attending at the choral practice for 2,5 hours, one person hada already captured Covid-19 prior the occasion.
- Risk of Covid exposure was recognized and people applied practices to avoid direct exposure
- 53 people got ill after the practice (87%)

- Estimated airborne (indirect exposure) infection risk in this situation, when a basic (ASHRAE) ventilation is assumed: 86%

➡ Estimation of infection risk using Wells-Riley equation in these documented cases demonstrate a possibility that infection risk could be explained even merely by indirect airborne exposure.
(The role/importance of airborne infection is still under consideration by authorities)

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Design Examples of Room Air Cleaning

Next 2 examples are typical applications for room air cleaning:

- **Target 1: Reduce airborne infection risk during use**
  - It is necessary to reduce amount of viable particles in the air
  - In long term stay the focus is on Steady State Concentration of particles (e.g. Microbes)

- **Target 2: Protext Next User of the room from acquiring airborne infection from earlier use**
  - It is necessary to reach fast reduction of particles (e.g. Micgobes) in the space between usages (CleanUp)
  - Concentration Decay of particles (e.g. Microbes)

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Steady State Concentration comparison

Room design case 20m², e.g. office/dentist/hotel room

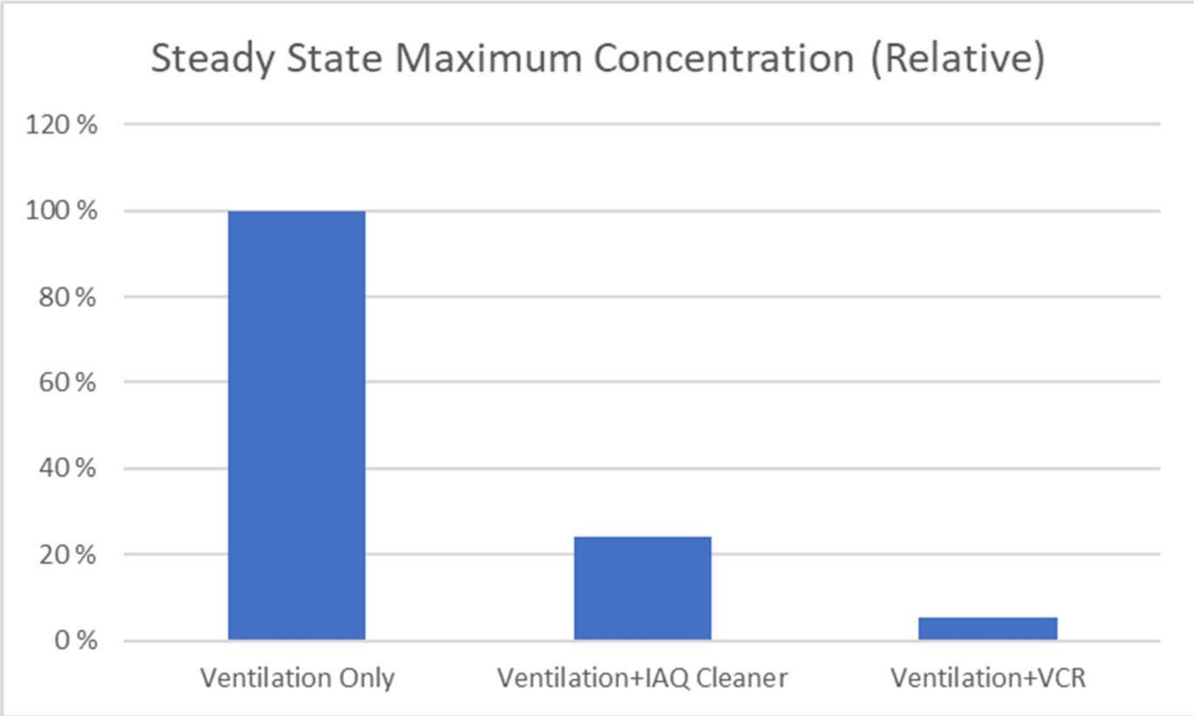
- Ventilation airflow 72 m^3/h
- Regular air cleaner 188* m^3/h
- High capacity air cleaner 900* m^3/h

- Ventilation efficiency (air diffusion):
  - High capacity air cleaner 100%,
  - Ventilation and Regular air Cleaner 70%

- With high capacity air cleaner the room is:
  - 20 Times cleaner than ventilation only
  - 5 Times cleaner than with IAQ Cleaner

  ➡ Corresponds to reduction of infection risk by 1:20 or 1:5 respectively

*(CADR , < 0,3 µm particles)



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Concentration Decay in Unventilated Room

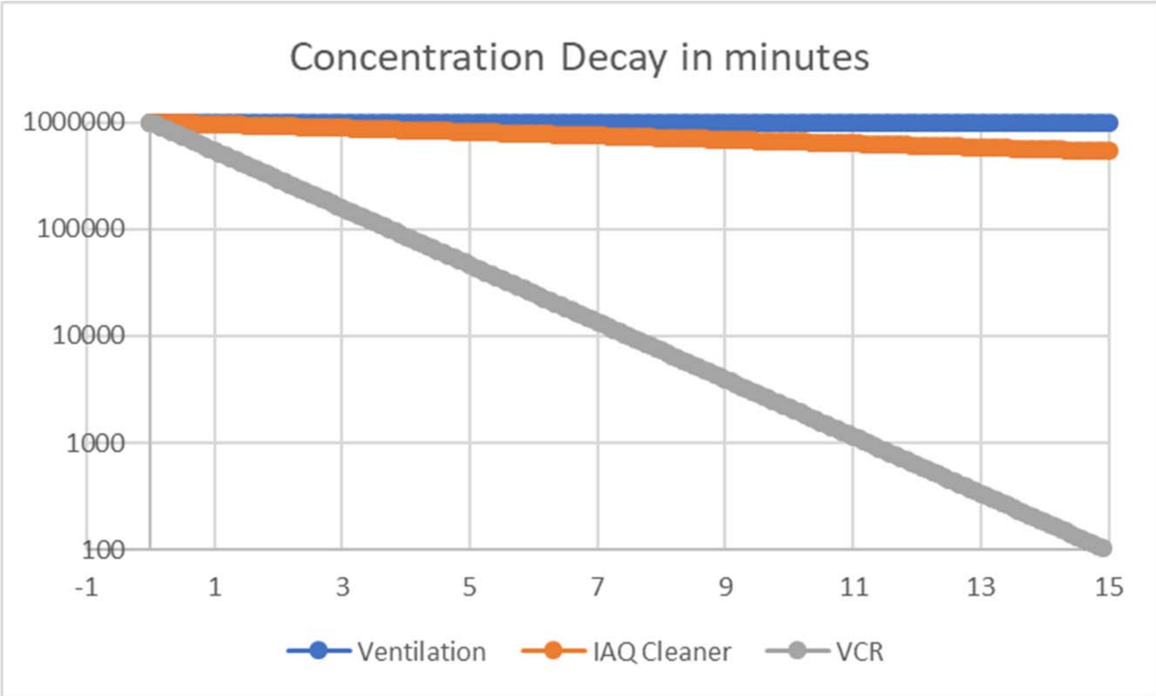
Room design case 20m^2, e.g. office/dentist/hotel room

- Situation, when Room Air Cleaner is started after usage, no ventilation

- Regular air cleaner 188* m^3/h
  - Up to 46% concentration decay after 15 minutes

- High capacity air cleaner with 2700* m^3/h for
  - 90% concentration decay in <4 minutes
  - 99% concentration decay <8 minutes
  - 99,9% conentration decay in 15 minutes
  - Removes the risk of airborn infection for next user in very short exhange period

*(CADR , < 0,3 µm particles)



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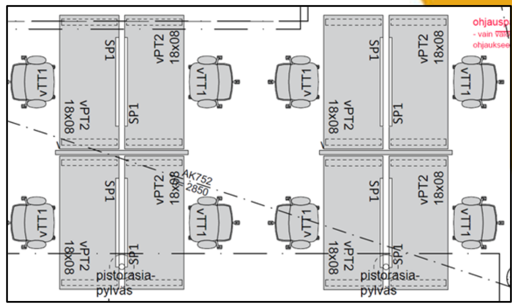
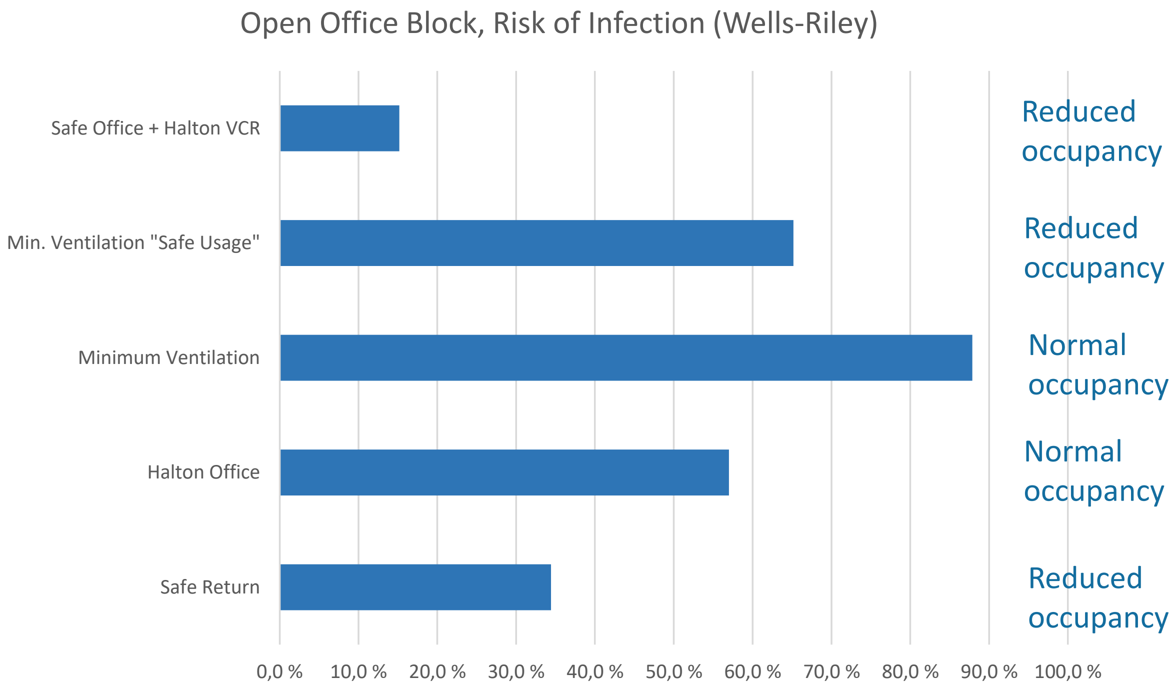
Indirect airborne exposure reduction
Case: Open space office



- **Scenario:** In the area of eight workstations, the number of employees is halved to four. Both before and after, 25% of people spread the infection (2/8 vs, 1/4 of the people) and cause a risk of infection to those working in the same area
- **Infection risk assessment using the Wells-Riley method:** *Percentage of those working concurrently in the office to fall ill during one working day (7.5 hours)*
- **Estimate:**
  - The risk of infection in a targeted scenario is higher than when looking at the entire office
  - The planned measures will significantly reduce the risk of infection



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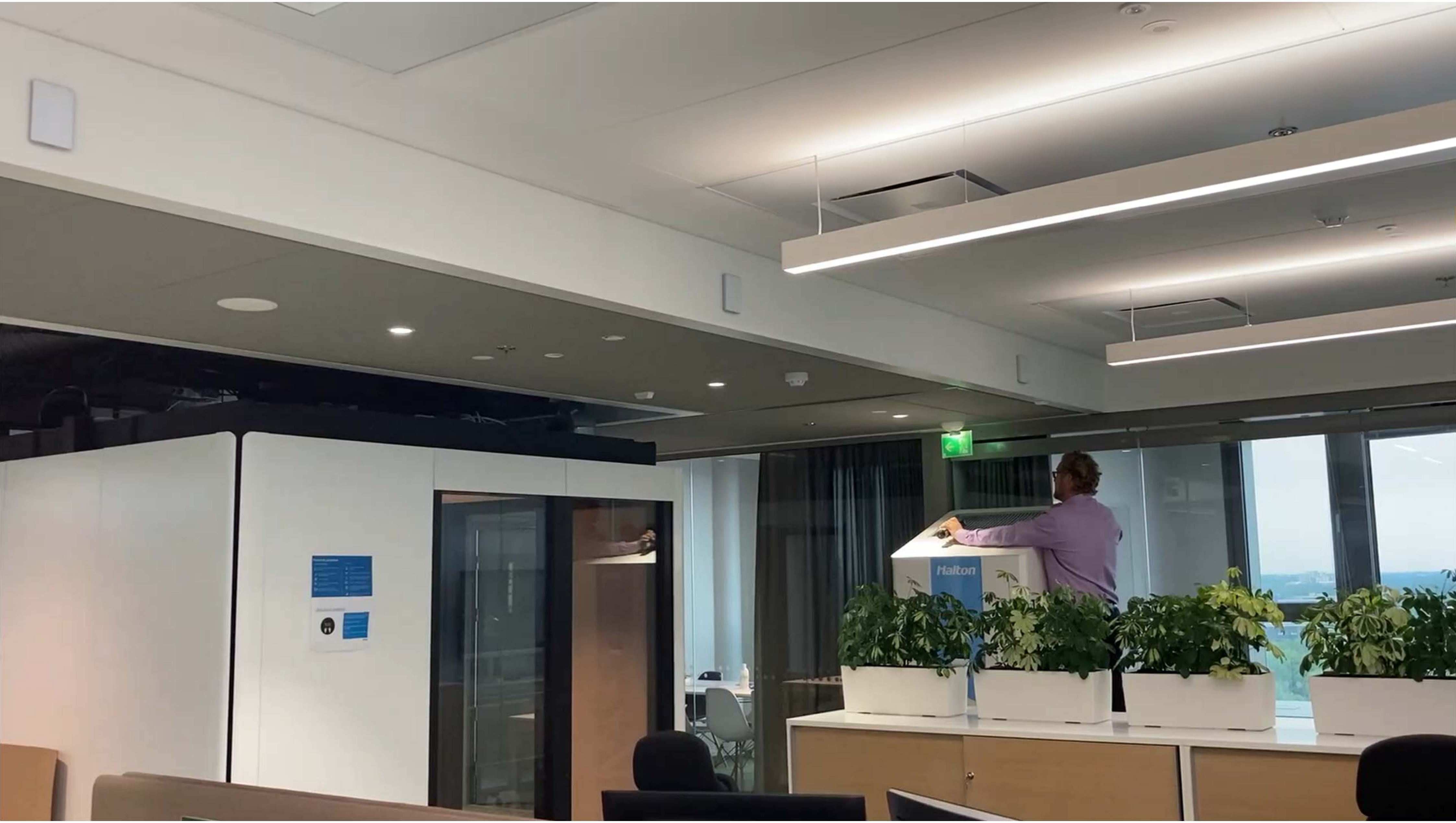
Source: Halton: Tarja Takki / Kim Hagström


Halton

Indirect airborne exposure, summary

- The risk of indirect exposure by air cannot be ruled out
- The risk analysis can be used to assess the risk of exposure in each space separately
- Indirect airborne exposure risk indoors cannot be completely eliminated, but can be significantly reduced by ventilation measures
- A high quality indoor climate increases the daily comfort of workers and significantly reduces the risk of airborne infections compared to the minimum ventilation level of international standards.
- High capacity Air cleaners are able to make significant impact on airborn infection risk

For consideration:

What is an acceptable / responsible infection risk in your workplace / buildings?

Source: Halton: Tarja Takki / Kim Hagström

Designing workplaces - enhancing wellbeing and safety

Thank you!