Air purification technologies against the spread of airborne pathogens

Hannu Salmela, VTT

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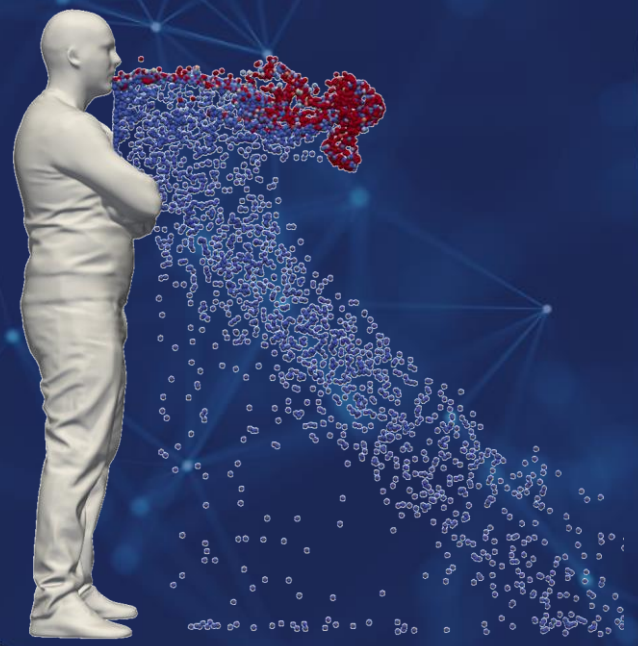

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- Technologies
- Performance evaluation
- Ongoing/future acitivities
- Conclusions

➢To highlight existing and **novel air cleaning technologies** for biocontamination control in indoor environments.

➢To present **scientific background** behind the technologies and their **applicability**.

Air purifiers – for consideration

- Clean Air Delivery Rate (CADR)
  - Finnish regulation: only for ventilation (1009/2017, fresh air)
  - Guideline: Finnish classification of indoor climate 2018
  - Guidelines for air purification: at least 2 ACH, up to 5 ACH (EPA)
- Noise: average/maximum sound pressure levels
  - Finnish regulation: 796/2017, 545/2015
- Sizing and placement, use of (floor) space
- Air distribution, effect to ventilation flow field and effectiveness
- Thermal comfort (draught risk)
- CO2 concentration
- Byproducts
- Energy consumption
- Long-term performance
- Special applications/devices
  - E.g. personalized air purification and integrated approaches
- Overall costs and benefits

Technologies

Technolgies utilized in air cleaners

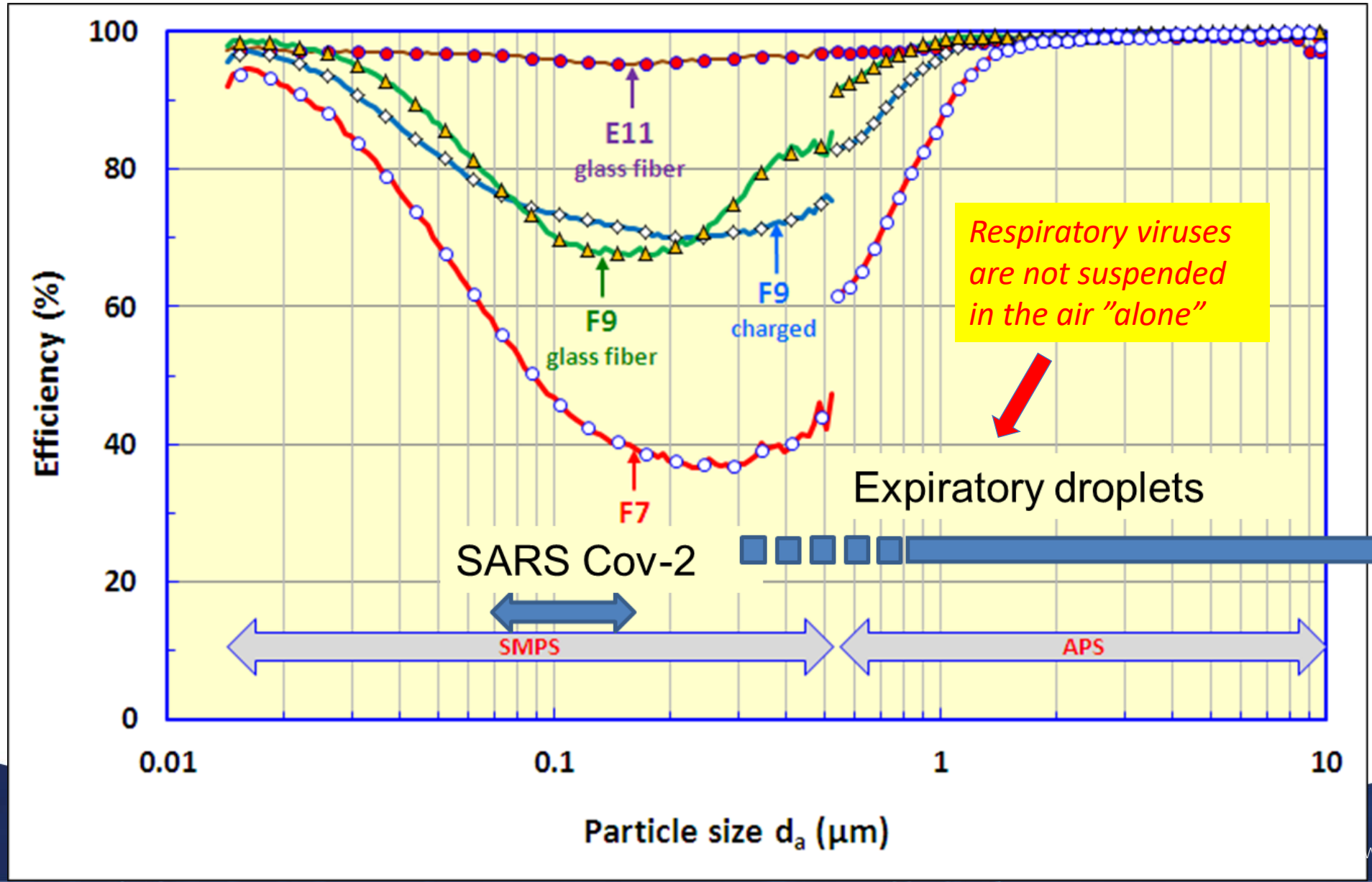
Technology	Main impurity
Mechanical filtration (fibre filtration)	Particles
Electric filtration	Particles
Adsorption (e.g. active carbon)	Organic and inorganic gases
Optical radiation (e.g. UV)	Bioaerosols
Photocatalytic oxidation	Organic and inorganic gases
Plasma	Organic gases
Ionization	Particles
Ozonation	Organic gases
Botanic plants	Organic and inorganic gases

https://www.isec.fi

https://almesolutions.com

https://air0.fi

Filtration efficiency of fibrous filters



Comparison of the technologies applicable against airborne pathogens

Technology	CADR (Clean Air Delivery Rate)	Energy consumption	Byproducts (e.g. ozone, UFP, HCHO)	Cost vs. performance
Mechanical filtration	+ … +++	+ … ++	+++	++ … +++
Electric filtration (ESP)	++ … +++	++ … +++	0 … ++	++ … +++
Optical radiation (UV)	0 … ++	+	0 … ++	0 … ++
Air ionisers	0 … +	++	0 … +	0 … +

0 not acceptable; + tolerable; ++ satisfactory; +++ good

Can be tolerated e.g. with gas filtration, lamp coatings or low-emitting solutions

Inactivation by optical radiation (UV)

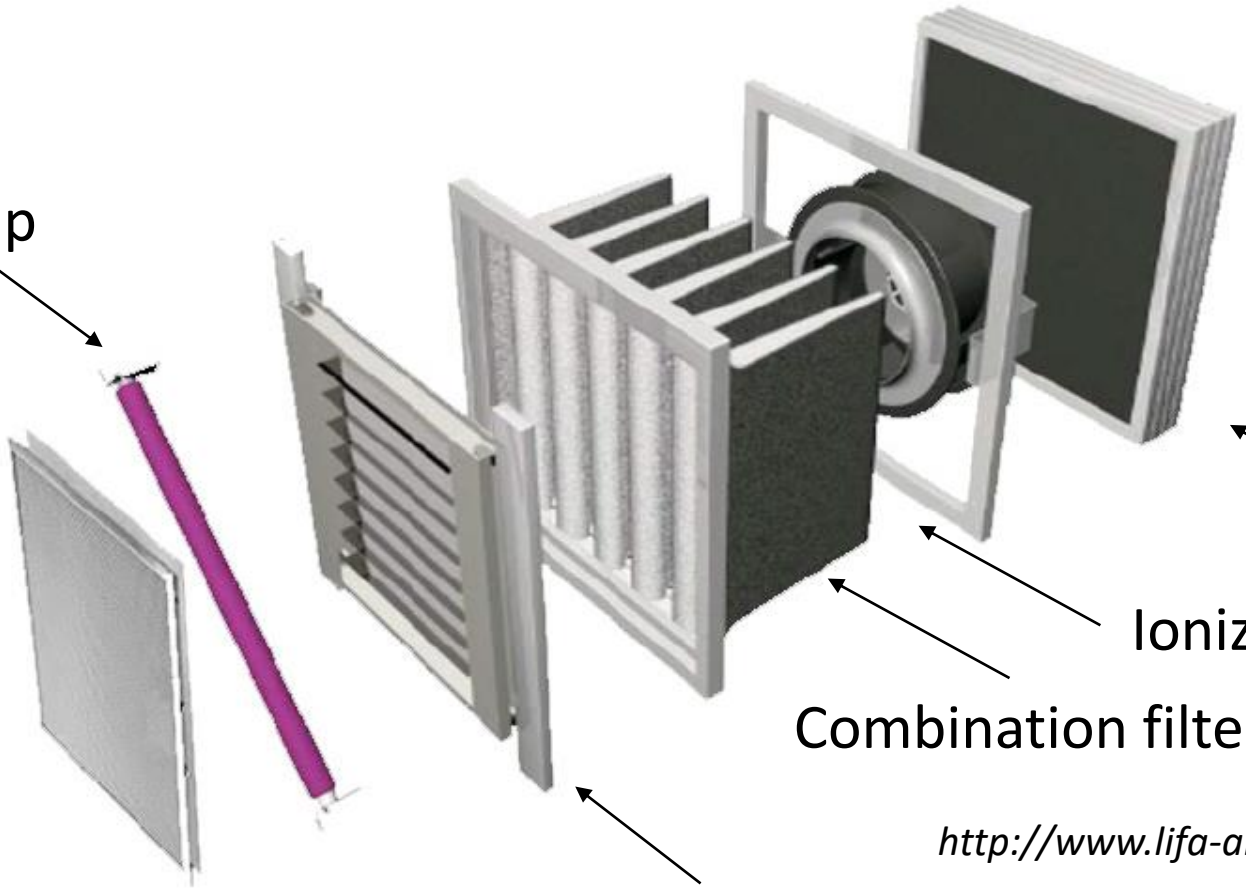
Technologies

- UVC low pressure lamps (254 nm)
- **UVC LEDs** (~265…278 nm)
- **Far-UVC** (222 nm)
- Blue light (400…450 nm; 460…470 nm)

Things to consider

- Application
  - Air/surface disinfection or both
  - In-duct/free space/cabinet
- Pathogen vs. UV dose
  - Irradiance field, exposure time
- Safety
  - Occupancy, by-products, remaining impurities, lamp damage, …
- Lifetime and maintenance
- Energy consumption
- Cost vs. other technologies

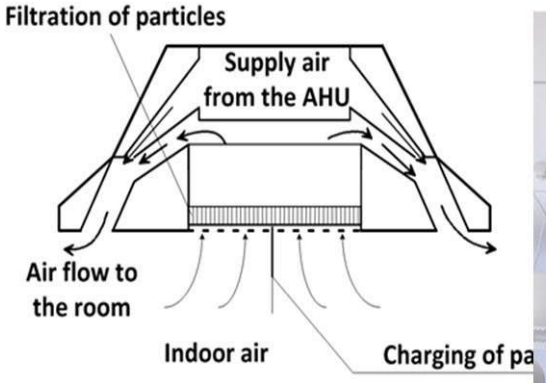
An example of a combination technology



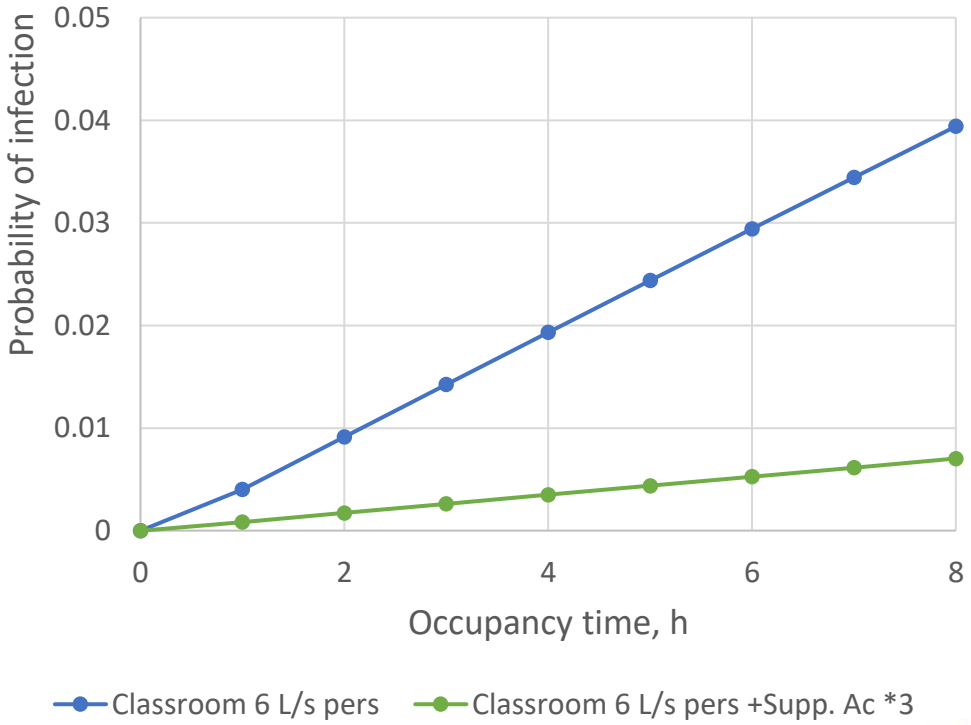
http://www.lifa-air.com/en-gb/consumer/3g-filter

Air purification concept for significant IAQ improvement

- Combining advanced supply and room air filtration
- Reduction of particulate impurities by 90 % without major changes to existing mechanical ventilation system
- Multiplication of ventilation CADR



Enbom et al. (2014)



Performance evaluation

Standard test methods for air purifiers

Standard for reduction of microorganisms is under development in IEC/ISO 63086 series

USED TECHNIQUES IN AIR CLEANERS	SUITABILITY OF THE STANDARD							
	ANSI/AHAM AC-1 (USA)	ANSI/AHAM AC-3 (USA)	GB/T 18801 (China)	JEM 1467 (Japan)	NF B 44-200 (France)	NT CONS 009 (Nordic countries)	NT VVS 106 (Nordic countries)	IEC/PAS 62587 (International)
Mechanical filtration	x	x	x	x	x	x	x	x
Electrical filtration	x	x	x	x	x	x	x	x
Adsorption			x	x	x			
Ultraviolet radiation					x			
Photocatalytic oxidation			x	x	x			
Plasma			x	x	x			
Ozonation								
Botanical systems			x	x	x			

Mattila I (2018) Methods for Measuring Performance of Room Air Cleaners

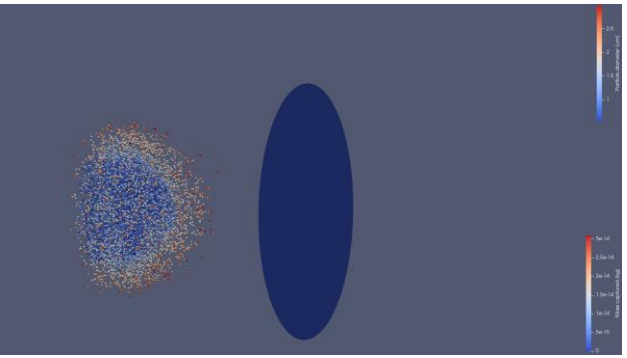
TARKASTELTAVA OMINAISUUS			STANDARDI / MENETELMÄ							
			ANSI/AHAM AC-1 (Yhdysvallat)	ANSI/AHAM AC-3 (Yhdysvallat)	GB/T 18801 (Kiina)	JEM 1467 (Japani)	NF B 44-200 (Ranska)	NT CONS 009 (Pohjoismaat)	NT VVS 106 (Pohjoismaat)	IEC/PAS 62587 (Kansainvälinen)
PUHTAAN ILMAN TUOTTO	HUONEEN ALENEMA	Testikammion koko [m3]	28,5	-	3 / 30	1 / 20-30	-	-	50	28,5
		Hiukkaset: Tupakansavu	x		x	x			x	x
		Hiukkaset: Testipöly (0,5-3,0 µm)	x							x
		Hiukkaset: Allergeeni (siitepöly)	x							x
		Hiukkaset: DOP (di-octyl-phthalate)						x		
		Kaasut: Formaldehydi (CH_2O)			x					
		Kaasut: Tolueeni (C_7H_8)			x					
		Kaasut:				x				
		Kaasut:				x				
		Kaasut:				x				
		Kaasut:		x						
		Kaasut:					x			
	LÄPIVIRTAUSMENETELMÄ	Hiukkaset: DOP (di-octyl-phthalate)						x		
		Hiukkaset: Allergeeni (kissa)					x			
		Hiukkaset: Bakteeri (Staphylococcus epidermidis)					x			
		Hiukkaset: Home (Aspergillus niger)					x			
		Kaasut: Formaldehydi (CH_2O)					x			
		Kaasut: Tolueeni (C_7H_8)					x			
		Kaasut: Asetaldehydi (C_2H_4O)					x			
		Kaasut: Heptaani (C_7H_{16})					x			
		Kaasut: Asetoni (C_3H_6O)					x			
SIVUTUOTTEIDEN MÄÄRITYS		Otsoni (O_3)					x	x	x	
		Hiilimonoksidi (CO)					x			
		Typpioksidi (NO)					x	x		
		Typpidioksidi (NO_2)					x			
ILMAVIRTA				x		x	x	x	x	
LASKENNALLINEN KÄYTTÖIKÄ (KUORMITUS)					x	x				
ILMANPUHDISTIMELLE SUOSITELTU HUONEKOKO			x		x					x
PUHDISTUSKAPASITEETTI										
PUHALLUSILMAN HEITTOPITUUS								x		

Hardly any for microbes

Determination of microbiological reduction efficacy of an air purifier

- Metal upholstered test room (30 m3)
- High concentration microbial aerosol (mixture) generated with a medical atomizer
- Sample collected with an impactor to a gelatin filter, followed by dilution, culture, incubation and plaque counting
- The principle has been applied to flow-though, field tests and tailored settings

CFD modelling: general air filter



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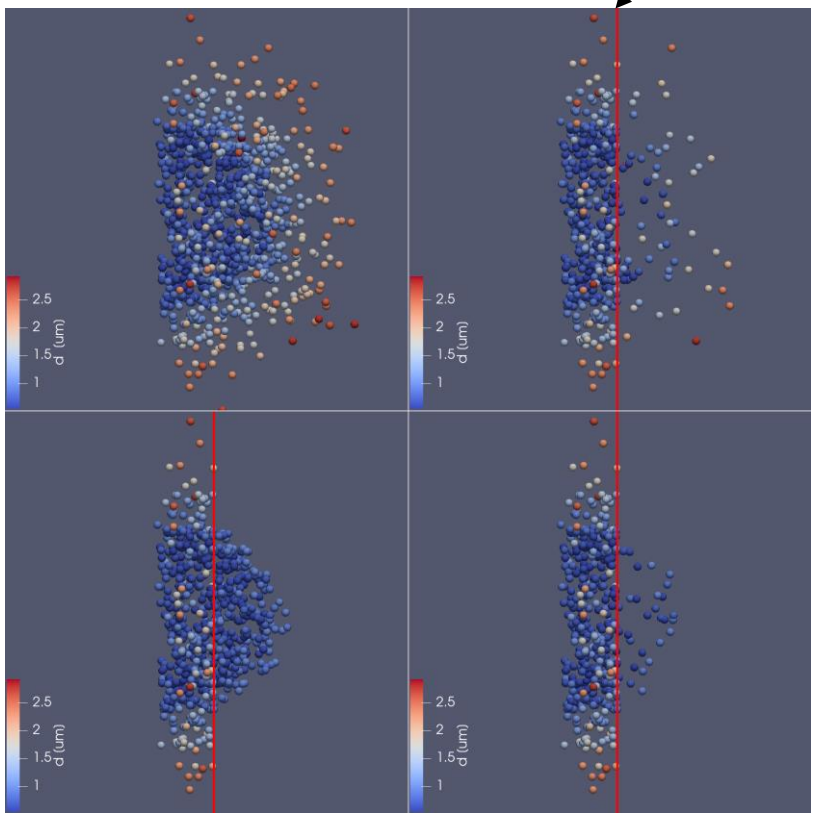
Filter

Without filter

With filter with 90 % efficiency



With filter with 100 % efficiency for larger than 1 µm particles

With filter with 100 % efficiency for larger than 1 µm particles and 90 % for others

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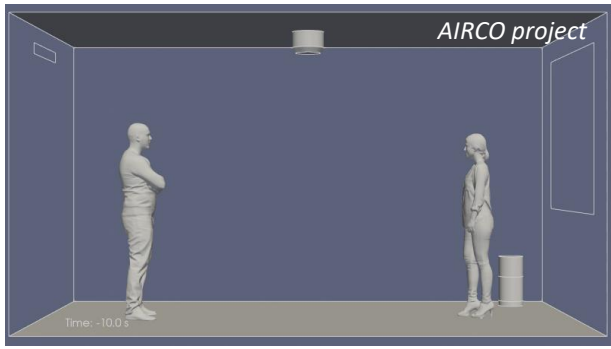


Ongoing/future activities

Development of legislation (Belgium)

- Legal framework regarding indoor air quality
  - Law of 6 November 2022 on the improvement of indoor air quality in closed spaces accessible to the public
  - A series of measures help to ensure effective ventilation and air purification to reduce the risk of airborne virus transmission.
  - To assess the IAQ (both in terms of certification and risk analysis) the law puts forward 2 reference levels: a level B at 25 m3/h of outdoor air ventilation per person and a level A at 40 m3/h per person, of which **a minimum of 25 m3/h should be outdoor air, while the rest can be supplemented through air cleaning.**
- Standards for air purification installations and CO2 meters.
  - A new royal decree will be issued during 2023 to regulate the placing of these devices on the market.

Cost comparison of air cleaning solutions

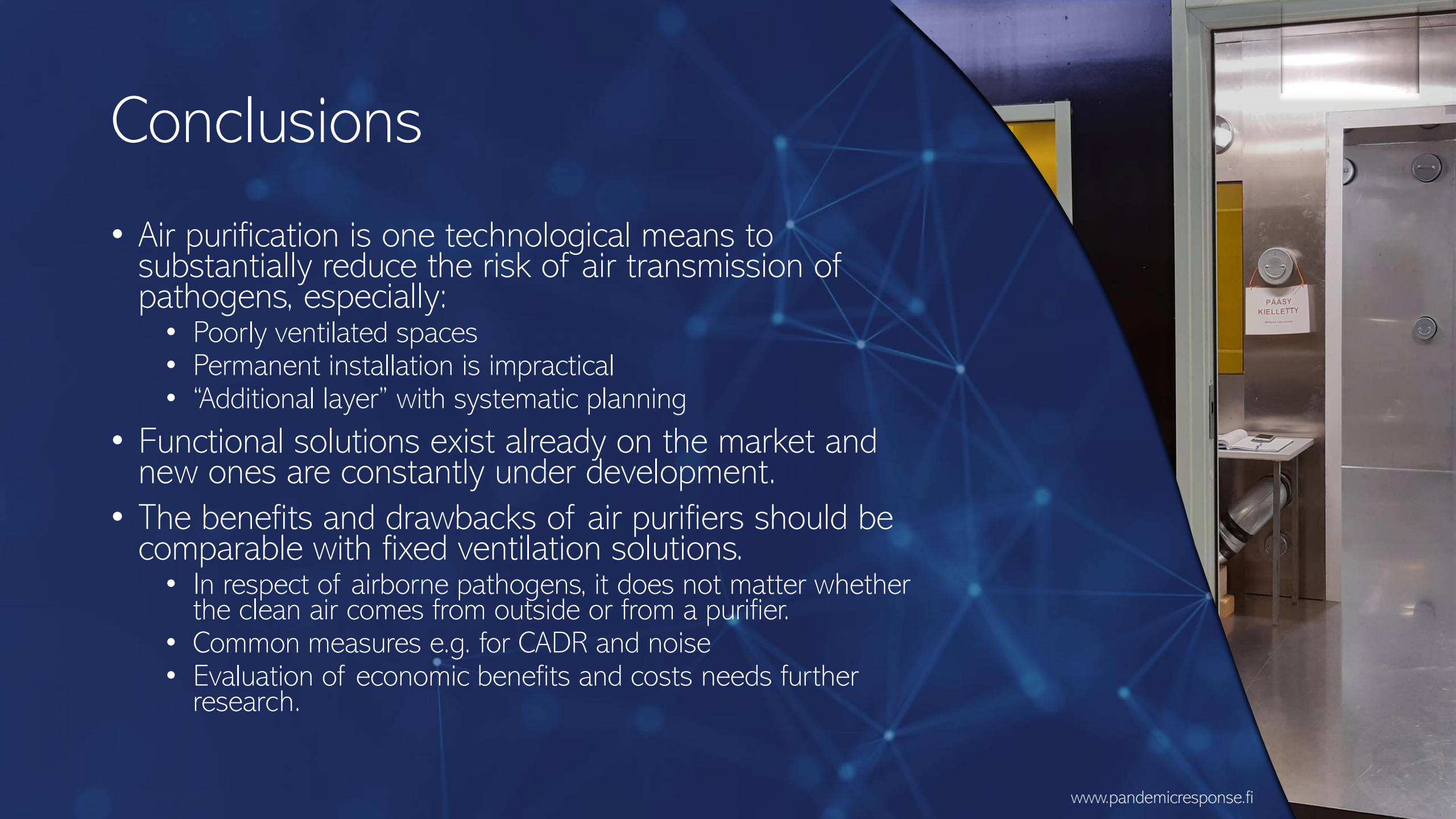
- an example of particles vs. morbidity

Quantity	System							
	a	b	c	d	e	f	g	h
Supply air, $dm^3/s/m^2$	2.67	2.67	2.67	2.67	2.67	3.74	2.67	2.67
Concentration, $\mu g/m^3$	29.63	14.12	11.37	10.39	5.11	10.39	8.7	13.33
Clean air delivery rate, $dm^3/s/m^2$	0	0	4.33	5	5	0	6.5	3.3
Energy, €/a/m^2	0	0.20	0.46	0.10	0.30	0.65	0.68	1.05
Capital + maintenance, €/a/m^2	0	0.44	13.58	9.20	9.64	16.73	20.38	20.45
Noise nuisance, €/a/m^2	0	0	6.73	0	0	0	8.27	4.03
Total expenses, €/a/m^2	0	0.64	20.77	9.30	9.94	17.38	29.33	25.53
Total yield, €/a/m^2	0	13.6	16.44	17.52	24.00	17.52	19.45	14.39
Profit, €/a/m^2	**0**	**12.96**	**-4.33**	**8.22**	**14.06**	**0.13**	**-9.89**	**-11.14**

Salmela H et al. (2017) Calculation model for cost comparison of air cleaning solutions

Conclusions

- Air purification is one technological means to substantially reduce the risk of air transmission of pathogens, especially:
  - Poorly ventilated spaces
  - Permanent installation is impractical
  - “Additional layer” with systematic planning
- Functional solutions exist already on the market and new ones are constantly under development.
- The benefits and drawbacks of air purifiers should be comparable with fixed ventilation solutions.
  - In respect of airborne pathogens, it does not matter whether the clean air comes from outside or from a purifier.
  - Common measures e.g. for CADR and noise
  - Evaluation of economic benefits and costs needs further research.



Thank you!

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