



Halton

Cohort Based Training 3 - Modelling of the hospital indoor environment

Healthcare specific standards, Tools for room air distribution
design, Target specific ventilation considerations

PROJECT 101119726 — HumanIC — HORIZON-MSCA-2022-DN-01

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23.1.2026



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Healthcare specific standards and guidelines

- There are multiple national and regional standards and guidelines giving guidance for hospital ventilation
 - E.g. HTM, DIN, NF, R3 Nordic, ASHRAE, GB, SIS etc.
- Some of the guides focus on specific environments, while some have broader focus
- The given recommendations differ from generic standards due to
 - They include healthcare specific insights and learnings
 - Alternatively, they document current practise





Example; Patient Rooms

- Suggested airflow rates in different guidances vary from 25-100 dm³/s, person (Compare to EN 16798-1 ~15 dm³/s, person)
 - WHY – Justification?
 - There are both patient and treatment specific emissions (VOC's)
 - Patients are given treatments within patient rooms, too
 - There is increased infection risk in patient rooms, also patients are more vulnerable
 - Varying occupancy (Visitors, HCW)
- Temperature levels - EN 16798-1 currently give different temperature suggestions for Summer/Winter
 - However, in practise the thermal conditions and boundary conditions are quite constant throughout the year
 - E.g. sedentary patient comfort temperature is relatively constant (23°C-24°C)
- Quite the same applies for treatment rooms, additionally:
 - Occupancy variation – physician & patient only or the whole family at the visit ?
 - Additionally, there is a recognized need to “flush” between patients due to smells





General Room Ventilation

Airflow pattern design

- Design is typically made using design tools by manufacturers of air diffusion devices
- As an example Halton has different tools for dimensioning of
 - individual diffuser – Web Based design tool, eHIT
 - [eHIT Page - Halton](#)
 - Room design with multiple diffusers – Desktop, multiple diffusers in room
 - Download from: <https://www.halton.com/wp-content/uploads/HitDesign.msi>
 - Displacement Ventilation
 - Not freely available today





Halton eHIT, Example – Nozzle Diffuser JSC

- eHIT Page - Halton

Halton eHIT - Your tool for easy product selection

Room air conditioning / Diffusers and plenums / Halton Jaz JSC - Nozzle diffuser

Halton Jaz JSC - Nozzle diffuser

Order code: JSC-125-420(R4), CO-SW.ZT-N

More info | Product page | Downloads

Add plenum: PD

Mode: S=Supply | Diffuser connection size (mm): 125 | Diffuser size (mm): 420 | Jet type: R4=Radial jet, 4 directions

Colour: SW=Signal white (RAL 9003)

Room		Normal	
Room temperature [°C]	0	25	30

Air		Normal	
Supply air temperature [°C]	13	18	40
Airflow [l/s]	31	43	61
Total pressure drop [Pa]	10	20	40

Results | Product 3D | Room

q_v [l/s]	Δp_{tot} [Pa]	Air velocity [m/s]	$L_{p,224}$ [dB]
43	20	3.5	32

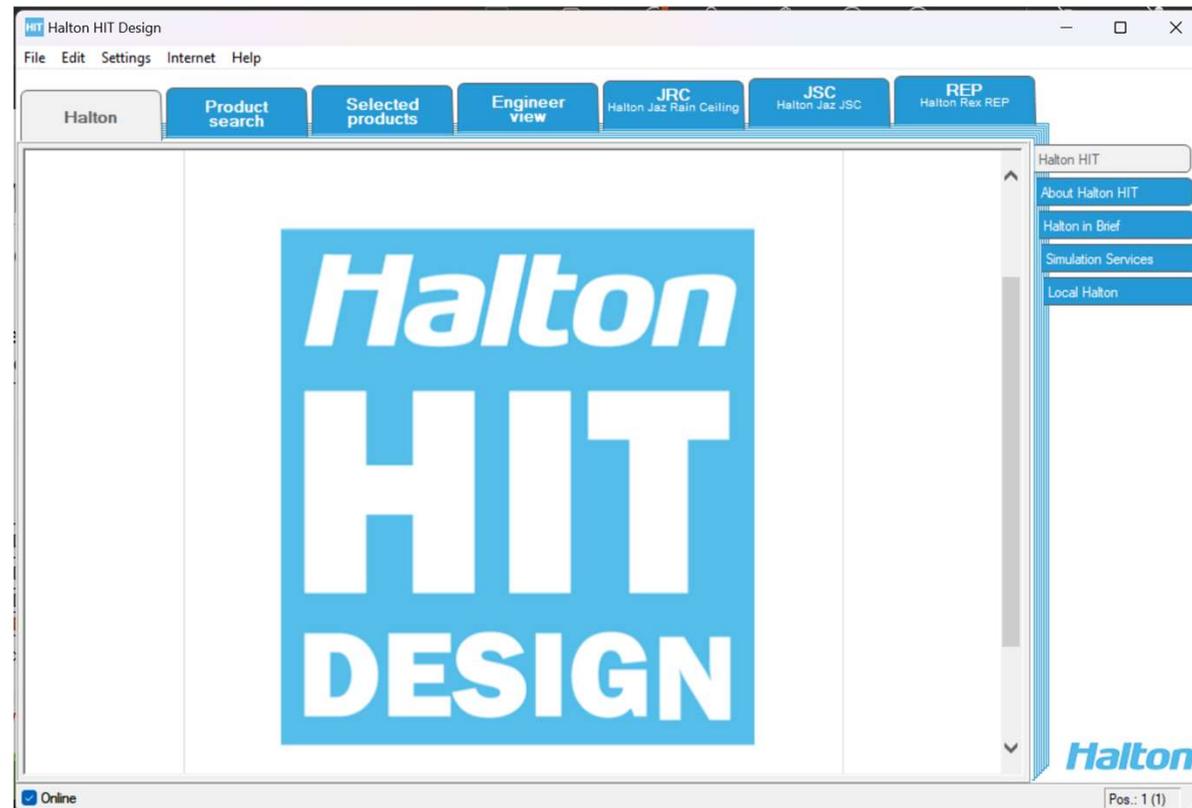
$L_{p,224}$ [dB]	airNR	Sound power level, L_w [dB] by octave band							
		63Hz	125Hz	250Hz	500Hz	1kHz	2kHz	4kHz	8kHz
32	29	31	32	35	37	29	16	10	9

Sound attenuation, ΔL [dB]								
63Hz	125Hz	250Hz	500Hz	1kHz	2kHz	4kHz	8kHz	
21	15	10	5	2	2	4	3	



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Halton HIT, Example – Room Design



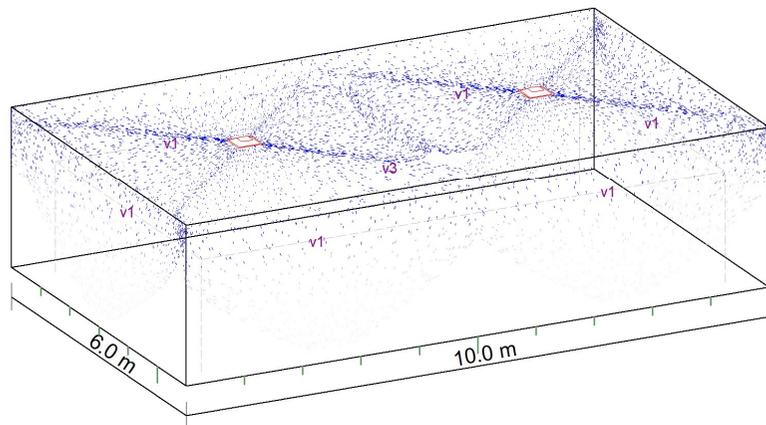
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Halton HIT, Example – Room Design

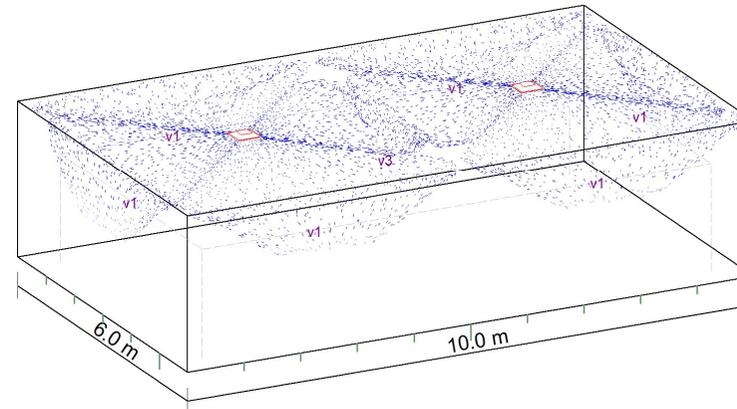
Cooling:

Cooling		JSC-160-420(R4)		09.2023	
Room:	10.0 x 6.0 x 2.6 m	Supply air flow rate:	140 dm ³ /s (2 x 70 dm ³ /s)		
Room size:	h=1.8 m / dw=0.5 m	Supply air temperature:	18.0 °C		
Occupied zone:	24.0 °C / 50 %	Total pressure drop:	19 Pa		
Room air:	-	Total sound pressure level:	29 dB(A)		
Heat gain:	2.60 m	Total cooling capacity:	1020 W (2 x 510 W)		
Installation height:	-		17 W/m ²		
		L _d :	-		
Velocity point	v1	v3			
v	~0.10 m/s	~0.20 m/s			
ΔT	-0.1 °C	-0.4 °C			
v _{lim} = 0.20 m/s					



Heating:

Heating		JSC-160-420(R4)		09.2023	
Room:	10.0 x 6.0 x 2.6 m	Supply air flow rate:	140 dm ³ /s (2 x 70 dm ³ /s)		
Room size:	h=1.8 m / dw=0.5 m	Supply air temperature:	25.0 °C		
Occupied zone:	20.0 °C / 50 %	Total pressure drop:	19 Pa		
Room air:	-	Total sound pressure level:	29 dB(A)		
Heat loss:	2.60 m	Total heating capacity:	828 W (2 x 414 W)		
Installation height:	-		14 W/m ²		
Velocity point	v1	v3			
v	~0.10 m/s	~0.20 m/s			
ΔT	0.1 °C	0.3 °C			
v _{lim} = 0.20 m/s					



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Target specific ventilation vs general room ventilation

- Principal difference:
 - General room ventilation aims to provide uniform airflow pattern/ conditions within the whole room space
 - No consideration of the effect of room loads to air movement
 - If considered typically physical / CFD Mock Up is used for verification
 - There is expected variation/efficiency deficit in general room ventilation, typically considered 25-30%
- Target specific ventilation
 - The target is to optimize conditions in specific zone/Sub-space within the ventilated room (Contaminant -, Thermal -, IAQ conditions)
 - Techniques used to create conditions are Localized Supply/- Exhaust/Supply & Exhaust/Physical barriers



General Room Ventilation

- In practice General Room Ventilation / Air diffusion in a room is always result of combination of supply air jets and convective currents
- Certain basic strategies may be identified/targeted (see figure)
- Design of attractive strategy necessitates consideration of these multiple forces
 - Strategy may also change/be changed for example seasonally.

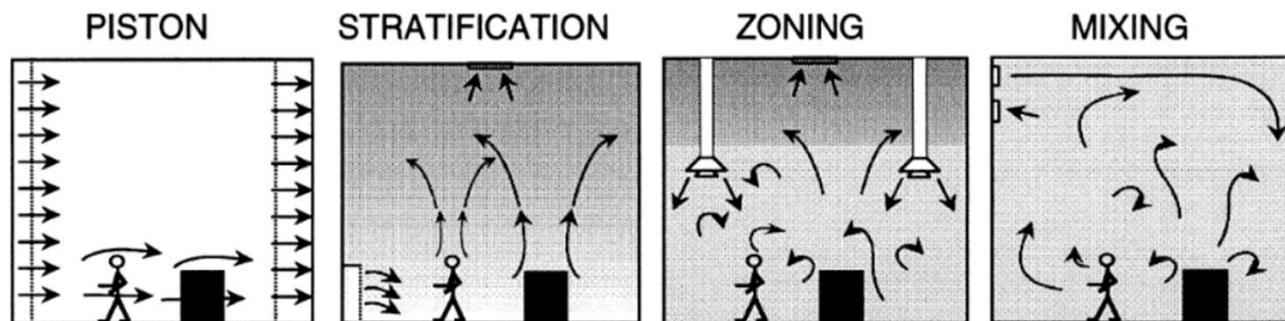


Figure 1.1. Strategic principles for room air distribution [56].



Target Specific ventilation

- When to use target specific ventilation ?
 - A specific sub-zone which need to be focused is identified, for example:
 - Zone of principal emissions
 - Zone of principal occupancy (Location, time)
 - Zone of especial concern – personal exposure
- When to consider time-specific ventilation modes?
 - Whole room use case - Use of the room is intermittent
 - High impact/ energy is used only upon specific time intervals of high activity
 - Operational mode variation
 - When different operational modes have variable user requirements
 - When different operational modes have different usage conditions





Target Specific ventilation

- What needs to be known to decide & design for Target Specific ventilation ?
- Understanding user processes
 - Location and movement of occupants and their interactions
- Identifying especial challenges and zones
- Understanding characteristics and factors of the emissions
 - Source strength, dispersion characteristics; initial speed and direction, physical form (gaseous, Particulate/-size, etc.)
- Cases, Patient/Isolation room, Isolation airlock, Operating Room





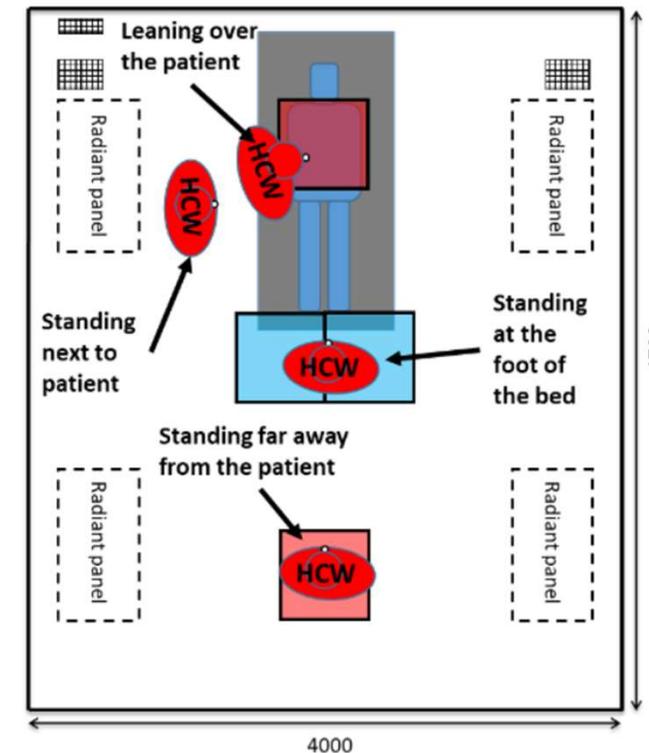
Target Specific ventilation, case Patient room

- Understanding user processes – Patient room use
 - Patient only mode – highest time density
 - Multiple patient mode
 - 1 patient room with an extra patient
 - Multipatient room with variable usage
 - Treatment mode
 - Consultation mode
- Identifying especial challenges and zones
- Understanding characteristics and factors influencing
- Cases, Patient/Isolation room, Isolation airlock, Operating Room



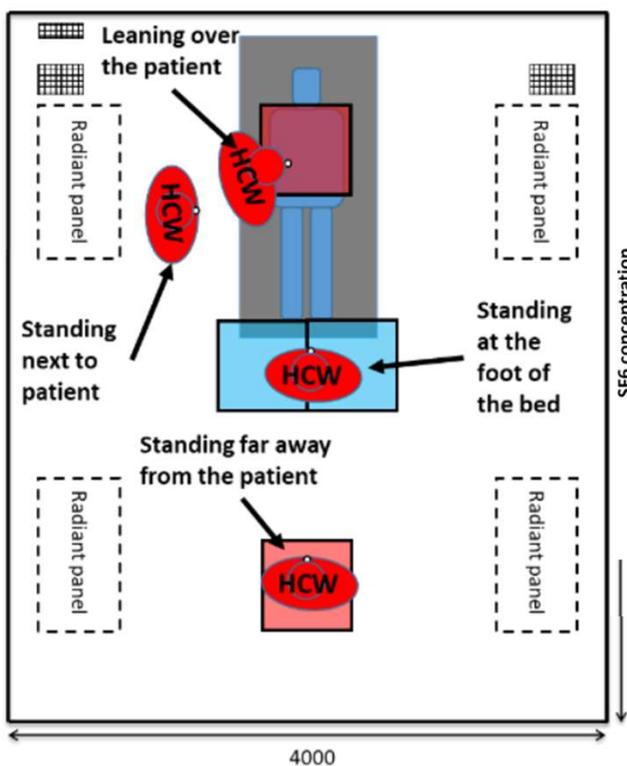
Target Specific ventilation, case Patient room

- Identifying especial challenges and zones
 - Patient typically lying in the bed
 - Nurse / HCW
 - Consultation – at the end of the bed /next to patient
 - Treatment – Leaning over the patient
 - Learned by observatory study in operating hospital
 - Regularity / Time expenditure (estimate)
 - HCW in the room maximum of 4 hours/24h
 - Significant time share spent for treatment
 - In this respect Isolation room and patient room are relatively identical
 - Naturally infection risk factor within Isolation is higher
 - On the other hand, in patient room the risk is more regular – yet less recognized by HCW

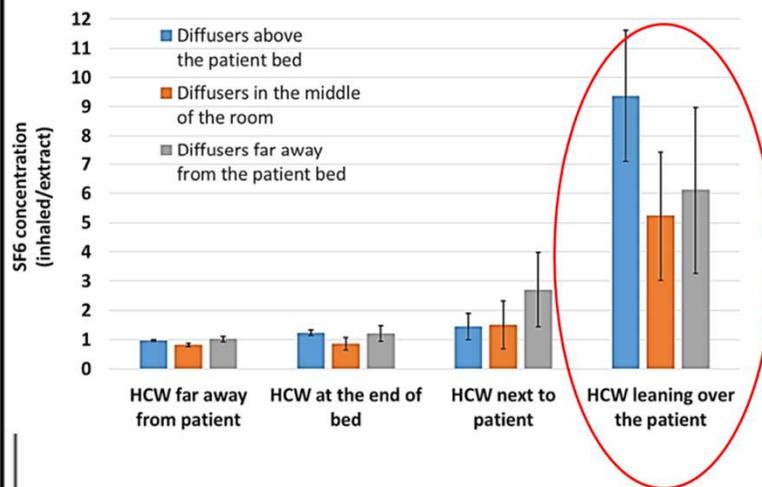


Target Specific ventilation, case Patient room

- Nurse location – effect on the exposure
- During treatment exposure exceeds > 5 fold the room average
- Target Specific Ventilation (or other protective means) should be considered !



Overhead circular ceiling jet (mixing ventilation)



Kalliomäki P., Koskela H, Protective Airflow in Hospital isolation rooms (In Finnish), TuAMK Report 244, 66p. 2018.



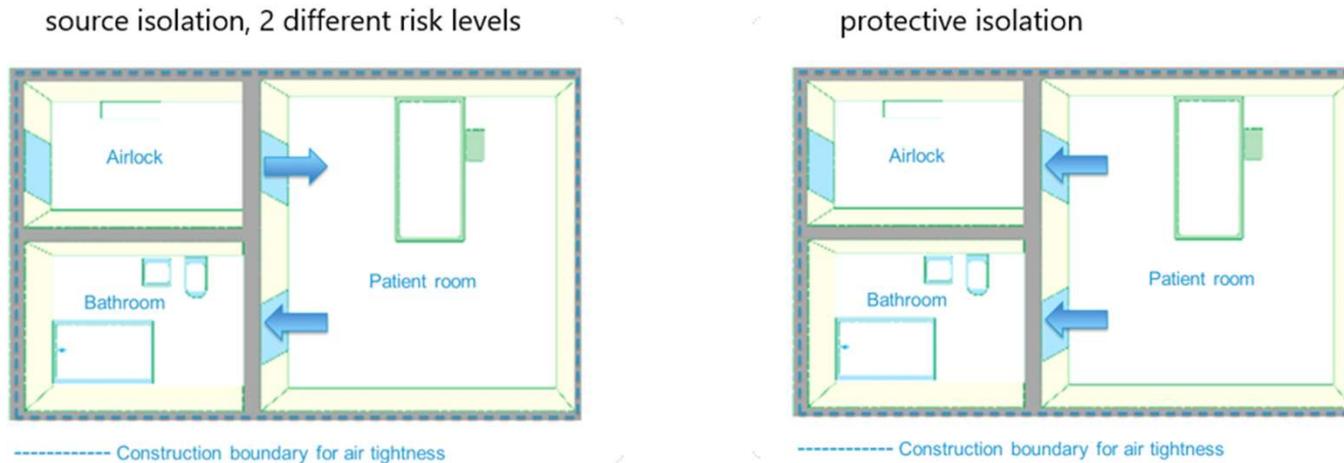
Target Specific ventilation, case Patient room

- Understanding characteristics and factors influencing emission and preventive methods
 - Breathing/speaking – emission mainly small particles
 - Ventilation - Possible to influence exposure
 - Personal Mask weared by HCW
 - Limited efficiency, Adverse health effects on HCW, Sustainability issue of medical waste
 - Personal mask by patient
 - Good efficiency, practical, psychological and waste issues
 - Coughing – large particles
 - Ventilation has no/minor efficiency
 - Mask provides protection



Target/Mode Specific ventilation, case Airborne Isolation Unit

- Understanding user processes
 - Isolation rooms are used to either protect environment from the patient (infection isolation) or patient from the environment (protective isolation)
 - Isolation Unit consist of patient room with toilet and airlock.
 - Patient room usage close to basic rooms (Higher Risk, Protective clothing, Treatment)
 - Airlock, additional barrier and clothing room for HCW – Intermittent Use



Leakage rate through the construction boundary should be minimized – tightness requirement given in guideline.



Isolation Rooms - Design Principles

- Based on targeted protection degree, ventilation efficiency consideration, and nursing process.
- Design based on influence from the nursing process:
 - Patient room, steady state source (patient's breathing) - Room size has no effect on airflow rate
 - Increased exposure risk of HCW close to patient - “worst case” situation addressed
 - 0,7 Contaminant removal efficiency used in R3 guideline for mixing airflow calculation
 - Airlock used only few minutes at a time - dynamic dilution ventilation
 - High airflow during usage stage

Type of isolation unit	Source isolation Level S _A	Source isolation Level S _B	Protective isolation	Combined isolation
Air flow rate				
Patient room (/bed)*	200 l/s	400 l/s	200 l/s	200 l/s
Airlock	Upon recovery time	Upon recovery time	Upon recovery time	Upon recovery time
Recovery time (100:1)				
Patient room, 60m ³	< 24 min	< 12, min	< 24 min	< 24 min
Airlock	< 6 min	< 6 min	< 6 min	< 6 min
Waiting time in the airlock**				
	>3 min	>5 min	>3 min	>3 min
Typical ACH**				
Patient room, 60m ³	12 ACH	24 ACH	12 ACH	12 ACH
Airlock	46 ACH	46 ACH	46 ACH	46 ACH
WC	-	-	-	-

[Guidelines - R3 Nordic](#)



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Susceptible exposure and Intake Fraction

- We have used below indexes with breathing mannikin to magnify the effect of occupant targeted ventilation in patient environments
 - The susceptible exposure index (ε) describes the ratio between the local (inhaled) concentration and the concentration in the exhaust

$$\varepsilon = \frac{C_i(t) - C_s(t)}{C_e(t) - C_s(t)}$$

- Intake Fraction (IF) - Share of the exhaled contamination inhaled by the exposed person

$$IF = \frac{m_i}{m_{exh}} = \frac{\int \dot{m}_i dt}{\int \dot{m}_{exh} dt} = \frac{\int Q_i(t) \cdot C_i(t) dt}{\int Q_{exh}(t) \cdot C_{exh}(t) dt}$$

- Intake fraction is quite handy index, when comparing results from different cases and used airflow rates

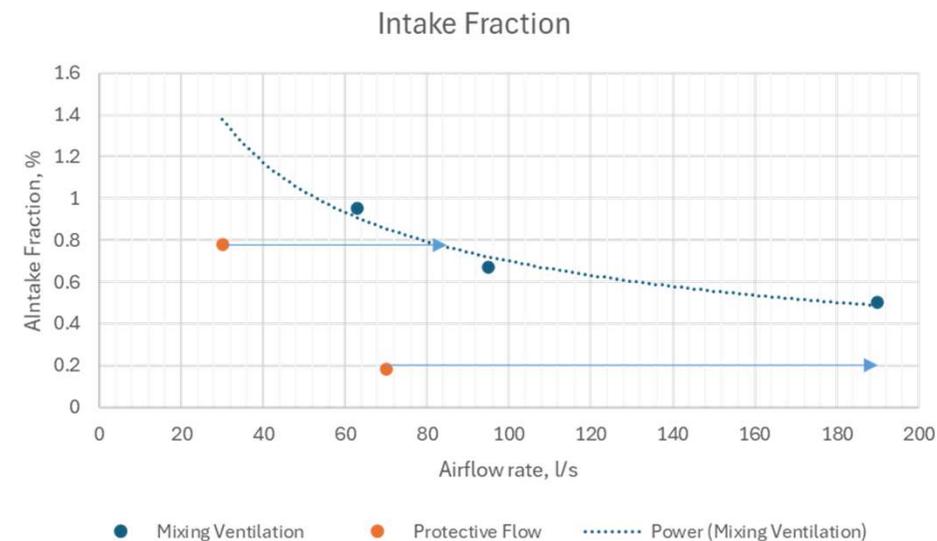


Figure:
Hagström et.al., "Patient-to-patient airborne exposure in patient and isolation rooms with 2 patients", *Clima2025*





Target Specific ventilation, Case Operating Room

- Understanding user processes

Operating rooms

What to consider, be aware of contamination from:

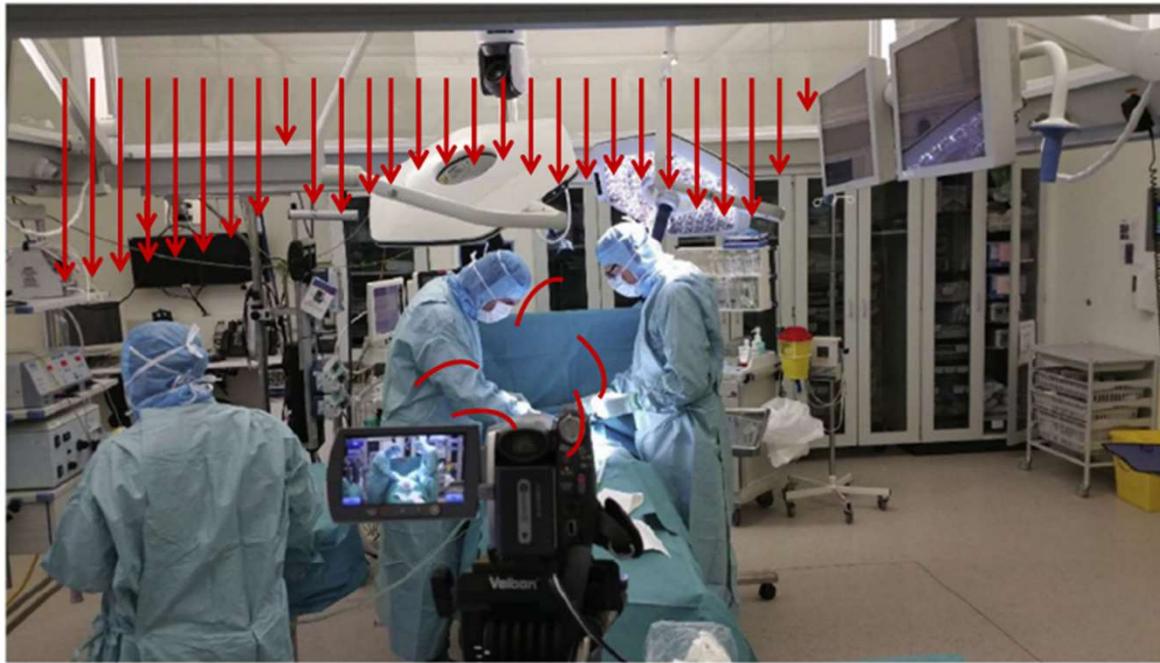
- Number of people
- Clothing
- Behavior
- Door openings
- Cleanliness outside
- Logistics – for example of sterile goods
- Pollution sources (anesthesia gases, surgical smoke, etc.)
- System operating parameters (dT, v)





Target Specific ventilation, Case Operating Room

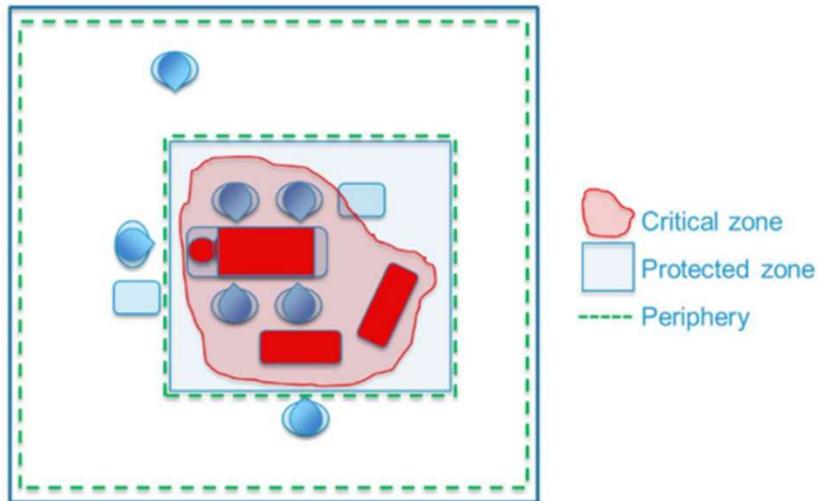
Understanding User processes - At Rest is different from In Operation



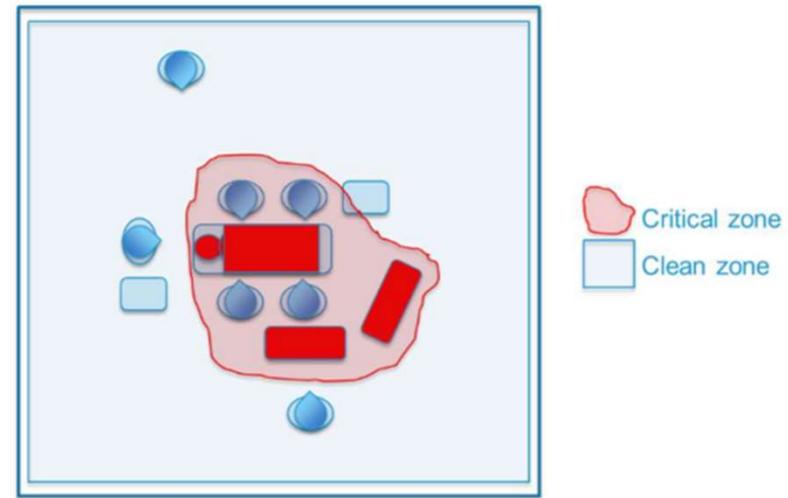
Target Specific ventilation, Case Operating Room

- Understanding user processes – Positioning Analysis to Identify Critical Zone

ZONING

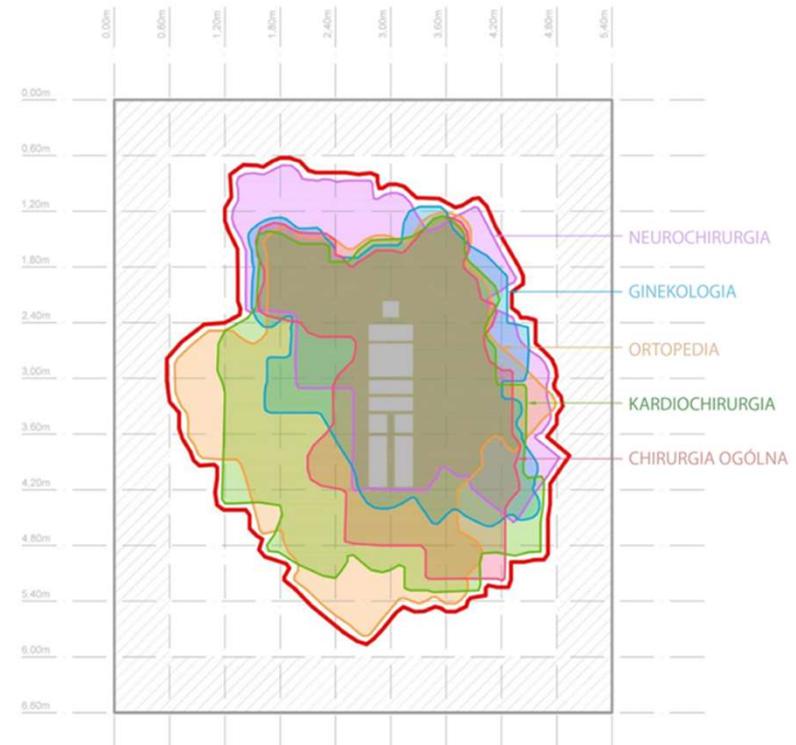


DILUTION



Target Specific ventilation, Case Operating Room

- Positioning Analysis is important, because:
 - Critical Zone is different for different types of operations
 - There is variance even between operating teams
 - When designing multipurpose operating room, it is important to understand and cover different usages



Picture courtesy of dr n. med. Maciej Matłok, Industria Project, Poland



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Target Specific ventilation, Case Operating Room

- In Practice – *All effective Operating Room ventilation systems are Target Specific*

Halton Vita OR Space
Controlled Dilution Flow



Halton Vita OR Zone
Unidirectional Flow



Halton Vita OR Cell
Local Unidirectional Flow



THANK YOU!



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