

# Welcome to Kuopio!

## OVERZICHT VAN INDOOR AIR 2022 KUOPIO - FINLAND

ISIAQ.NL SYMPOSIUM 2022 – GEZONDHEID & COMFORT |  
PIET JACOBS



Healthy People in Healthy Indoor Environments

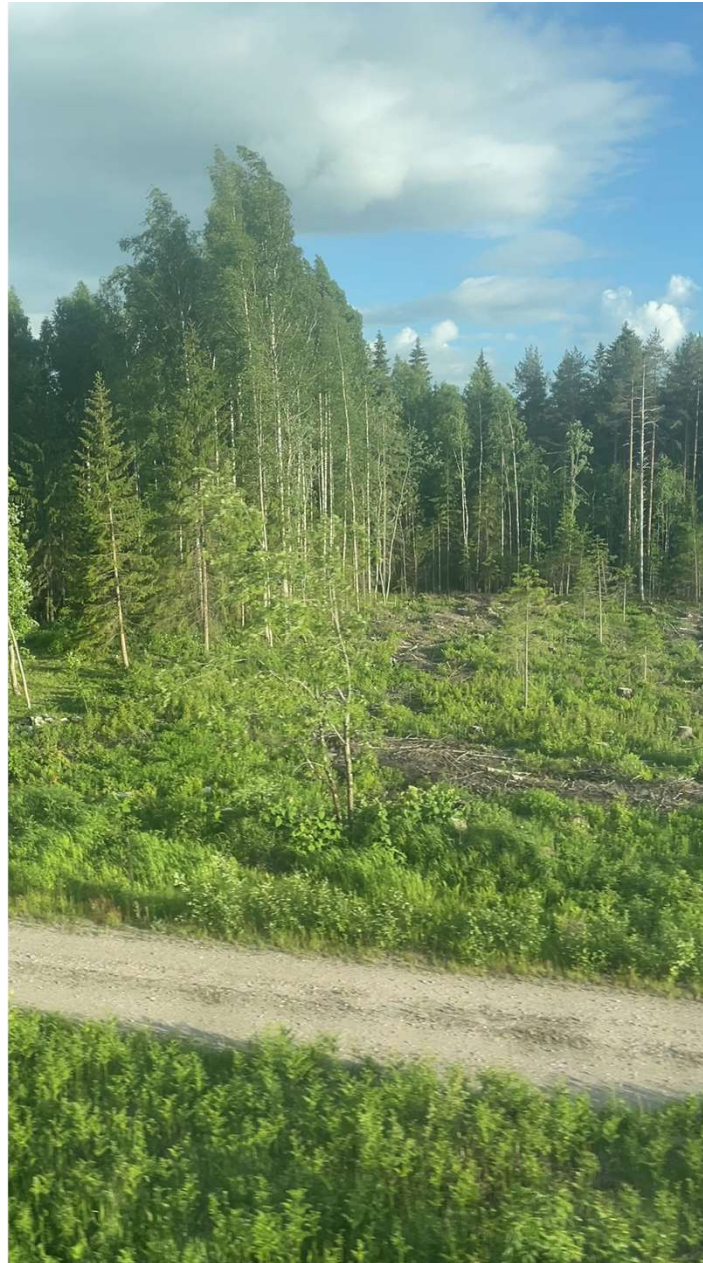
**INDOOR AIR**  
**2022** June 12<sup>th</sup> to 15<sup>th</sup>  
Kuopio FINLAND



## › KUOPIO

Twee maal vliegen!

Of 1 x vliegen + 400 km trein




## › EERSTE GROTE CONFERENTIE NA COVID: 602 DEELNEMERS

### NL delegatie:

Philomena Bluijssen TUD  
Piet Jacobs TNO  
Twan van Hooff TUE  
Tim de Graaff Philips  
?

Participants by country (n=41)



Country	n	Country	n	Country	N
Finland	138	Netherlands	8	Iran	2
United States	73	Luxembourg	7	Latvia	2
Japan	46	Hong Kong	6	Poland	2
France	41	Norway	6	Slovakia	2
China	38	Australia	5	Austria	1
Germany	37	Italy	5	Czech Republic	1
United Kingdom	33	Ireland	4	Estonia	1
Denmark	31	Singapore	4	Etiopia	1
Sweden	19	Slovenia	4	Greece	1
South Korea	18	Thailand	4	Iceland	1
Canada	17	Cyprus	3	Indonesia	1
Portugal	13	India	3	New Zealand	1
Belgium	11	Lithuania	3	Thailand	1
Switzerland	9	Spain	3		

## › ONDERWERPEN

1. Effect van ventilatie en luchtreiniging in klaslokalen
2. Nationaal onderzoek naar ventilatie en aerolsol verspreiding in openbaar vervoer, vliegtuigen
3. Bijproducten bij gebruik van luchtreinigers
4. How I was infected during clima 2022 conference in Rotterdam

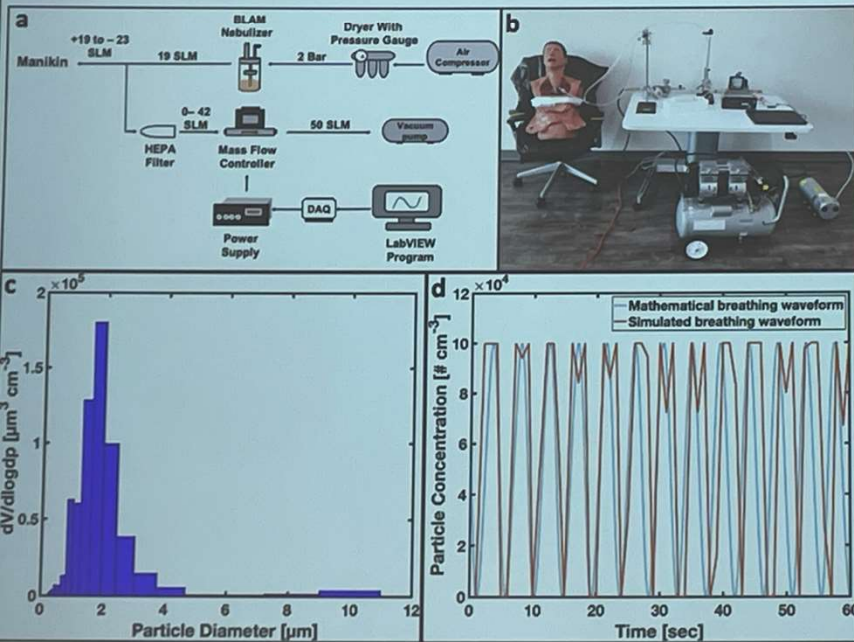




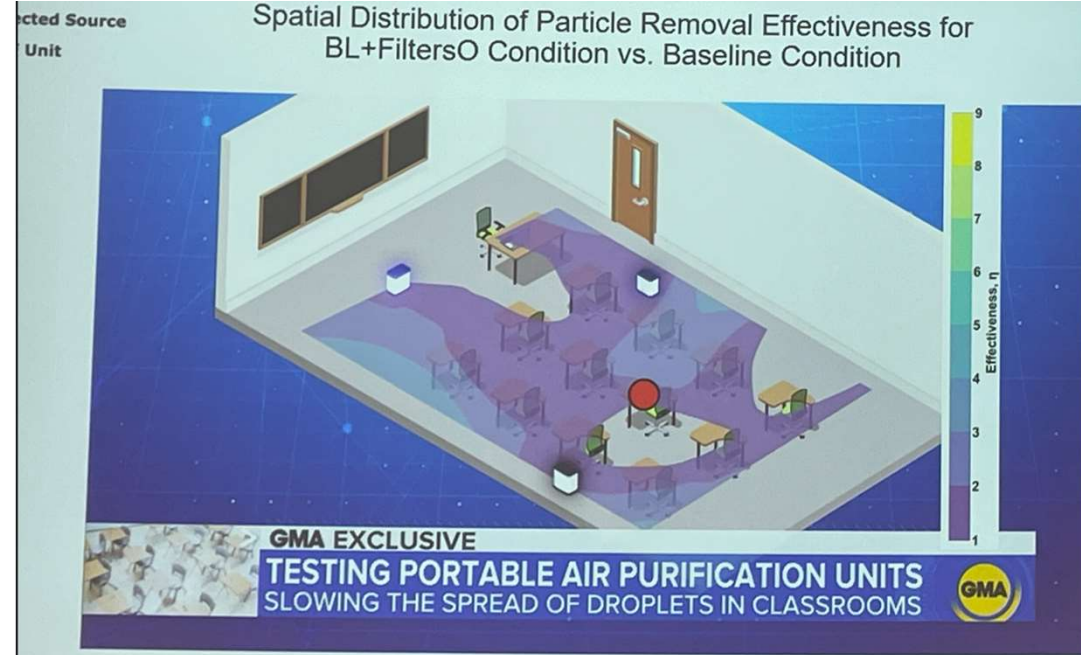
## Localized and Whole-Room Effects of Portable Air Filtration Units on Aerosol Particle Deposition and Concentration in a Classroom Environment

Meng Kong, Ph.D., Linhao Li, M.S., Stephanie M. Eilts, M.S., Li Li, Ph.D., Christopher J. Hogan, Ph.D., Zachary C. Pope, Ph.D.

## Methods



Eilts, S., L.  
C.J. (2021)  
exhaled p  
ventilation  
Atmosphe  
10.1016/j.



## Conclusions and Limitations

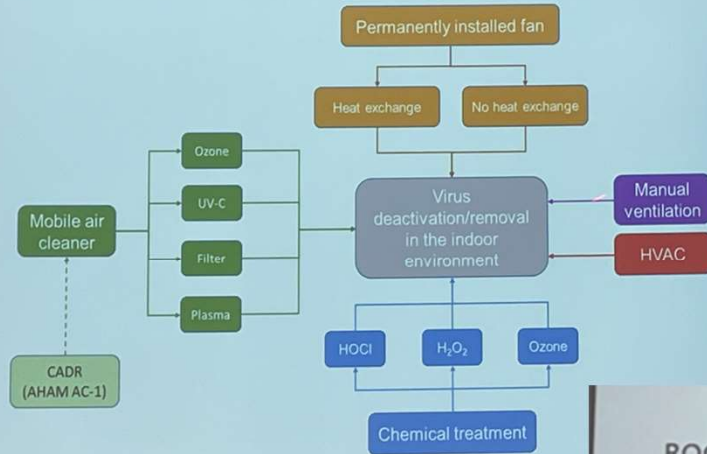
### Conclusion:

- PAF units can supplement the HVAC system and assist in reducing particle concentration and deposition if properly placed and sized for the room
- Particle exposure risk within ~2 m of infectious source is minimally influenced by the HVAC or PAF units

### Limitations:

- Thermal effects of the human body not investigated (e.g., thermal plume, higher temperature of exhaled air)
- Excluded other occupants (only one manikin in this study; no other movement in room)
- HVAC operational mode varied (heating vs. cooling)

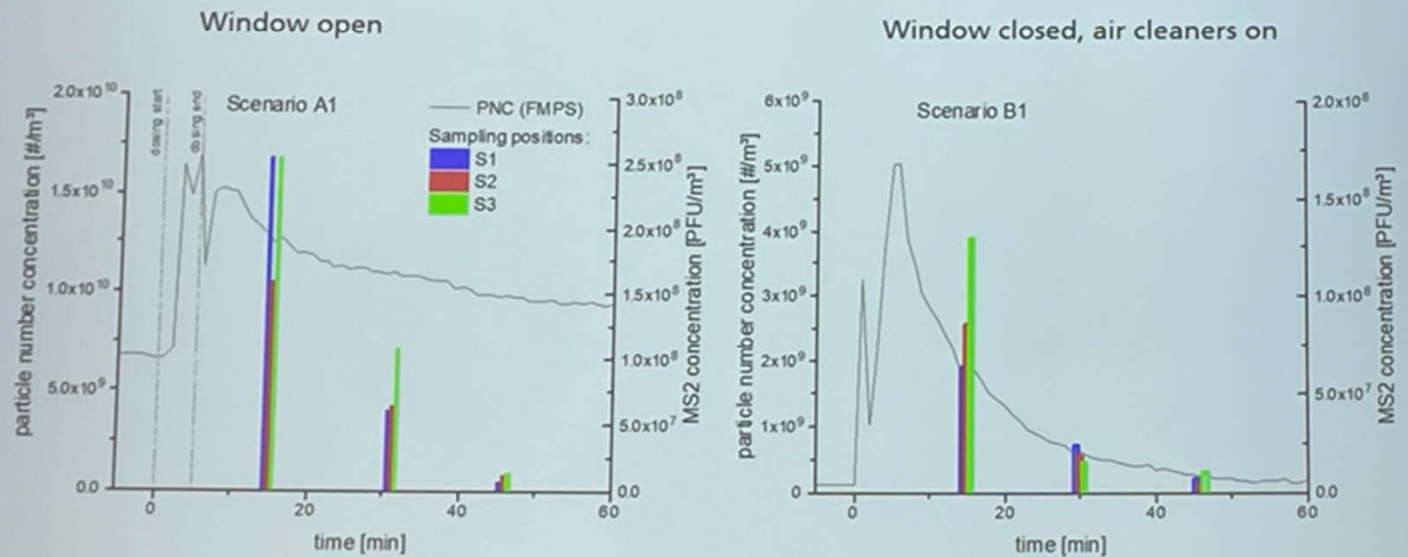
# VIRUS AEROSOL REDUCTION IN CLASSROOMS



## AIR-CLEANERS FOR VIRUS REMOVAL IN CLASSROOMS: TEST CHAMBER VS. REAL-WORLD ROOM, ERIK UHDE (1432/1637) FRAUNHOFER

Effect of ozon from outdoor air on deactivation of MS2 virus?

### ROOM MEASUREMENT MEASUREMENT RESULTS



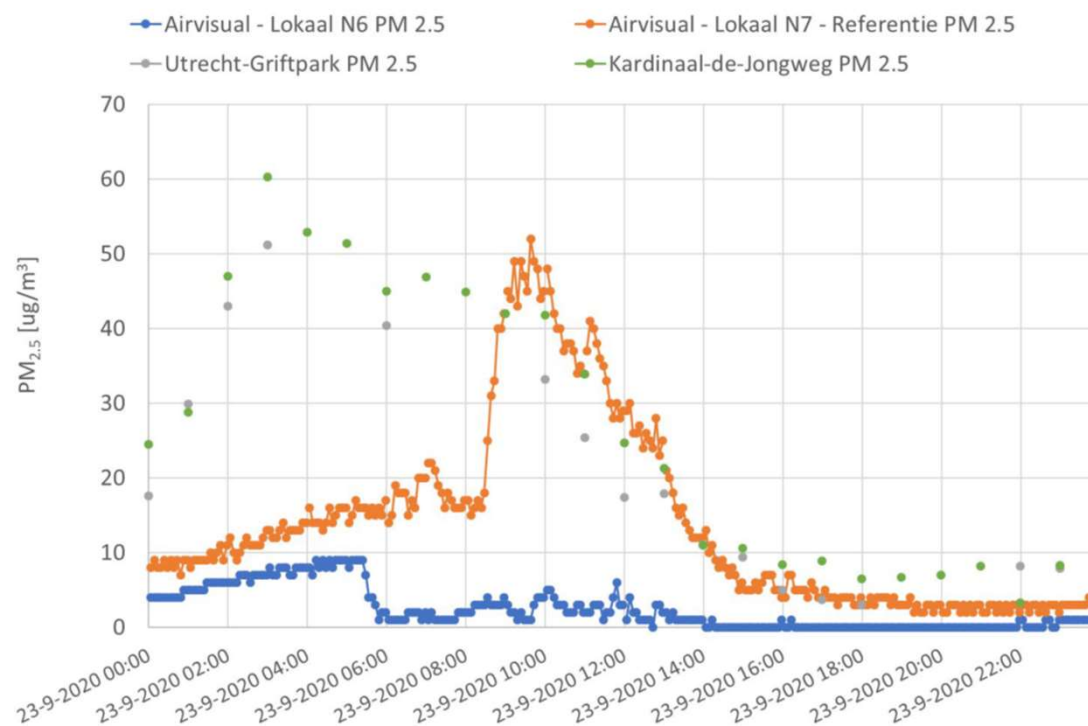
Uhde, Selthammer, Wientzek, Schulz, Springorum: Effectiveness of air-purifying devices and measures to reduce the exposure to bioaerosols in school classrooms. Submitted for publication.



› **VENTILATION SYSTEM FOR SCHOOLS  
WITH INDIRECT ADIABATIC COOLING AND HIGH EFFICIENCY  
FILTRATION | IR. P. JACOBS**

14 June 2022

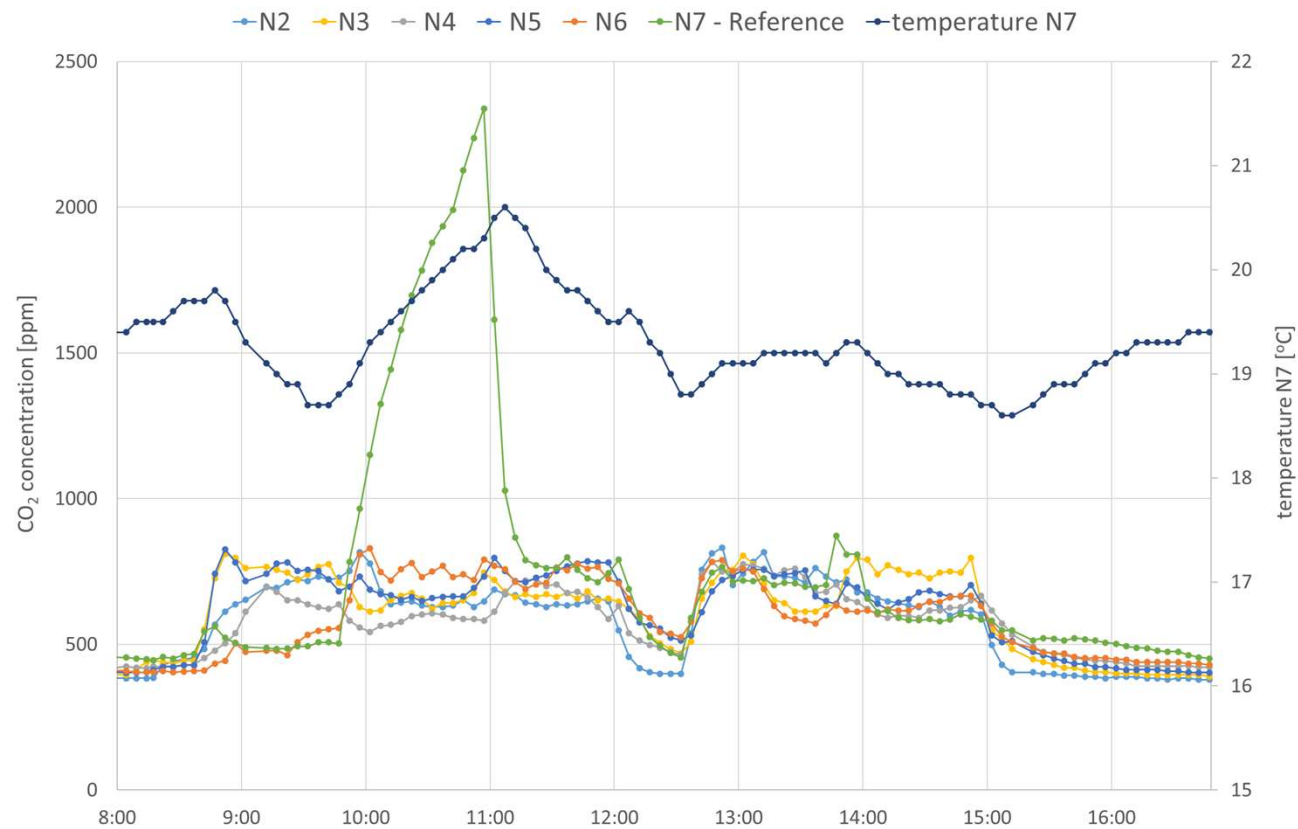
# PM<sub>2.5</sub> IN REFERENCE ROOM = OUTSIDE



70 - 96% lower PM<sub>2.5</sub>  
concentration in SchoolVent  
class room compared to  
reference class room



# DILEMMA BIJ NATUURLIJK VENTILEREN: GOED VENTILEREN EN KOUD OF RAAM DICT EN COMFORTABEL?



**VENTILEREN IS BELANGRIJK, MAAR  
HET THERMISCH COMFORT OP DE  
BOOTTOCHT OOK...**





## › BUONANNO, KEYNOTE

Validation through epidemiological study (3/3)

The government of the central Italy's Marche region on March 2021 launched a 9 M€ call to fund the installation of MVSS in classrooms to prevent the airborne transmission of SARS-CoV-2 and limit the adoption of distance learning solutions.

There were a total of 10 441 classrooms with an average occupancy of 20 students per classroom. 10 125 classrooms relied on natural ventilation (i.e. ventilation due to the leakages of the building and to the manual opening of the windows) while 316 were equipped with MVSS.


The maximum (nominal) air flow rates of the MVSS installed in the different classrooms ranged between 100 to 1000 m<sup>3</sup> h<sup>-1</sup> (with 25<sup>th</sup>, 50<sup>th</sup>, and 75<sup>th</sup> percentiles equal to 360 m<sup>3</sup> h<sup>-1</sup>, 600 m<sup>3</sup> h<sup>-1</sup>, and 800 m<sup>3</sup> h<sup>-1</sup>, respectively) resulting in a ventilation rate per person between 1.4 and 14 L s<sup>-1</sup> student<sup>-1</sup>.

In order to stratify the analysis, we have also introduced two sub-cohorts: i) the sub-cohort 1 represents the classrooms with MVSSs characterized by a ventilation rate per person between 1.4 and 10 L s<sup>-1</sup> student<sup>-1</sup> that meets the standard requirements of indoor air quality, ii) the sub-cohort 2 includes classrooms with a ventilation rate per person >10 L s<sup>-1</sup> student<sup>-1</sup> and up to 14 L s<sup>-1</sup> student<sup>-1</sup> and it could represent a health-based ventilation to protect from airborne transmission.

Buonanno et al., Increasing ventilation reduces the SARS-CoV-2 airborne transmission in schools: a retrospective cohort study in Italy's Marche region, The Lancet – Infectious diseases, submitted

Indoor Air 2022 the 17th International Conference of the International Society of Indoor Air Quality & Climate - June 12th to 16th Kuopio, Finland

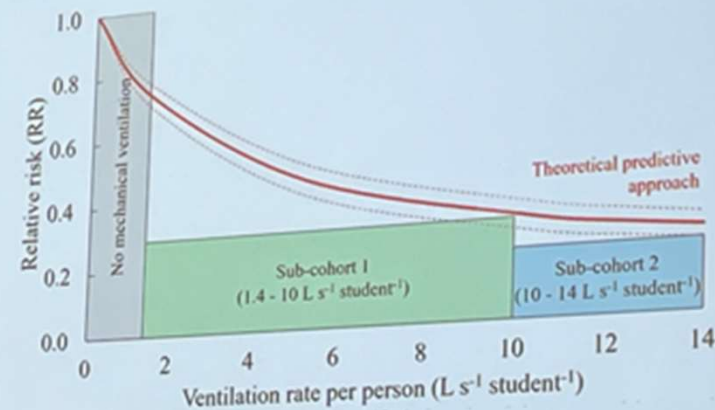
12/16



# NB: IN ITALIË DRAGEN KINDEREN OP SCHOOL ALTIJD MONDKAPJES

## Validation through epidemiological study (3/3)

Parameter	Period of investigation	Classrooms without MVS	Classrooms with MVS
Incidence cases	Sept. 13 <sup>th</sup> - Dec. 23 <sup>rd</sup> , 2021	1272	18
	Jan. 7 <sup>th</sup> - 31 <sup>st</sup> , 2022	1818	13
	Entire period	3090	31
Incidence proportion (per 1 000 students)	Sept. 13 <sup>th</sup> - Dec. 23 <sup>rd</sup> , 2021	6.3	2.8
	Jan. 7 <sup>th</sup> - 31 <sup>st</sup> , 2022	9.0	2.1
	Entire period	15.3	4.9
Incidence proportion ratio	Sept. 13 <sup>th</sup> - Dec. 23 <sup>rd</sup> , 2021	0.45	
	Jan. 7 <sup>th</sup> - 31 <sup>st</sup> , 2022	0.23	
	Entire period	0.32	



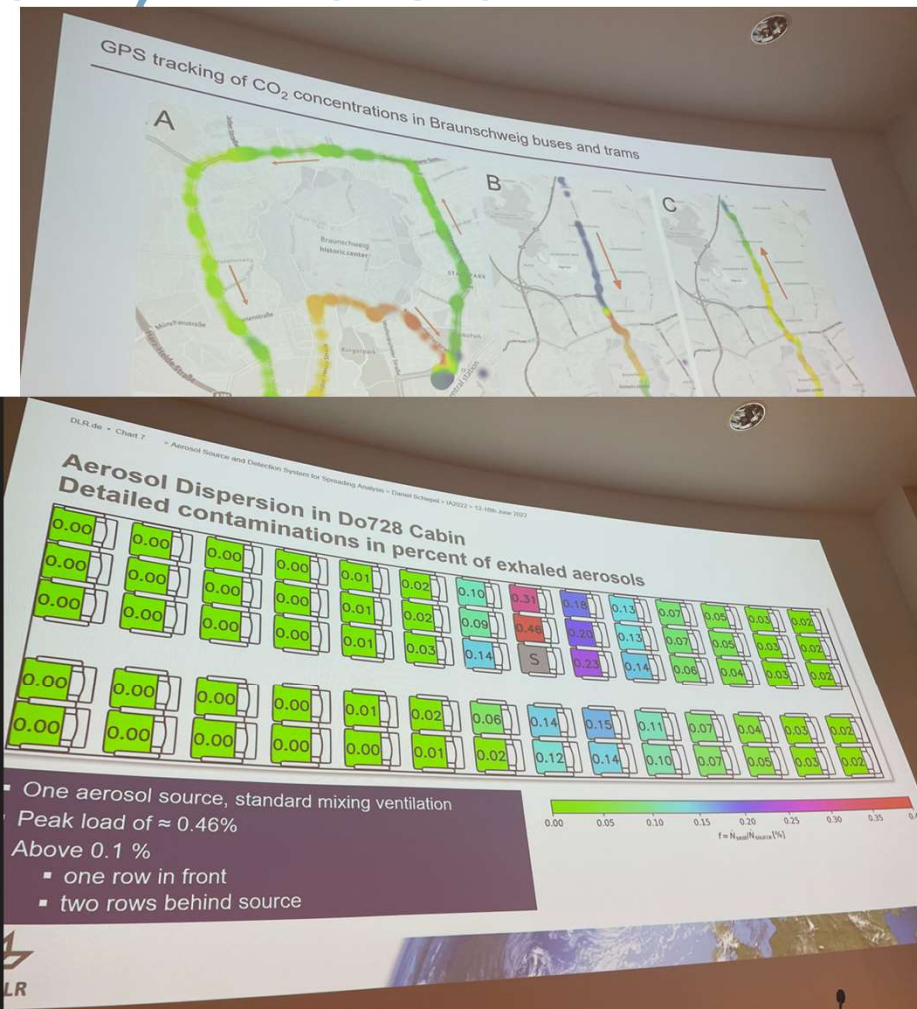
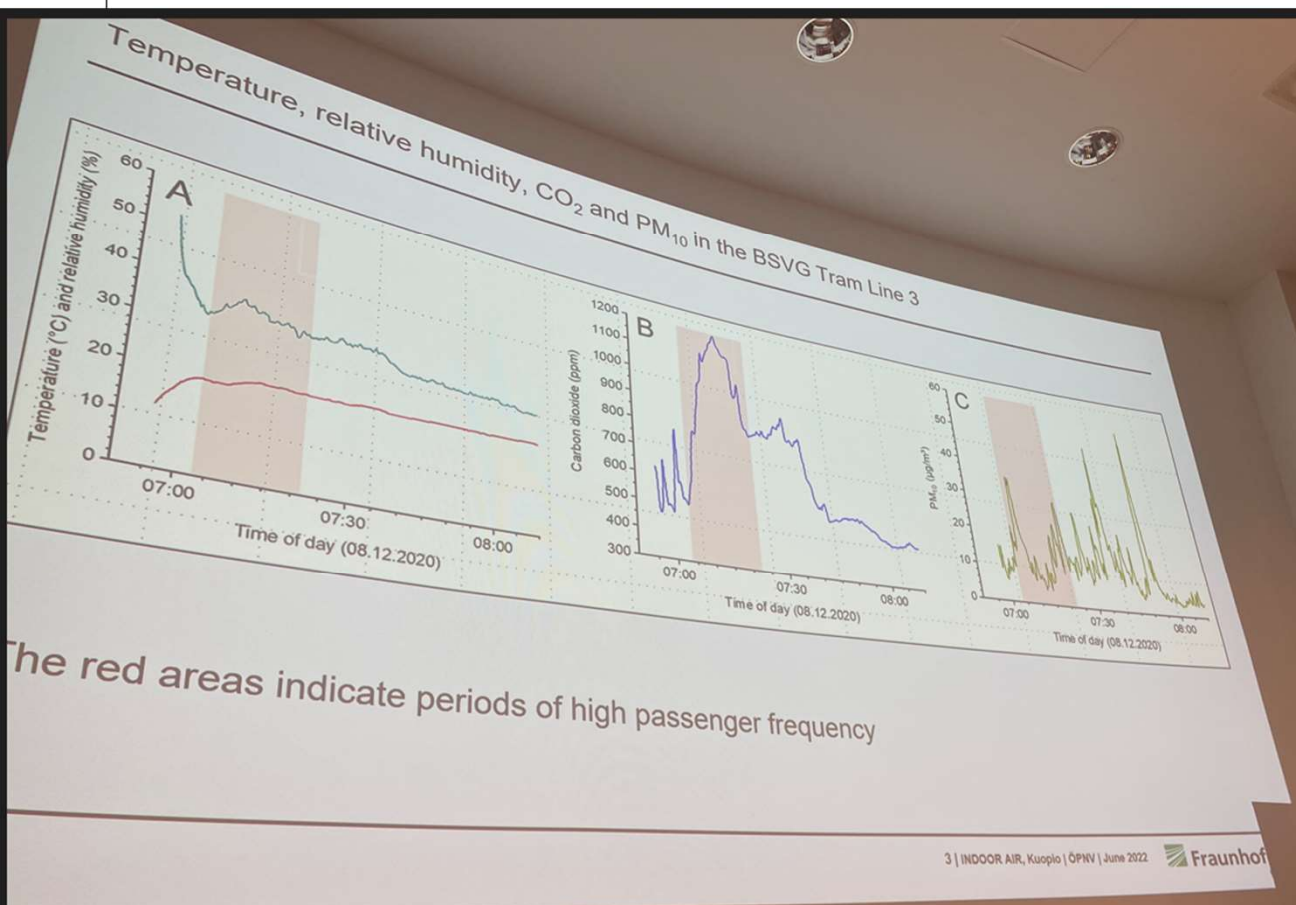
The agreement between the results obtained from the retrospective cohort study and values calculated through the predictive represents a validation of the approach through a retrospective cohort study.

Such validations confirm the possibility of extending the use of the approach, once the scenario has been defined, to any indoor environment of interest in addition to school classrooms and providing predictive estimates of the effectiveness of the ventilation for different exposure scenarios and variants of concern.

Buonanno et al., Increasing ventilation reduces the SARS-CoV-2 airborne transmission in schools: a retrospective cohort study in Italy's Marche region, *The Lancet - Infectious diseases*, submitted



# NATIONAAL ONDERZOEK NAAR VENTILATIE EN AEROLSOL VERSPREIDING IN OPENBAAR VERVOER, VLIEGTUIGEN



## ANDREA BURDACK-FREITAG (1195): RELEASE OF UNDESIED BY-PRODUCTS DURING THE OPERATION OF VIRUS INACTIVATING AIR CLEANING DEVICES

Background of the study  
Reduction of the virulence of inactivating air cleaners on basis of UVC or plasma technology

**Nebulizer**

- Aerosolizer for active surrogate viruses Continuously dosing (constant emitter, "Super spreader event")

**Online sensors and detectors**

- Particle counters (covering nm and  $\mu\text{m}$  ranges,
- Ozone and NOx analysers
- TVOC analyser

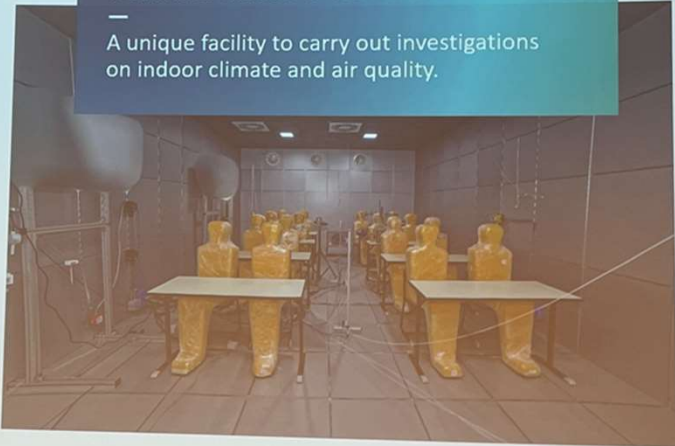
**Air sampler**

- VOC (by-products)
- Airborne germs

**Laboratory analysis**

- Gas chromatography-mass spectrometry
- Liquid chromatography
- Plaque assay test (Host cell *Pseudomonas spp.*)

Fraunhofer Indoor Air Test Center  
—  
A unique facility to carry out investigations on indoor climate and air quality.



Indoor Air 2022, Kuopio

Fraunhofer IBP



Best Full Paper Awards

Andrew Persily and Brian Polidoro: "Indoor Carbon Dioxide Metric Analysis Tool"  
Andrea Burdack-Freitag et al.: "Release of undesired by-products during the operation of virus inactivating air cleaning devices"



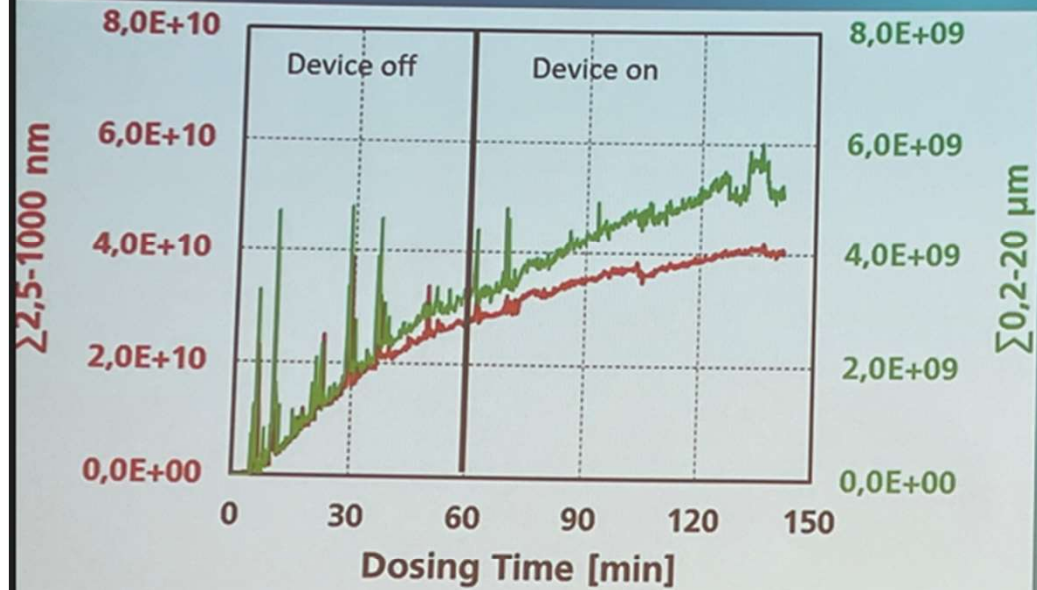
# Particle distribution

UVC

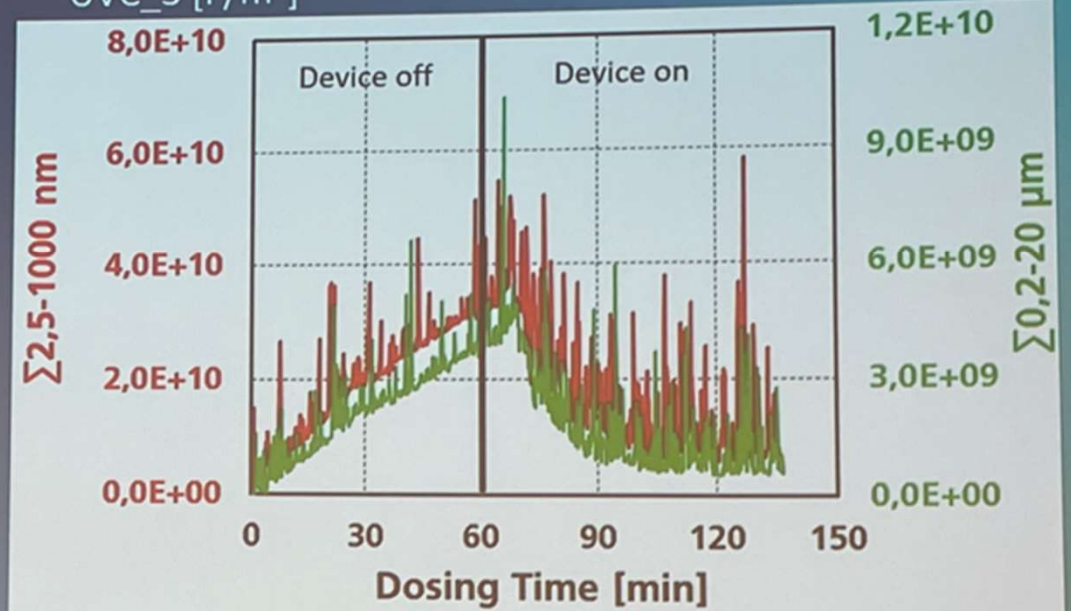
Zonder deeltjes filter

Met HEPA filter

UVC\_1 [P/m<sup>3</sup>]



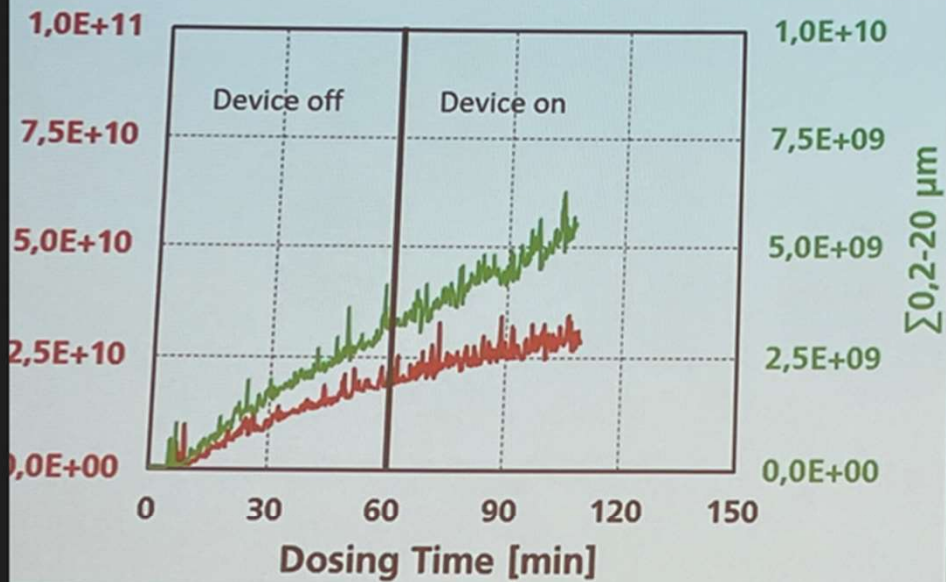
UVC\_3 [P/m<sup>3</sup>]



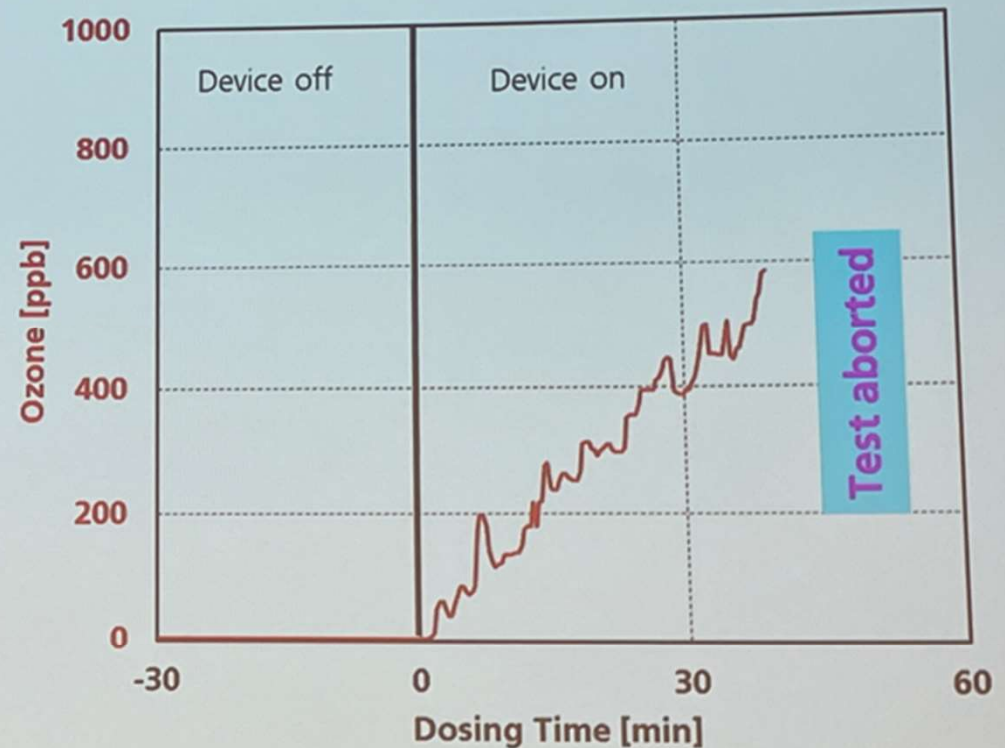
## Plasma device CP\_1

Device out of control!!!

CP\_1 [P/m<sup>3</sup>]



No EU-OEL for ozone, 100 ppb (by end of 2005)  
Odor threshold about 20 ppb



## › GROTE VERSCHILLEN IN EFFECTIVITEIT

Table 1. Investigated air cleaner.

Device No <sup>1)</sup>	Inactivating unit (additional filter technology)	Sound pressure level [db] <sup>2)</sup>	Max. Power consumption [W] <sup>2)</sup>	Measured flow rate [m <sup>3</sup> /h] <sup>3)</sup>
<b>UVC-Technology:</b>				
UVC_1	➤ UVC (without filter)	50	170	800
UVC_2	➤ UVC (coarse filter in front of the unit)	30 – 55	240	450
UVC_3	➤ UVC (coarse filter in front of and HEPA filter behind the unit)	25 – 45	110	1000
<b>Plasma Technology:</b>				
CP_1	➤ Ionization (dialectical discharge without filter)	n. s.	25	400
CP_2	➤ Cold plasma (coarse filter in front of and behind the unit, activated carbon filter behind)	n. s.	n. s.	120
CP_3	➤ Cold plasma (coarse and HEPA filter in front of and activated carbon filter behind the unit)	30 – 50	75	400

<sup>1)</sup> Anonymized in order not to draw any conclusions about specific manufacturers

<sup>2)</sup> Manufacturers specifications (if available), rounded values, n. s. – not specified

<sup>3)</sup> Adjusted and measured at the air outlet during measurements, rounded values

Table 2. Virulence (constant injection).

Sampling time	Virulence [%] <sup>1)</sup> of P1 (pfu/m <sup>3</sup> ) <sup>2)</sup>					
	UVC_1	UVC_2	UVC_3	CP_1	CP_2	CP_3
P1 maximum virus load	100 % (3 * 10 <sup>5</sup> )	100 % (1 * 10 <sup>4</sup> )	100 % (1 * 10 <sup>6</sup> )	100 % (2 * 10 <sup>4</sup> )	100 % (1.5 * 10 <sup>6</sup> )	100 % (3 * 10 <sup>3</sup> )
P2 30 min after device on	25 %	30 %	< 1 %	15 %	20 %	20 %
P3 1 h after device on	30 %	35 %	< 1 %	- <sup>3)</sup>	50 %	< 5 %

<sup>1)</sup> Results from fivefold determination, Rounded values: (P2)/(P1)\*100; resp. (P3)/(P1)\*100

<sup>2)</sup> Rounded values of plaque forming unit's pfu related to 1 m<sup>3</sup> sampling volume

<sup>3)</sup> Test aborted for safety reasons



# BIJ PLASMA VORMING VAN BIJPRODUCTEN O.A. FORMALDEHYDE

## Plasma device CP\_1

Correlation test: Release of ozone and formation of by-products

### Injection of a VOC mix:

- Isobutanol
- Acetophenone
- Limonene
- Hexanal
- Pentanoic acid

### Two concentration levels:

- 275  $\mu\text{g}/\text{m}^3$
- 850  $\mu\text{g}/\text{m}^3$



Adjusting  
Ionizator power  
steps:

- 100 %
- 31%
- 25 %
- 13 %

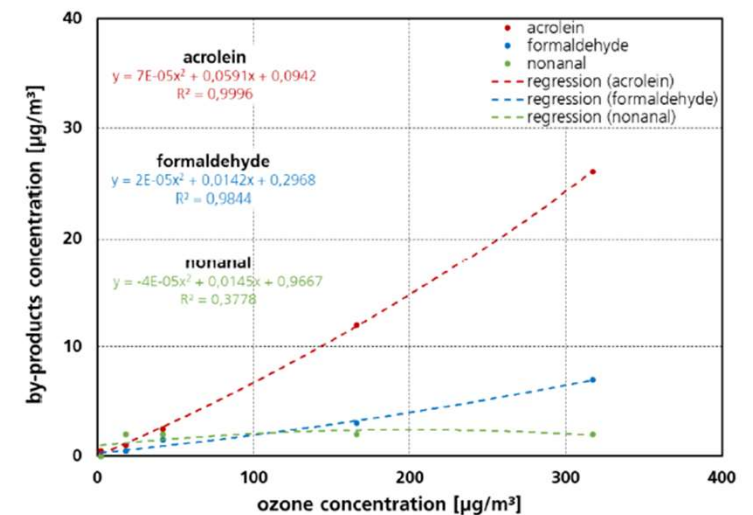


Figure 2. Correlation of ozone concentrations and formation of by-products for CP\_1.

## › WOLFGANG KARL HOFBAUER, FRAUNHOFER (1795)

### Motivation

Efficiency of UVC radiation as an air disinfectant in a real environment

Fraunhofer IMM, Fraunhofer IBP

#### Goal:

Characterization of the efficiency of air disinfection by use of UVC irradiation in a real situation of a highly frequented building.

#### Challenge:

How is it possible to determine the undisturbed reference load (background load)?

We also tested the applicability of already known D90 values (dose required for a 90% reduction)



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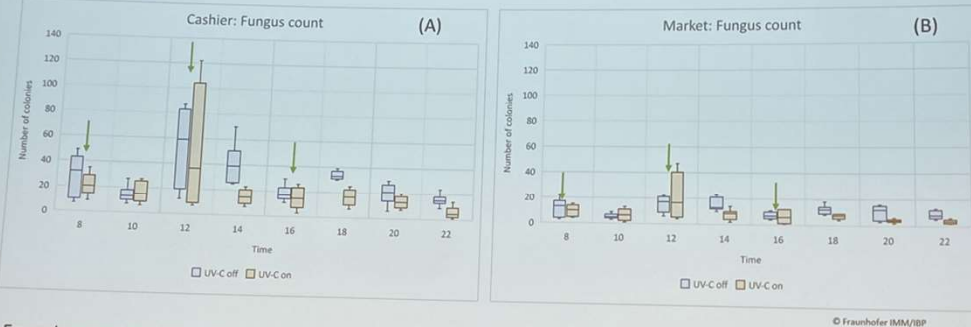
Fraunhofer IMM Fraunhofer IBP



# GEBRUIK MAKEN VAN DE IN DE SUPERMARKT AANWEZIGE SCHIMMELS EN BACTERIËN



Measuring campaign1: Daily counts of fungal spores in super market  
Efficiency of UVC radiation as an air disinfectant in a real environment; 1<sup>st</sup> trial



Fungal counts at cashier (A) and in the market (B), respectively, Monday to Friday. CFU's were counted after ten days. Green arrows indicate time points with temporary events (8: daily cleaning and restocking of fruits and vegetables; 12: increase purchase of open food stuff; 16: change of shifts).

© Fraunhofer IBP

Measuring campaign1: Assessment of UV-C effect

Efficiency of UVC radiation as an air disinfectant in a real environment, 2<sup>nd</sup> trial

2<sup>nd</sup> trial Bacteria count

Calculation:

$$N_{UV} / N_0 = e^{-kD}$$

59% reduction in bacteria:  $N_{UV} / N_0 = 0.41$

$$0.41 = e^{-kD}$$

$$-\ln(0.41)/k = D$$

$$D = 0.892/0.0377 = 23.7 \text{ J/m}^2$$

applied to corona viruses this corresponds to  
**4-log reduction in corona viruses = disinfection!**

\* Measured average for typical airborne bacteria

\*\* measured for airborne Corona viruses



Scenario:  
10fold higher k-value

Assumptions:

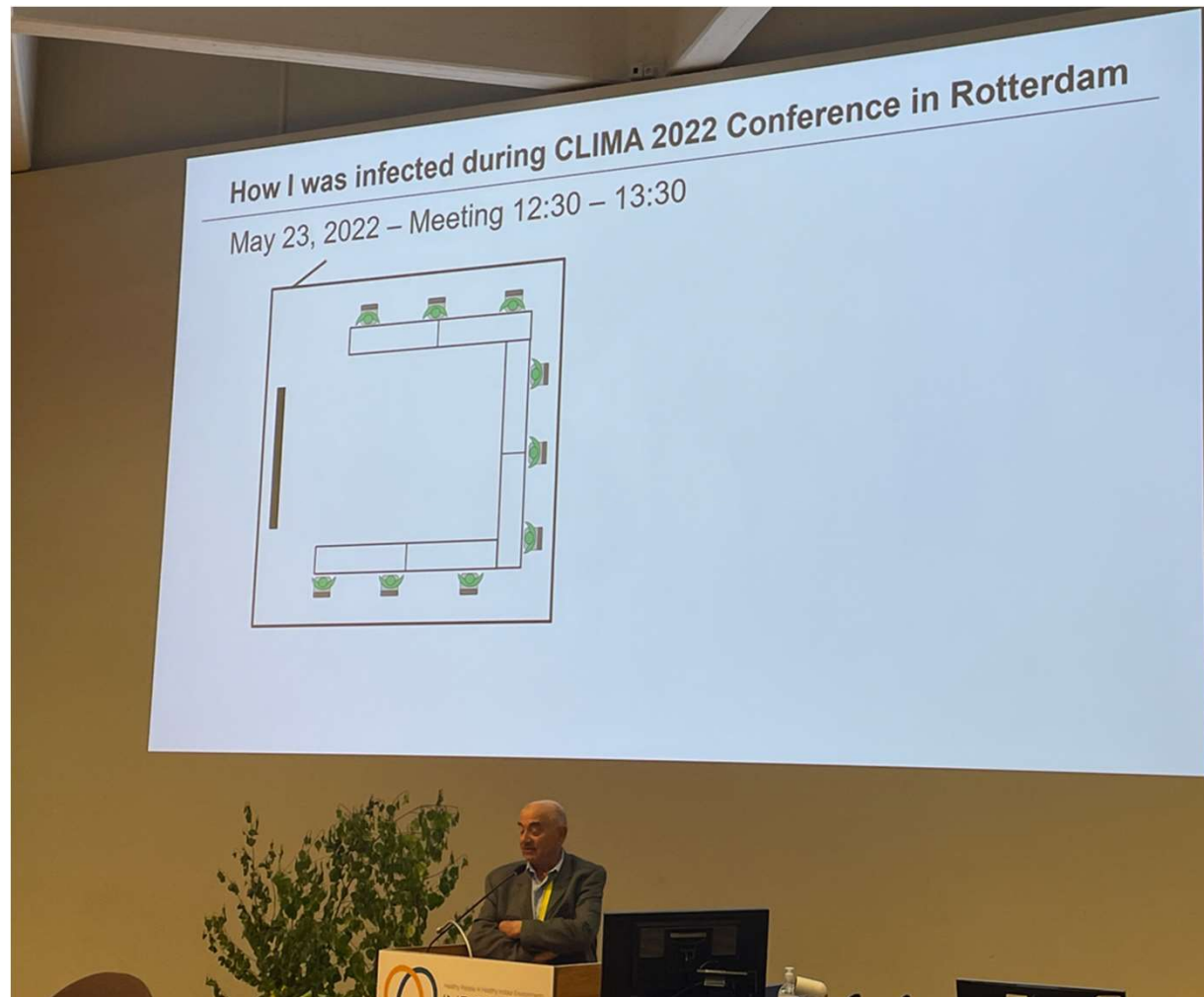
D90\*: 60J/m<sup>2</sup> (bacteria) →  $k = 0.038 \text{ m}^2/\text{J}$

D90\*\*: 6 J/m<sup>2</sup> (Corona viruses) →  $k = 0.377 \text{ m}^2/\text{J}$

© Fraunhofer IBP

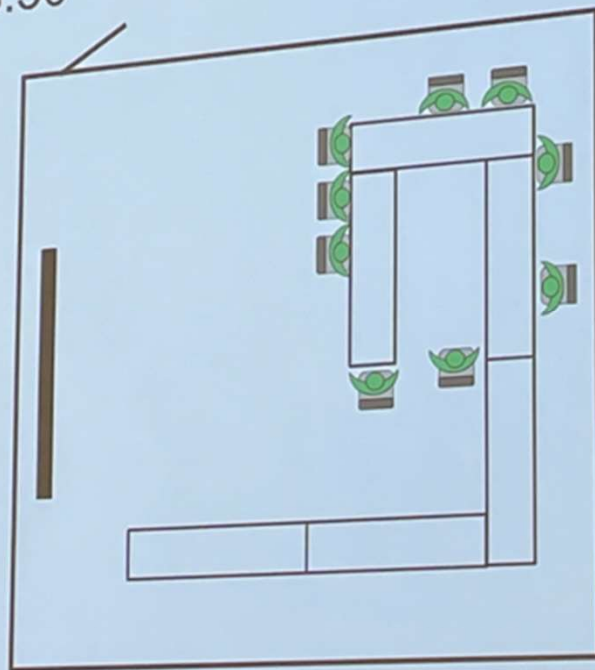
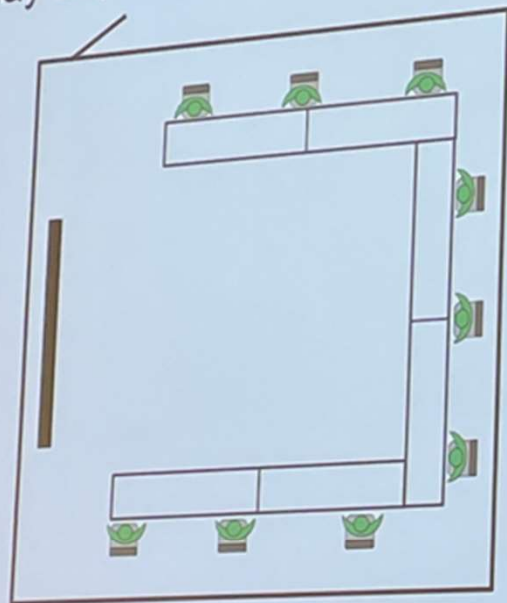


## › ARSEN MELIKOV – SPECIALIST ON LOCAL VENTILATION



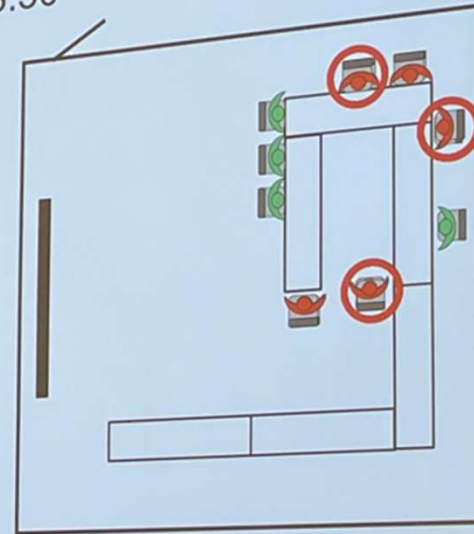
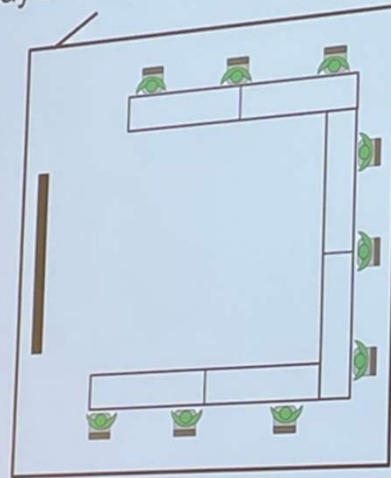
# How I was infected during CLIMA 2022 Conference in Rotterdam

May 23, 2022 – Meeting 12:30 – 13:30



## How I was infected during CLIMA 2022 Conference in Rotterdam

May 23, 2022 – Meeting 12:30 – 13:30



Short range airborne transmission most probable route! Keep distance  $>1.5$  m!  
Recommendation on distancing between occupants was ignored!







› **BEDANKT VOOR  
UW AANDACHT**

**TNO** innovation  
for life