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Prof. Dr. Philip Leistner

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Studies to measure the efficiency of the ionair air quality ionization system against viruses

Conducted on behalf of:
ionair AG
Mr. Beda Weibel
Staldenhof 3A
6014 Luzern
Switzerland

This report consists of:
14 pages text
11 figures
2 tables

Valley, December 14, 2020

Andrea Burdack-Freitag
Digital unterschrieben von Andrea Burdack-Freitag
Datum: 2020.12.14 19:41:41 +01'00'

Deputy Head:
Dr.-rer. nat. Andrea Burdack-Freitag

Sabine Johann
Digital unterschrieben von Sabine Johann
Datum: 2020.12.14 16:59:20 +01'00'

Group Manager:
M.Sc. Sabine Johann

Fraunhofer-Institute for building physics IBP
Nobelstraße 12 | 70569 Stuttgart
Phone +49 711 970-00
Fax +49 711 970-3395
www.ibp.fraunhofer.de

Branch Holzkirchen
Fraunhoferstr. 10 | 83626 Valley
Phone +49 8024 643-0
Fax +49 8024 643-366

Table of content

1 Test description

The investigation aimed to test the reduction and inactivation of airborne surrogate viruses (enveloped Phi6 bacteriophage with a structure, particle size, and environmental stability comparable to SARS-CoV-2 [1], [2], [3], [4], [5]) by the ionization system for air purification (system specifications, according to the customer's specifications, see Table 1). The measurements carried out referred exclusively to the aerosolization of surrogate viruses in the air. The natural half-life of the viruses must be taken into account when calculating the efficiency of the ionization system.
The structure was based on DIN ISO 16000-36 [6] to investigate airborne bacteria, realistically adapted to the specific requirements of viruses. The viruses were analogous to the indoor air DIN-ISO 16000-16 [7] collected. The filters were processed based on DIN ISO 16000-17 [8]. The number of active viruses ("virulence") was determined in the laboratory using the plaque assay method ([9], [10]).

Table 1: System specification

Name of system	ICE-A2000 (power controller) with LQ1, LQ2, flow, humidity, and ozone sensor Ionization module with four tubes (Development stage, see Fig. 1)
Manufacturer	ionair AG
Working principle	bipolar Ionization and dielectrical barrier discharge; Module for installation in a flow channel (ID 25 cm)
IBP internal test number	E3378-2
Day of testing	October 21, 2020

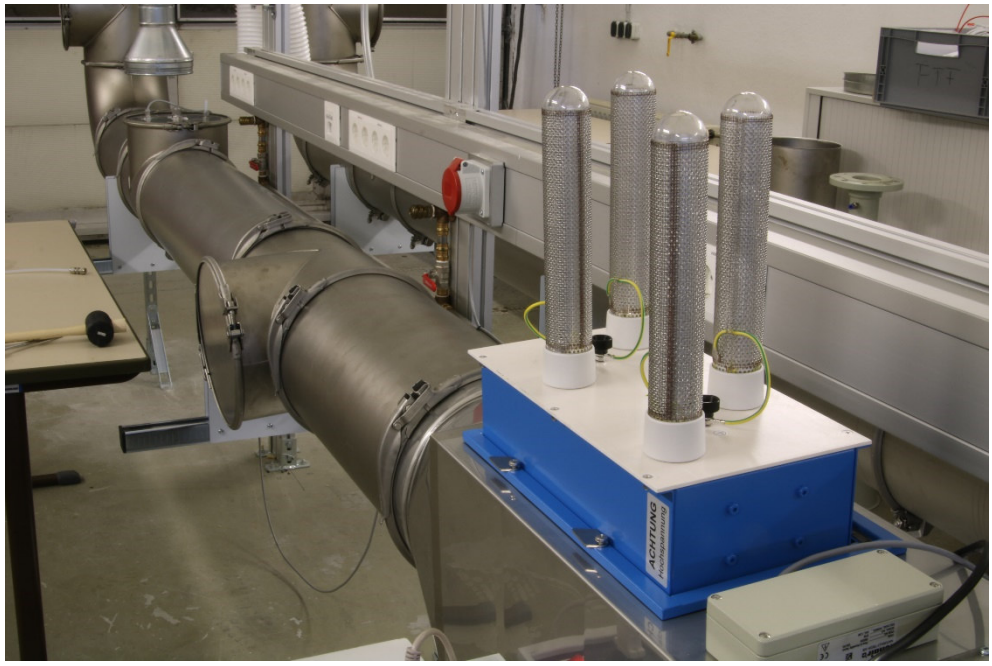

Figure 1: ionair ionization module.

2 Method

The tests took place in a temperature, humidity, and volume flow-controlled test stand (flow channel setting parameters: 23 ° C, 50% r.H., 400 m³ / h). The module was installed in the flow channel (see Figure 1). The preconditioned air flowing through was introduced into a connected test room (IBP-Indoor Air Test Center, IATC: 127 m³). The test setup is sketched in Figure 2.

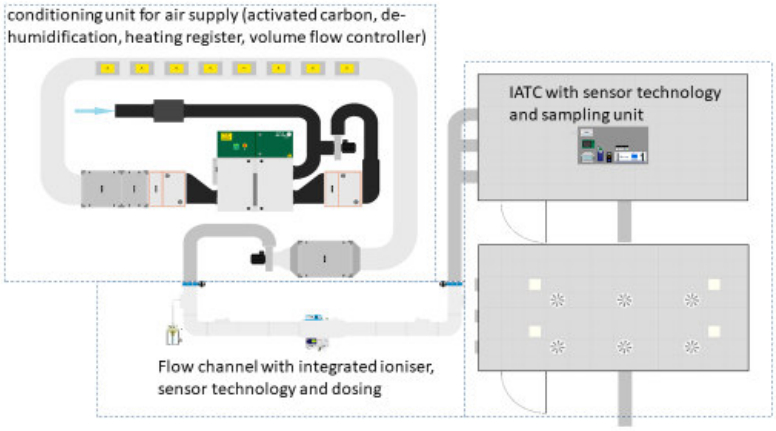

Figure 2: Test set-up.

The investigations were continuously monitored using appropriate sensors, sampling, and dosing units:

- In the flow channel, approx. 5 m upstream in front of the ionizer: dosing unit for virus dosing (AGK2000 / Pallas),

- In the flow channel: Module 2 (ionair, TVOC and flow sensor upstream, ozone sensor downstream)

- In the IATC (IATC structure, see Figure 3): ozone measuring system (O3-41M / ansyco), particle measuring device (Fidas Frog / Pallas, 0.2 - 20 µm), particle measuring device (P-Trak, 20 - 1000 nm), TVOC sensor (ppbrae / Honeywell, 1 - 10,000 ppb), sampling unit for VOCs (BiVOC2 / Holbach) and viruses (MBASS30 / Holbach),

- In the exhaust airflow (according to IATC): Module 1 (ionair, TVOC, ozone, particle sensor).

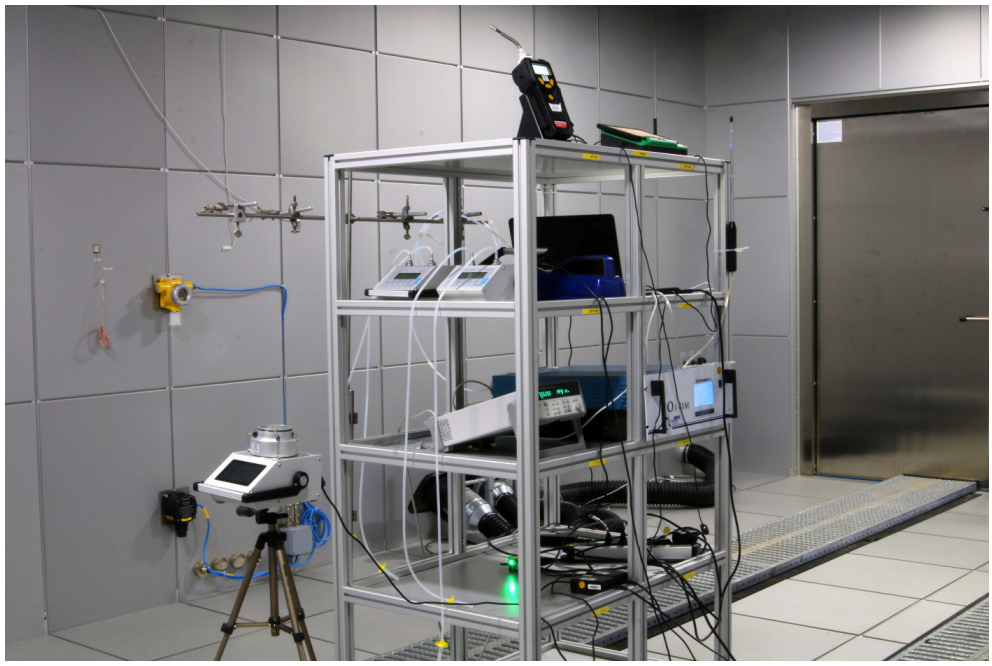

Figure 3: Setup of the sensor technology and air sampler in the IATC room.

The virus aerosols (pre-pressure 1.5 bar) were introduced into the flow channel at a distance of 5 m in front of the ionizer. The dosage took place before the ionizer was switched on to achieve a constant viral load in the channel and IATC area. When constant dosing was reached, the first samples were taken (after 1 hour) to determine the maximum virus concentration and the associated VOC value. The ionizer unit was then switched on (2.24 h after the start of the metering) and allowed to run in for 2 h before the second sampling took place. After the end of the second sampling, the ionizer was switched off after a total running time of approx. 3 hours. The exact sampling times for airborne germ collections and dosing times are shown in Figure 4. The sampling duration for the various analyses: VOC, aldehyde/ketones and airborne microorganism sampler lasted approx. 1 hour each.

In accordance with the specifications of the German Federal Environment Agency, the determination of by-products generated during operation is required when using ozone-producing air purification processes (UV-C, plasma technology; ozone direct injection) [11]. This sampling was performed on corresponding adsorptive tubes for the detection of VVOCs and VOCs, analyzed by means of gas chromatography-mass spectrometry [12], as well as on DNPH cartridges for the determination of selected ketones and aldehydes, analyzed by means of high-performance liquid chromatography-diode array methods [13].

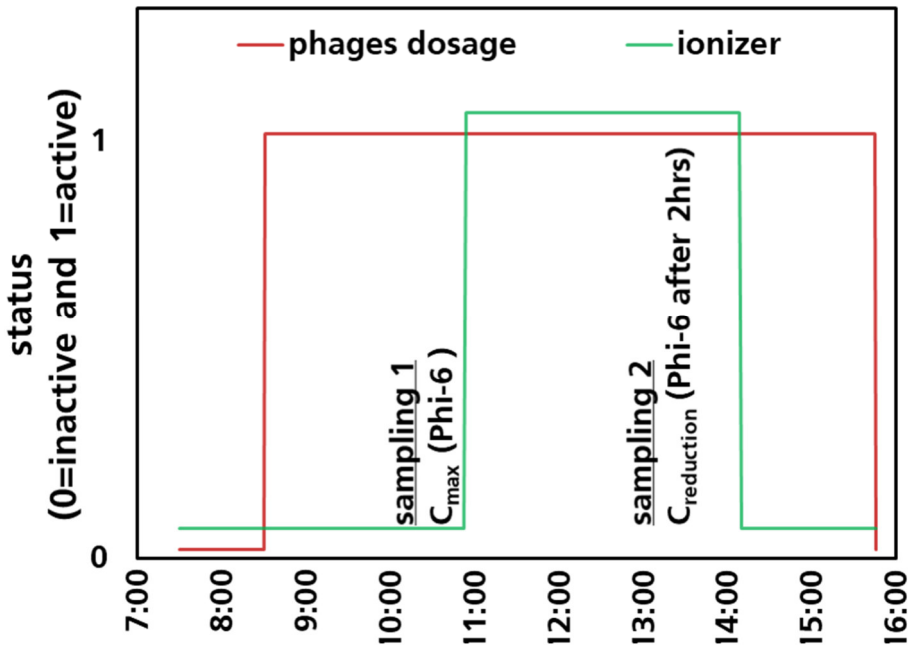

Figure 4: Diagram of the sampling and virus dosage referring to the time.

The effectiveness against viruses can be compared by the staircase-shaped test set-up consisting of the maximum viral load (sampling 1; P1) and the reduction effect of the ionair system (sampling 2; P2). During the entire running time, the particle distribution in the IATC from 20 nm to 20 µm in the room, the temperature and humidity, and the TVOC, air ions, and ozone content were measured. The air germ samples taken were subjected to microbial analysis in a plaque assay test in the laboratory (see Figure 5).

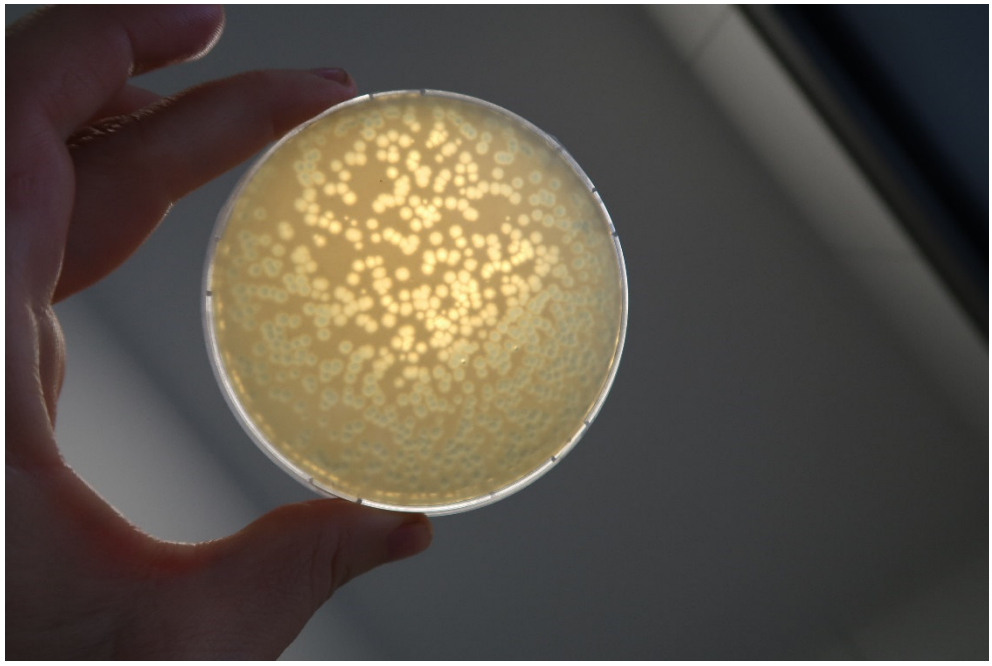

Figure 5: Microbial analysis

3 Results

The air purification system pulled the virus-contaminated air through the filter channel. The action of the ionization module inactivated viruses inside the system, and the ozone formed.

The following Figure 6 to Figure 10 show the graph over the day of the experiment.

- Figure 6: Distribution of the virus particles in the IATC.
- Figure 7: TVOC concentrations at the measuring points in and at the IATC.
- Figure 8: Room climatic conditions on the test setup.
- Figure 9: Volume flows and flow velocities at the IATC.
- Figure 10: Ozone and carbon dioxide concentrations at the IATC.

The distribution of the virus particles (Figure 6) showed that the aerosolization of the Phi6 phages was constant over the dosing period. The two curves reflect the measuring ranges of the particle measuring systems (p-Trak / TSI and Fidas Frog / Pallas). The p-Trak covers the nanoscale range from 20 to 1000 nm and therefore mainly covers the range of individual viruses (virus size (approx. 100 nm) in the air). The Fidas Frog covers a more extensive scale from 0.2 to 20 µm and thus detects aerosol-bound viruses (approx. 1 to 3 µm).

The TVOC values measured at the measuring points (Figure 7) show the interplay between the TVOC concentrations measured in the IATC and the control behavior of the ionair system, which readjusts moderately at different times. The indoor climate conditions in the IATC (Figure 8) and the set volume flows (Figure 9) each showed a constant measurement level between the sensor technology and the logged ionair measured values. The ozone concentration (Figure 10) in the IATC room rose to a maximum value of 45 ppb (equal to 90 µg/m³).

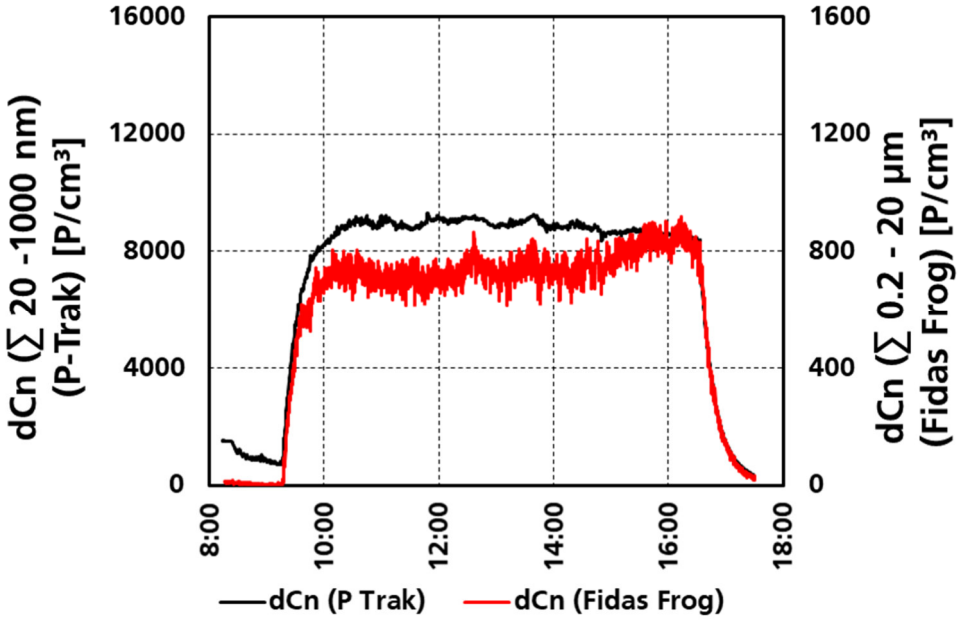

Figure 6: Distribution of the virus particles in the IATC referring to the time.

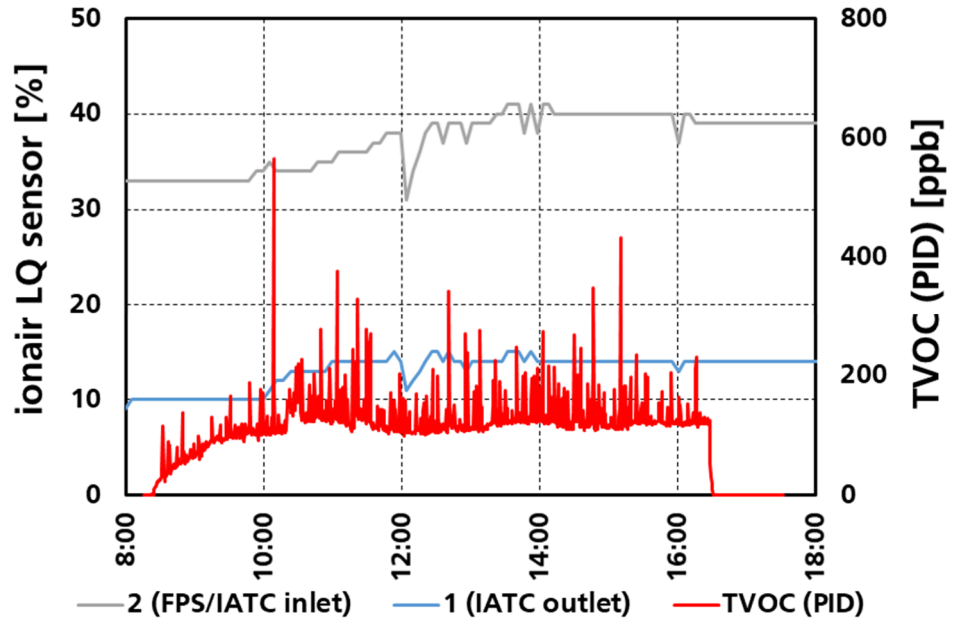

Figure 7: TVOC concentrations at the measuring points in and at the IATC referring to the time.

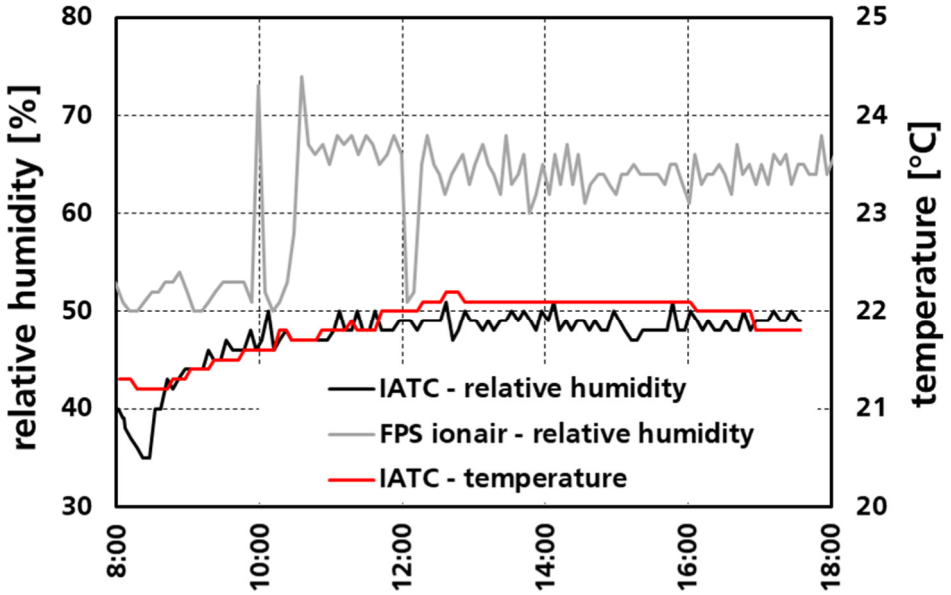

Figure 8: Room climatic conditions on the test setup referring to the time.

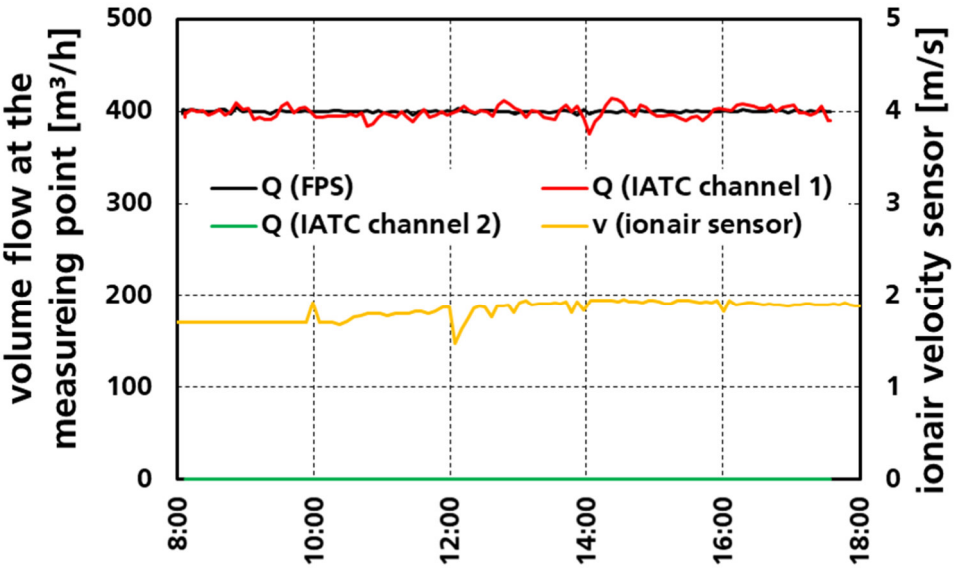

Figure 9: Volume flows and flow velocity at the IATC referring to the time.

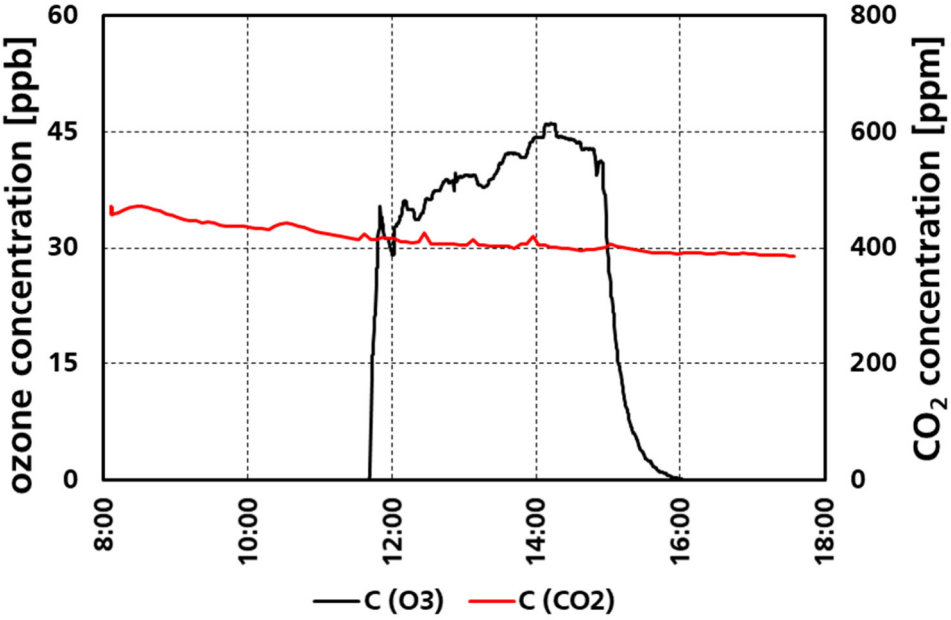

Figure 10: Ozone and carbon dioxide concentrations at the IATC referring to the time.

The laboratory analyses of substances formed by bipolar ionization and dielectrically hindered discharge (due to formed ozone) showed that few by-products could be detected. The by-products obtained were compared with the guide value recommendations of the AIR [14]. The guideline value I (RW I) describes the concentration of a substance in indoor air at which, according to current knowledge, no adverse health effects are to be expected when considering individual substances, even if a person is exposed to this substance for a lifetime. This RW I was complied with for all by-products formed.

The number of viruses in the air was kept constant during the system's operating times (see Figure 6). The effectiveness of the ionizer is primarily based on inactivating the viruses. The virus activity measured in the laboratory is shown in Table 2.

Because the P1 was above the limit of quantification of> 10,000 pfu/plate, the maximum concentration of 3.3 x 10 ^ 7 [pfu/m³] was assumed for the calculation of the reduction. To calculate the reduction, the loss of activity in the suspension as a function of time (known from our own measurements and determined by the exponential function; see Figure 11 and Figure 12) was used.

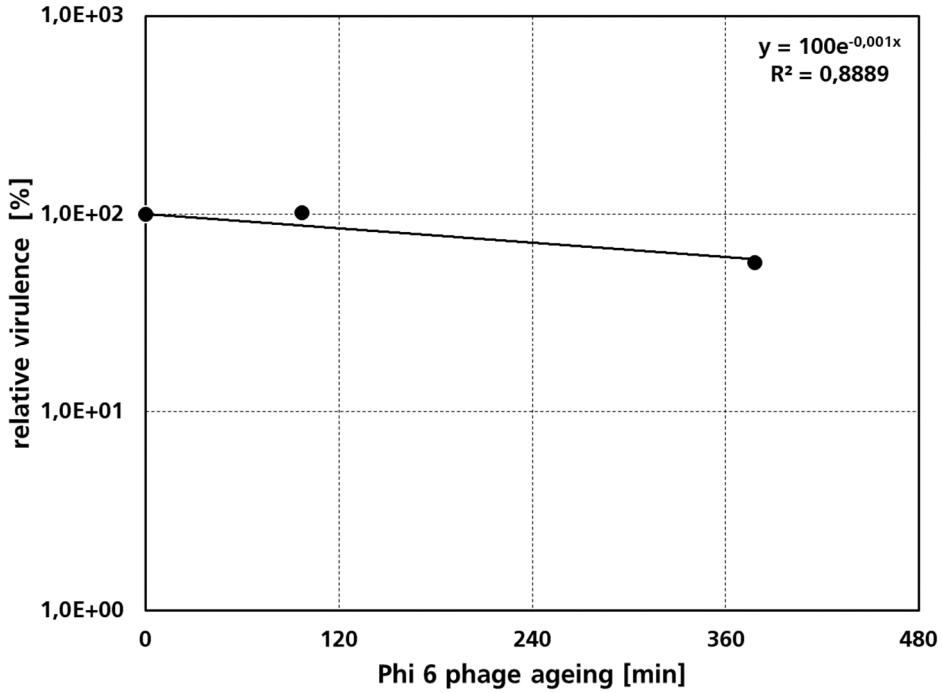

Figure 11: Relative recovery of active or virulent phages in the phage suspension used for exponential metering equation (intersects y at 100%; a = 100)

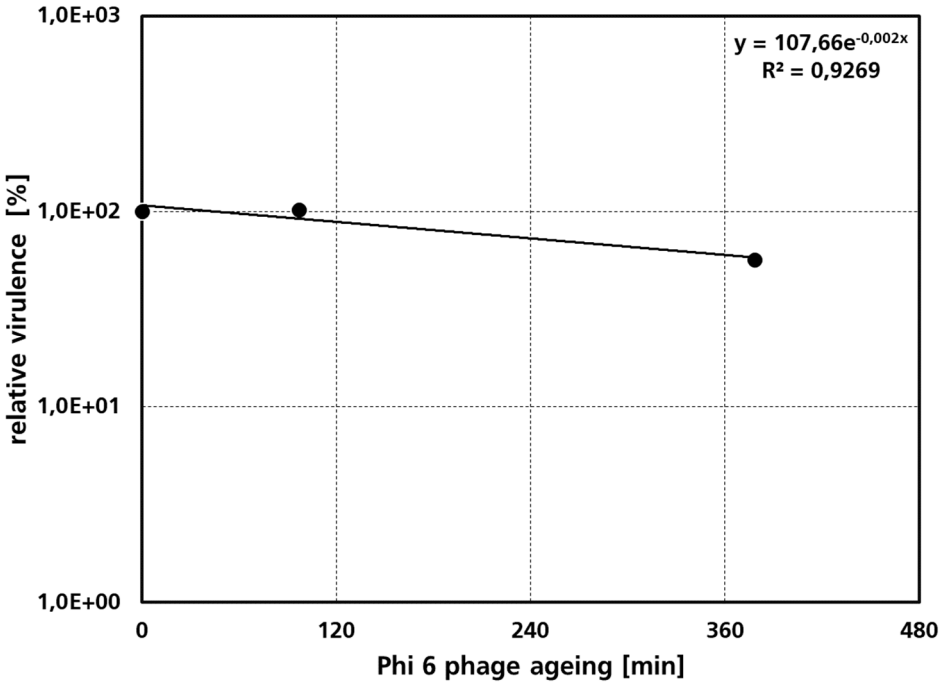

Figure 12: Relative recovery of active or virulent phages in the phage suspension used for exponential metering equation (intersects y at 107.6%; a = 107))

Table 2: Measurement of virus activity taking into account the P3

Time of sampling	Active units (plaque-forming units) [pfu/m³]	Measured reduction in viruses (pure Measurement data)	Calculated reduction rate R a=100 */**	Calculated reduction rate R a=107 */**
P1 (before switching on the ionizer)	3,3 x 10^7 ***	-	-	-
P2 (during ionizer operation)	111.444 (± 7 %) (1,1 x 10^5)	0,9967 */****	0,9959 */****	0,9949 */****

* Reduction rate R = 1-Ct / Ci (Ci without commissioning the air cleaner and Ct with the air cleaner running).

** taking into account the reduction in virus activity in suspension due to the exponential function with information on a

*** result above detection limit; Assumption: the agar plate was clear; this corresponds to a density of> 10,000 pfu/plate and therefore a concentration of 3.3 x 10 ^ 7 pfu/m³

**** P1 was used as Ci.

4 Conclusion

The ionizer was built into the Fraunhofer IATC's air supply duct. Surrogate viruses (enveloped Phi6 bacteriophage with a structure, particle size, and environmental stability comparable to SARS-CoV-2) were continuously added, and their concentration was microbiologically analyzed before, during, and after switching on the ionizer. The supply air ionization system was able to reduce the virus concentration in the range of 99.49% */**** and 99.59% */**** after only 2.5 hours of system operation and a continuous virus load, while at the same time adhering to all health-relevant indoor air quality parameters.

It could be verified that no by-products (VOCs and aldehydes and ketones) exceeding RW I were formed by the air purification device.
During the measurement, a maximum ozone concentration of 90 µg/m³ was measured in the air. The Federal Immission Control Act specifies up to 120 µg/m³ as a safe upper limit (maximum target value). [15]. This target value was observed.

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