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Evaluating clean air technologies for mobile air purifiers

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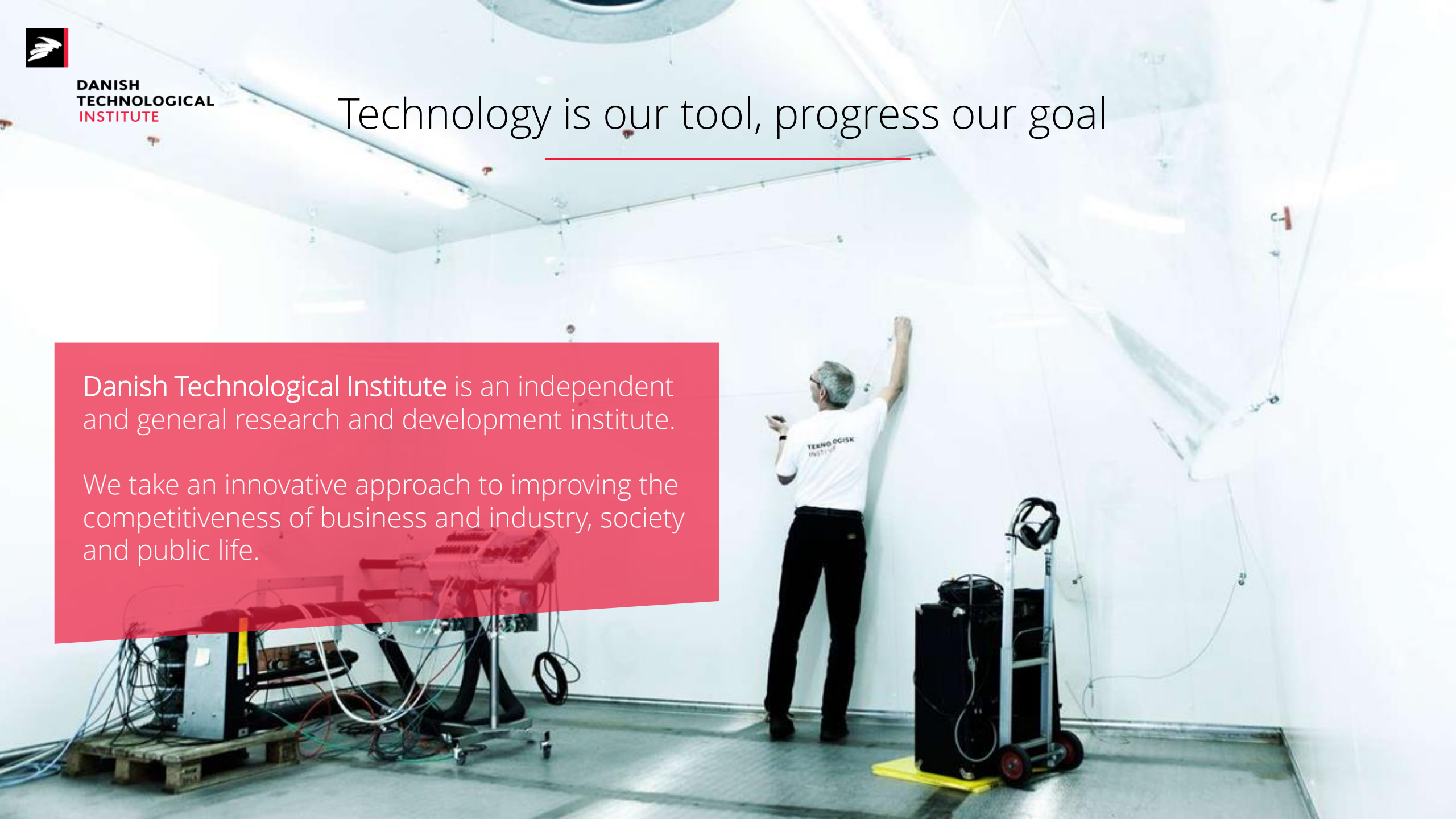


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Technology is our tool, progress our goal

Danish Technological Institute is an independent and general research and development institute.

We take an innovative approach to improving the competitiveness of business and industry, society and public life.





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Areas of expertise Department of Air & Sensor Technology



Clean Air Technologies
Development, supplier
selection, documentation



Air Quality Sensors
Development, calibration,
implementation, data-
driven optimization of
performance



Products
Development, Laboratory
Testing of efficiency and
By-product formation,
Documentation



Applications
Implementation, Operation,
Documentation,
Air Quality (indoor &
environment), Real-life
testing

Cleaning
Capacity

Trade-offs

Durability

Air Flow

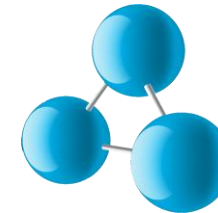
Efficiency

Maintenance

Noise

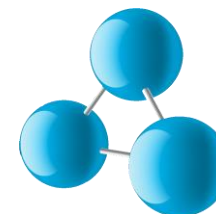
Price

Power



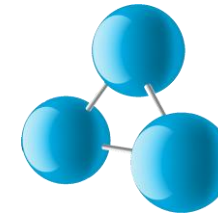
Clean Air Technologies

- Mechanical Filtration (e.g., HEPA)
- Electronic Air Filter (Electrostatic or ionizers)
- Adsorbent (e.g., activated carbon or zeolite)
- Ultraviolet Germicidal Energy (UV-C)
- Photocatalytic Oxidation (PCO)
- Ozone
- Nonthermal Plasma (NTP)
- (Biofiltration / Botanical)
- Combination
- ...



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The image features a variety of HEPA filters. On the left is a large, tall cylindrical filter with a silver-colored metal mesh exterior. To its right are two smaller cylindrical filters with white pleated interiors and black end caps; one is standing upright and the other is lying horizontally. In the foreground, a small, short cylindrical filter with a blue top and bottom ring and a white pleated body stands upright. To the right of these is a rectangular, flat filter with a black frame and a white pleated center. The background is a bright, out-of-focus laboratory with two people in white lab coats and safety glasses working at a bench.

HEPA FILTER

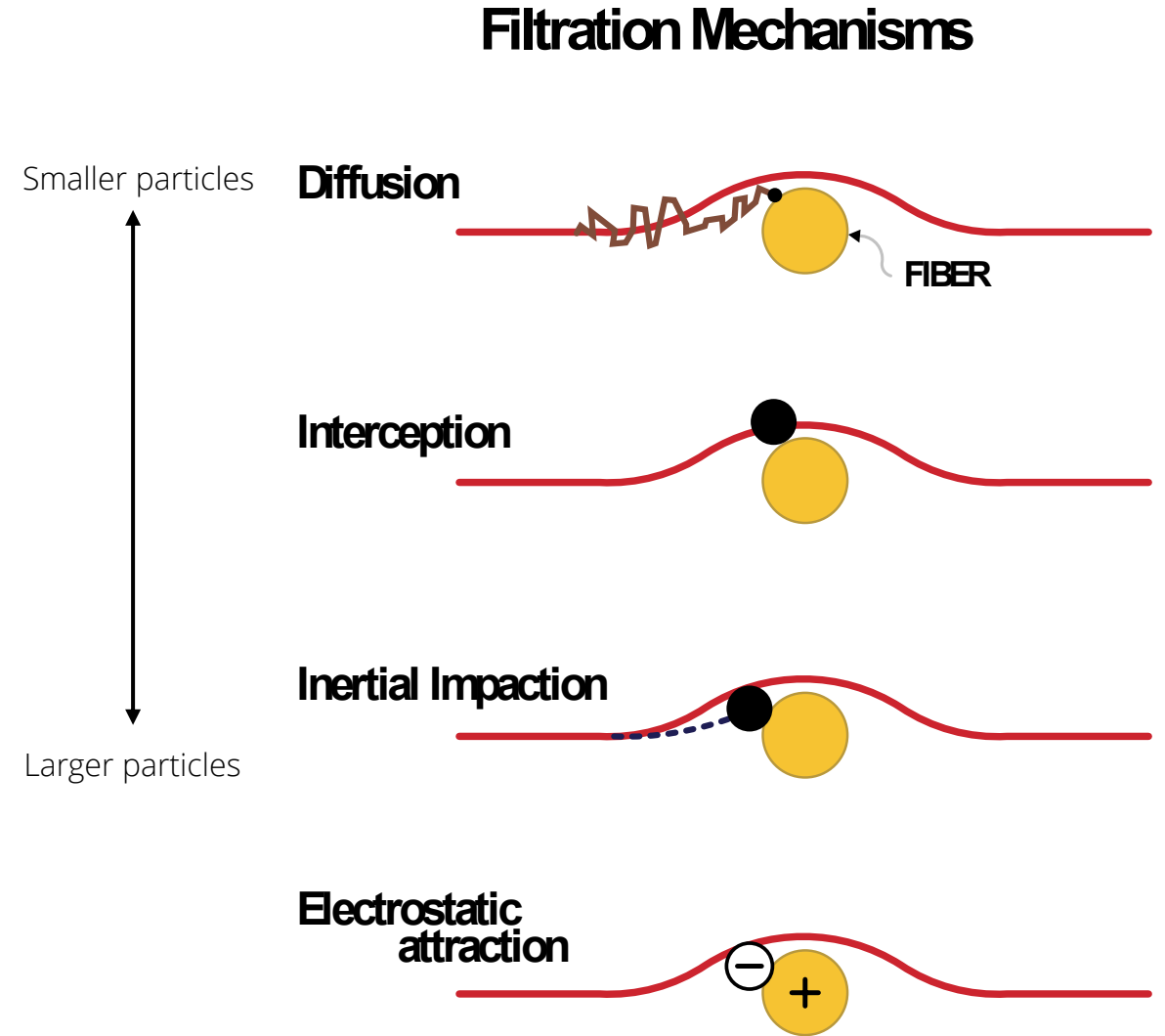
HEPA FILTER

Most commonly used clean air technology in mobile air purifiers (H13, 99,95% efficiency)

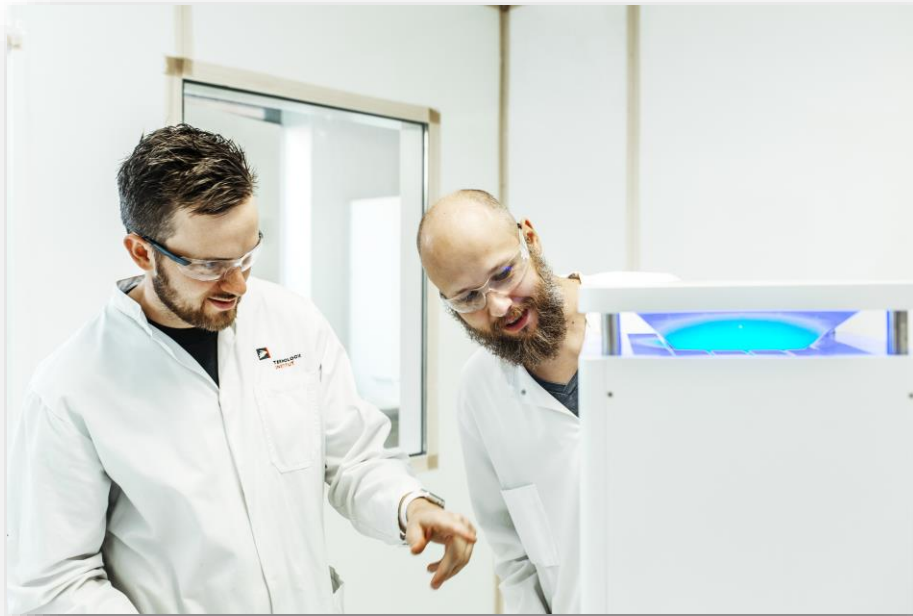
4 different filtration mechanisms in play

All mechanisms contribute to the overall efficiency
Each mechanism is affected differently by particle size and air velocity

Typically, also capable of removing ultrafine particles, but not gaseous compounds



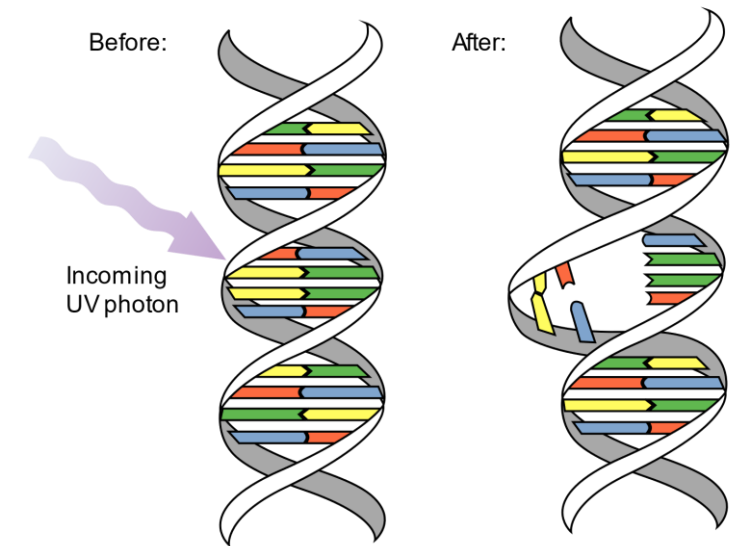
Ultraviolet Germicidal Energy (UV-C)



Ultraviolet Germicidal Energy (UV-C)

- Three major factors determine the ability of UV-C light to inactivate microorganisms
 - UV intensity (**I**)
 - Light intensity typically decreases with the distance squared
 - 2 x distance = 1/4 Intensity
 - Time of exposure (**t**)
 - Exposure time can be as short as a few milliseconds, whereas traditional disinfection is over many seconds
 - Microorganism susceptibility (D_{90}) or "rate constant" (**k**)
 - Determination of the rate constant of microorganisms is subject to significant uncertainties and varies somewhat from research result to research result
- The simplest way to describe efficiency can be done through exponential decay of a population via:

$$S = \exp[-k \cdot I \cdot t]$$



Billede fra: [Ultraviolet - Wikipedia](#)



Testing of mobile air purifiers



Clean Air Delivery Rate (CADR):

- *The volume of cleaned air delivered per hour by the product*
- “Sum” of air flow and the efficiency of the clean air technology
- Independent of test chamber size
 - Results are scalable
- Based on ANSI/AHAM AC-1-2015
- Separate CADR-value for different air pollutants
 - PM1, PM2.5, Ultrafine particles, TVOC etc.



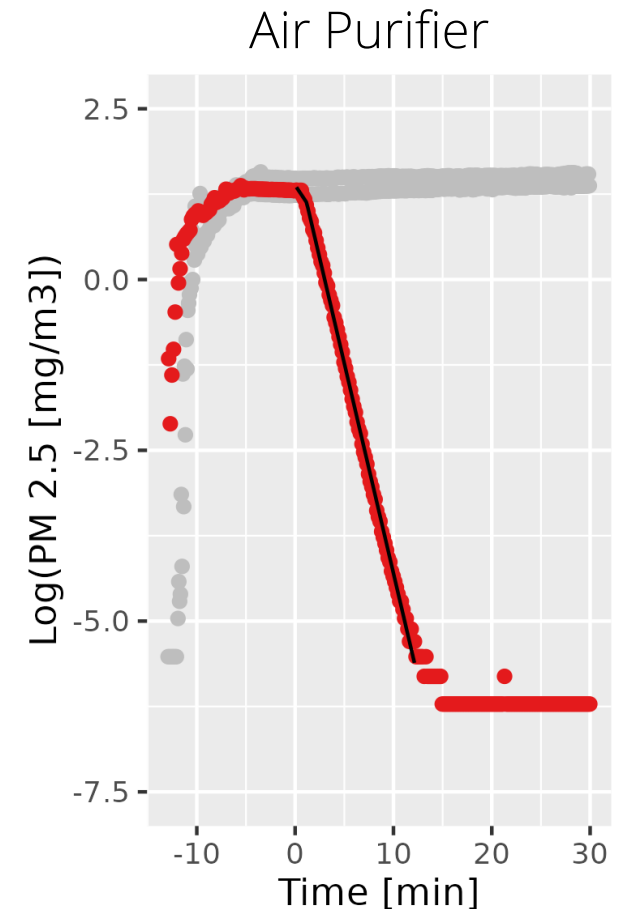
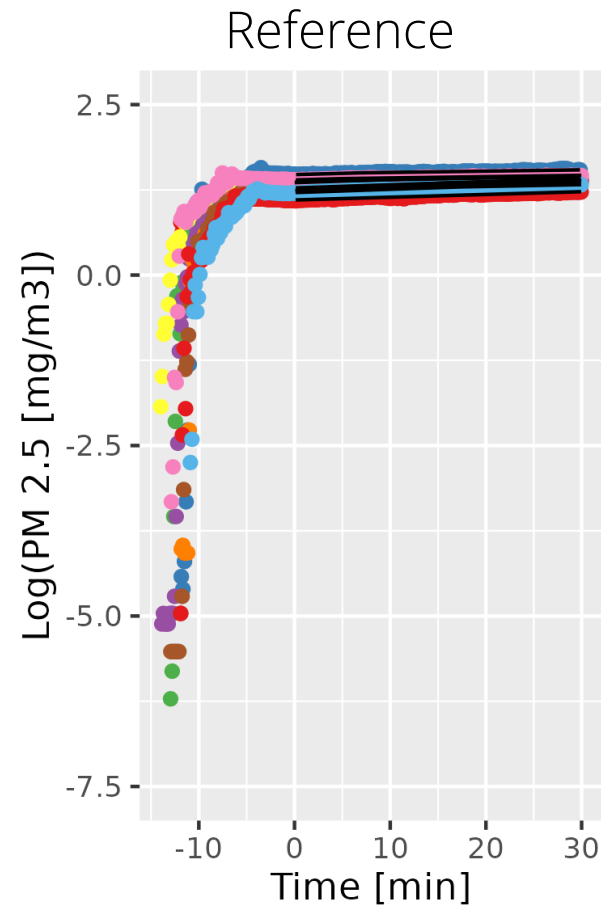
Testing of mobile air purifiers

Clean Air Delivery Rate (CADR):

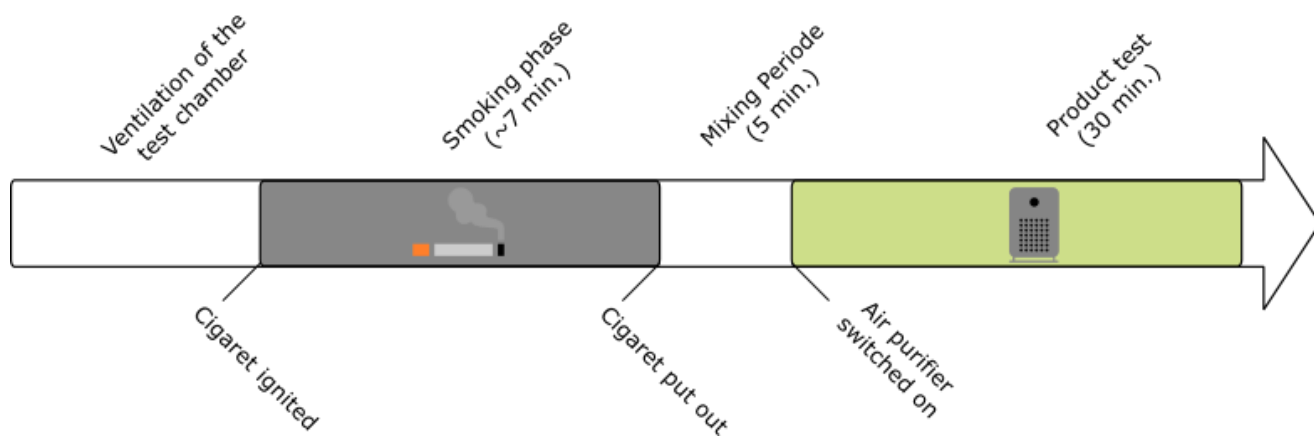
- Based on the rate constant from (k) exponential decay of pollutant concentration (C)

$$C_t = C_0 \cdot \exp[-k \cdot t]$$

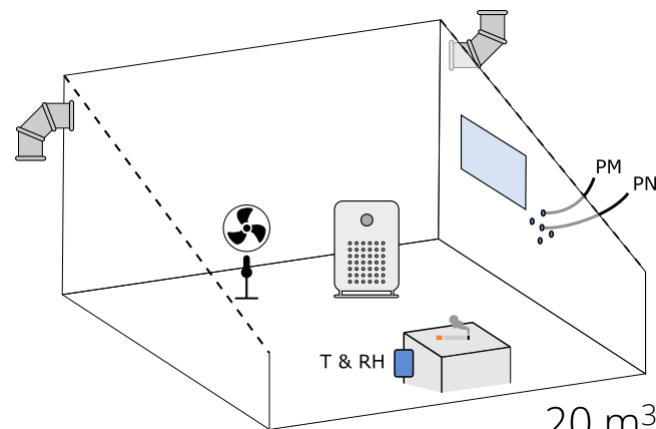
$$CADR = V \cdot (k_{air\ purifier} - k_{reference})$$



Protocol



Smoking "robot"



20 m³ test chamber
Teflon coated



Ultrafine particles
TSI Nanoscan SMPS



PM2.5
TSI Dusttrak

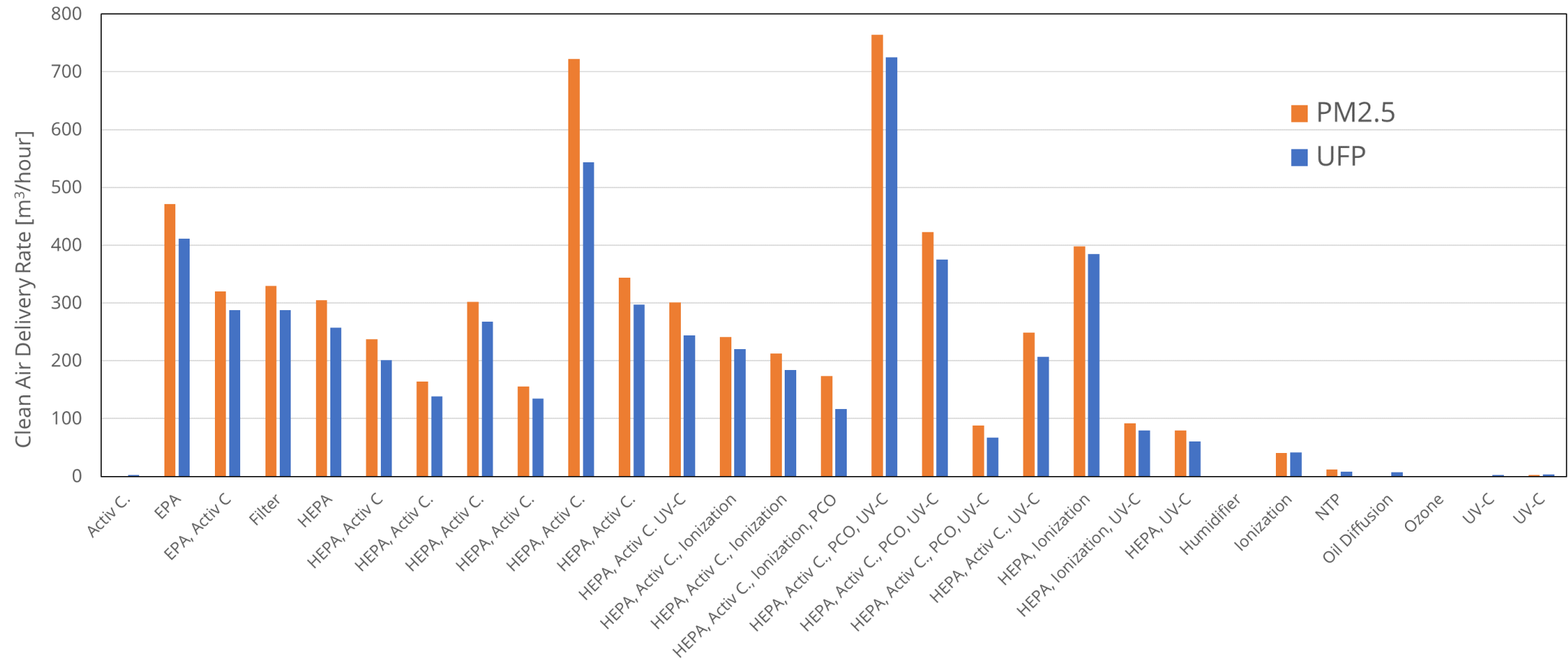


TVOC
Ion Science Tiger



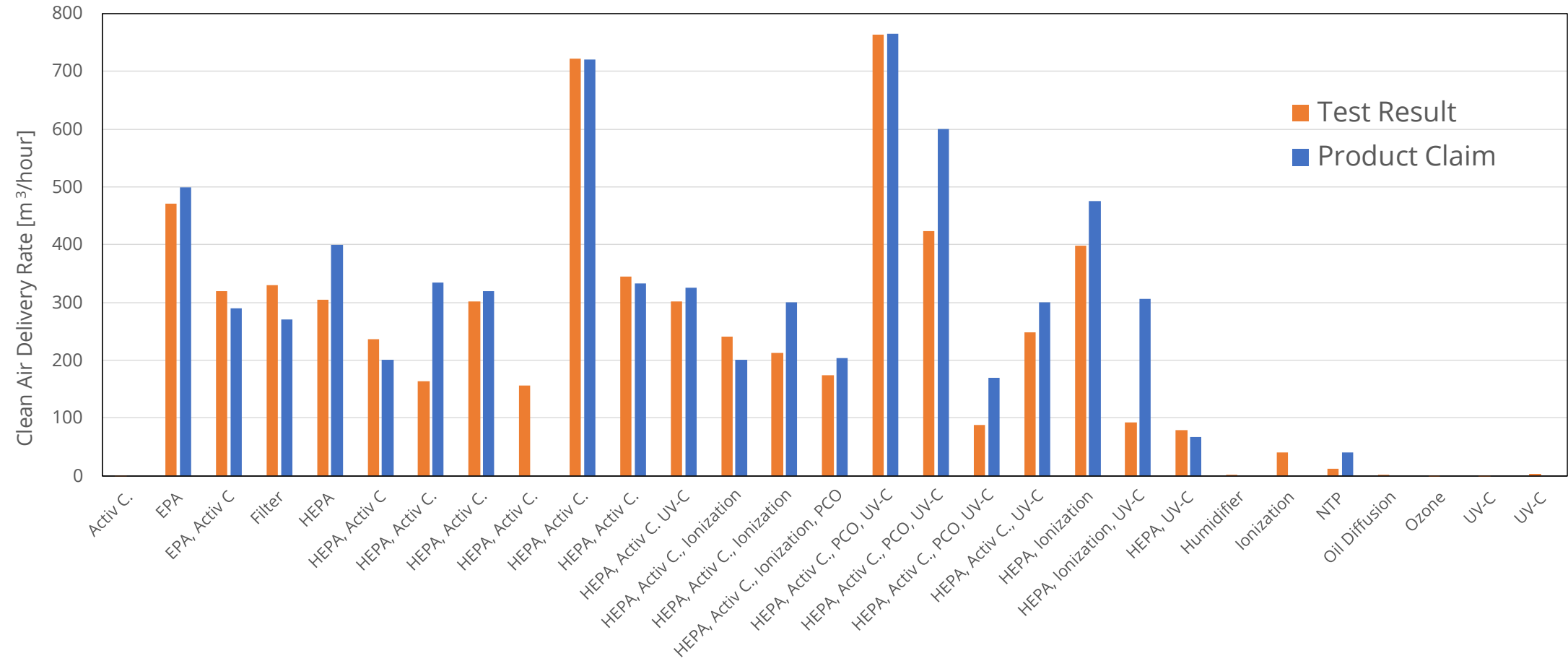


Project Results - 1



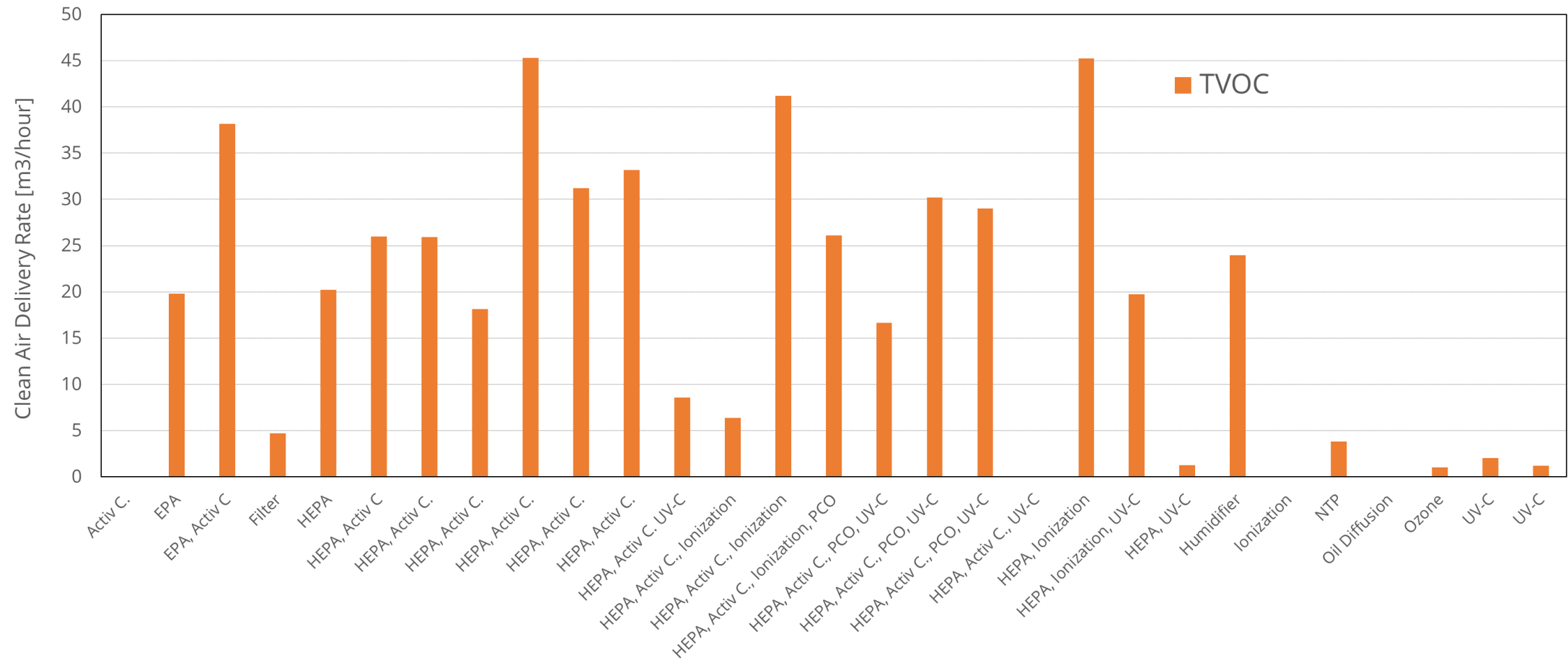


Project Results - 2





Project Results - 3



Airborne Viruses

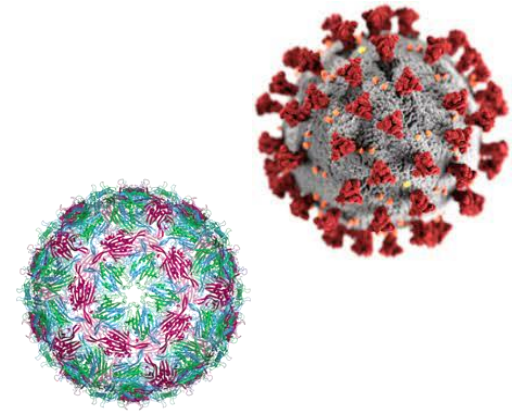
The Danish Technological Institute uses a virus surrogate to document efficacy against viruses in the air

MS2 bacteriophage is used as a surrogate for viruses in the air, due to its robustness -> Can survive aerosolization and sample collection

The US authorities (EPA and CDC) recognize "virus hierarchy" for disinfection claims

⊗ No unequivocal scientific relationship between MS2 and SARS-CoV-2

The ability to remove viruses from the air does not necessarily have an effect on the spread of infection

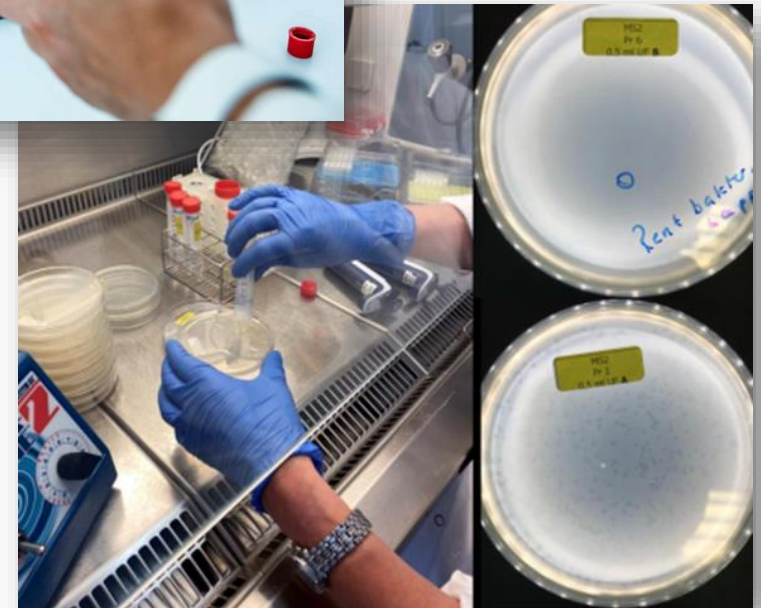


Small, non-enveloped virus

Large, non-enveloped virus

Enveloped virus





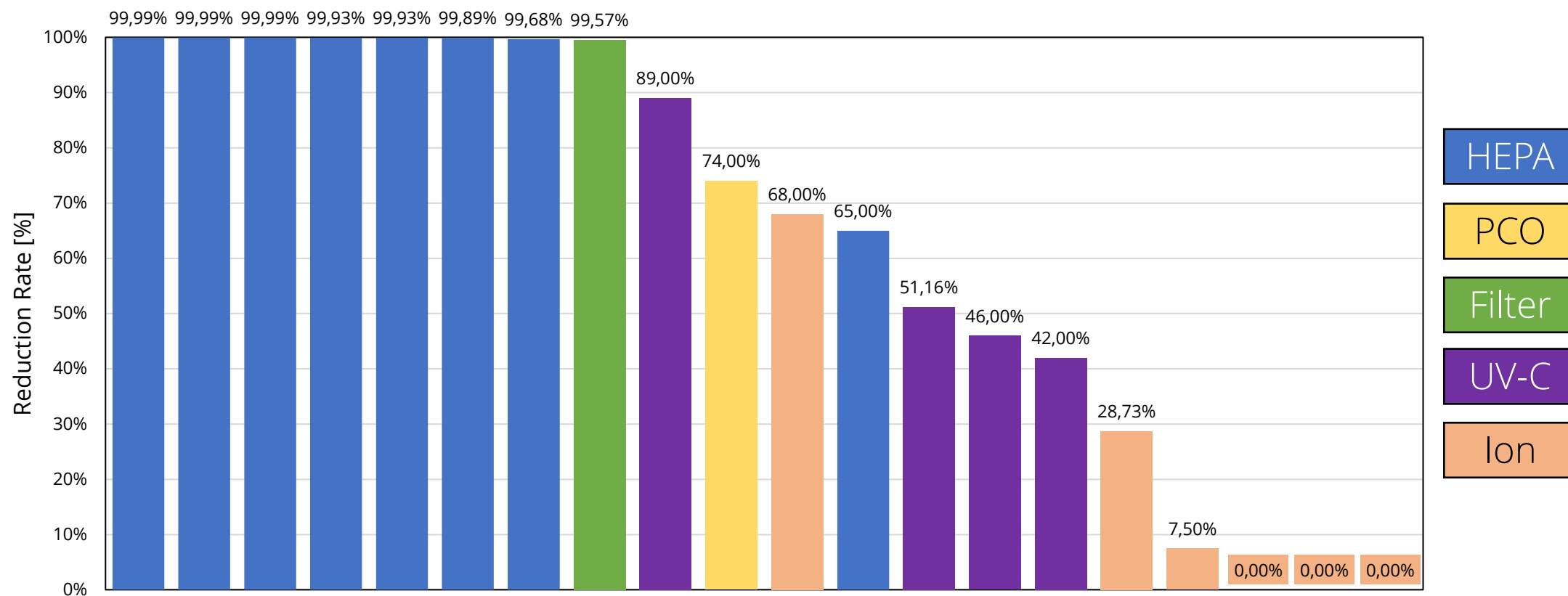


Project Results - 4

$$\text{Reduction Rate} = 1 - \frac{C_{\text{air purifier}}^*}{C_{\text{reference}}^*}$$

C^* = normalized concentration to time t ,
according to ISO 16000 – 36 : 2018

Reduction of airborne virus (30 min, 20 m³)



Take home messages

- Mobile Air Purifiers equipped with HEPA filter are generally efficient in removing PM2.5, ultrafine particles and viruses
- A low CADR towards particles was demonstrated for other clean air technologies (UV-C, Ionization, PCO)
- Products equipped activated carbon filters generally demonstrates higher TVOC CADR than products without
 - However, activated carbon filters does guarantee TVOC removal
- The market for mobile air purifiers is opaque
- Product claims are inaccurate or misleading
- Different clean air technologies solve different indoor climate problems
- Mobile air purifiers can be a supplement to ordinary ventilation and “the open window” (see next presentation by Kaare Press)

