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Efficiency of OXYTEC compact indoor air purifier (Freshair) on reducing and inactivating airborne viruses

Conducted on behalf of
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The report consists of:
9 pages of text
3 figures
2 tables

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Content

1 Subject of the study

The aim of the investigation was to test the reduction and inactivation of airborne surrogate viruses (enveloped Phi6 bacteriophage with comparable structure, particle size and environmental stability to SARS-CoV-2 [1], [2], [3], [4], [5]) by the air purifier (device specifications see Table 1).

Table 1: Device specifications

Device name	Freshair
Manufacturer	OXYTEC air & water purification system
Device installation	October 6, 2020
Operation principle	UV-C/Ozone circulating air technology (1 x 8 Watt)
Device dimensions	L 380 cm x Ø 130 cm
Room size	up to 50 m³
IBP internal check number	E3413
Measurement period	Week 45

The investigations were exclusively related to airborne aerosols. The natural half-life of the viruses (Phi6-bacteriophagous) must be included in the calculation to determine the device's efficiency.

The setup of the test was based on DIN ISO 16000-36 [6] to test airborne bacteria, realistically adapted to the specific requirements of viruses. The viruses were collected from indoor air in accordance with DIN ISO 16000-16 [7], the filters were constructed in compliance with DIN ISO 16000-17 [8]. The number of active viruses ("virulence") was determined in the laboratory using the plaque-based assays method ([9], [10]).

Note: Viral activity testing on surfaces require a different method, as the stability of viruses in liquids ("smear infection") must be considered.

2 Method

The experiments took place in a temperature and humidity controlled room used for testing (room size: 45 m³) without additional air exchange.

The air purifier was positioned in the center of the room at a height of two meters (see Figure 1). The viruses were introduced into the room at a distance of 45 centimeters facing the unit. The dosing was initially carried out without turning on the device in order to achieve a high virus load in the room. Then the dosing was stopped and the air purifier was operated for a total running time of 24 hours. During the entire running time, the particle distribution in the room, the temperature and humidity as well as the ozone content were measured.

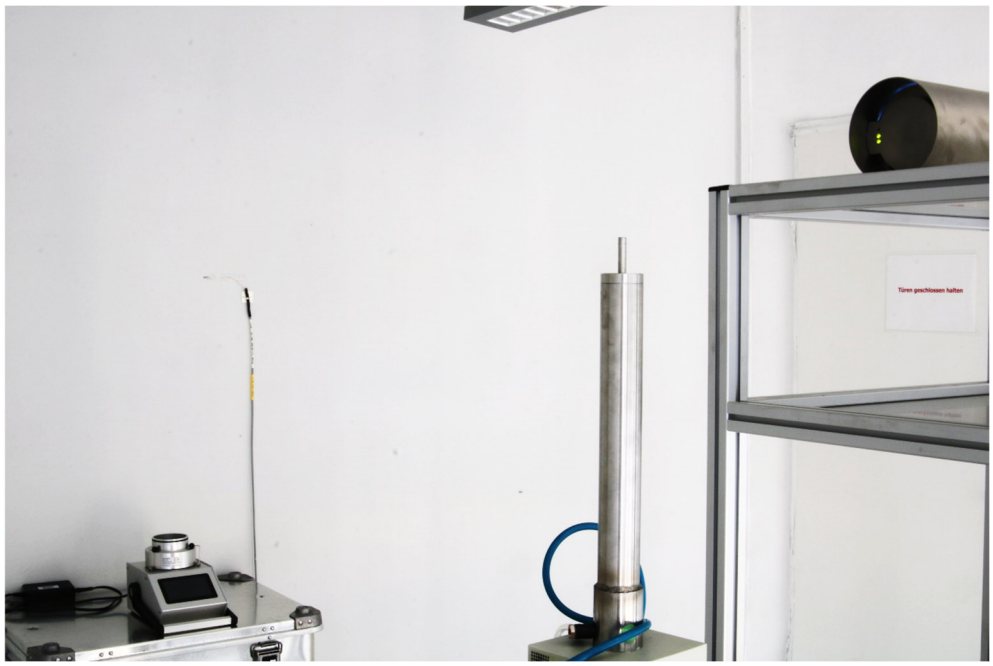

Figure 1: The (test) setup consisting of the air purifier (Freshair), a dosing unit and an air sampler in the testing room.

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 carried out on appropriate adsorption tubes for the detection of VVOCs and VOCs, analyzed by 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].

At certain times, the viruses were sampled by an air sampler (MBASS30 version 3 adapted for filter operation by the company Umweltanalytik Holbach GmbH, Wadern, Germany) and subsequently transferred to a plaque assay test for microbial analysis in the laboratory (see Figure 2).

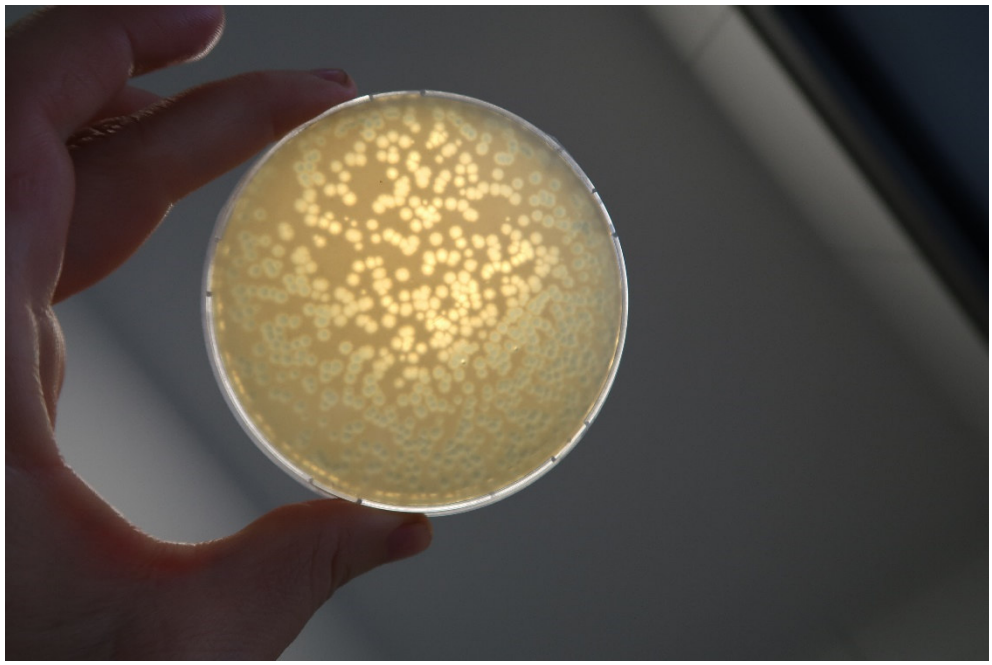

Figure 2: Microbial analysis.

3 Results

The contaminated air was pulled in by the air purifier and passed through the filter. Inside the device, viruses were inactivated when exposed to UV radiation and the ozone that was formed. The maximum concentration of ozone in the room itself remained low (max. 6 ppb; equal to 12 µg/m³). Figure 3 shows the distribution of viruses in the room over the measurement period and the sampling time were adjusted to the start of dosing:

- **P1:** 1 – 2 h, blank value before starting the dosing of the viruses
- **P2:** 2,33 – 3,33 h, dosing of viruses
- **P3:** 4 – 5 h, corresponds to 15 min to 75 min when the dosing of the viruses has been completed and the device is switched on.
- **P4:** 5 – 6 h, corresponds to 75 min to 135 min when the dosing of the viruses has been completed and the device is switched on.
- **P5:** 6 – 7 h, corresponds to 135 min to 195 min when the dosing of the viruses has been completed and the device is switched on

The two curves show the particle distribution recorded by the measuring instruments (p-Trak/TSI and Fidas Frog/Pallas). The p-Trak covers the nanoscale range from 20 to 1000 nm, therefore mainly covers the range of individual viruses (virus size (approx. 100 nm) in the air. The Fidas Frog covers a larger scale range from 0.2 to 20 µm and thus detects aerosol-bound viruses (approx. 1 to 3 µm).

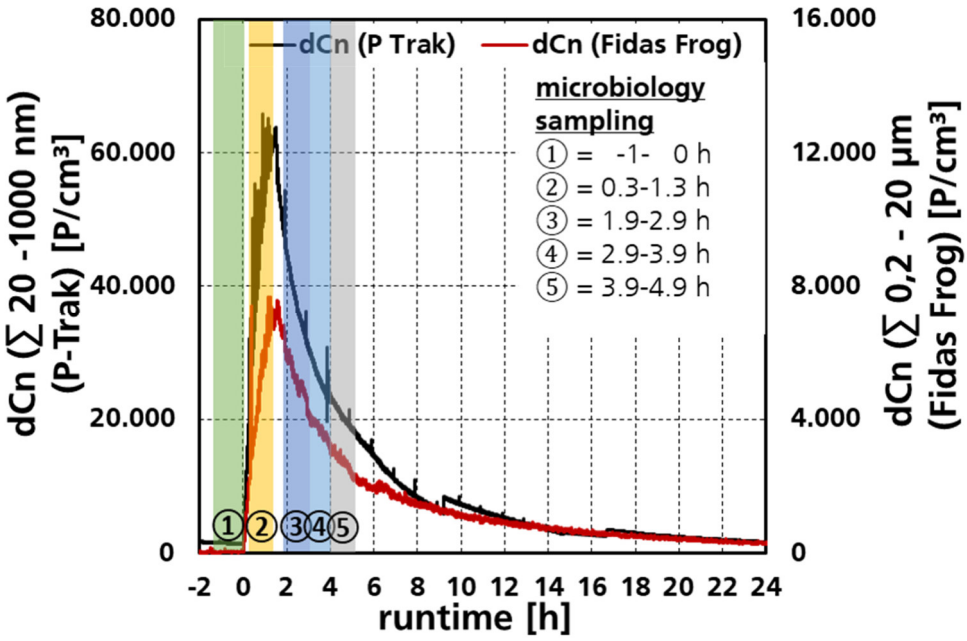

Figure 3: Distribution of viruses in the room and the sampling times.

The laboratory analysis for possible by-products due to formed ozone by UV-C technology did not develop corresponding substances. The by-product formation evaluation was aligned with the guideline value concept of the AIR board [14]. The guideline value RW I („Richtwert I“) describes that, according to the current state of knowledge, no adverse health effects are expected from single substances in the case of lifelong exposure. RW I was not exceeded for all by-products formed. No by-product was formed in critical concentration.

The number of airborne viruses decreased along the curve (temporal progression) due to sedimentation ("deposition"). Since the room air purifier is based on the principle of inactivation of viruses, the level of inactivation or the duration of inactivation was measured.

The sampling periods for airborne viruses are highlighted in the diagram. Their activity measured in the laboratory, i.e. the extent to which the viruses are potentially capable of replication, is calculated in Table 1. Included in the calculation are the sedimentation and the natural half-life of the airborne viruses which was determined during the tests [1-3]. The reference value for calculating the reduction was based on the loss of activity of viruses in suspension in relation to time (known from laboratory specific measurements) and the decay curve of the particle measuring device (P-Trak). Concerning microbiological samplings, each of which lasted one hour, all data of the particle measurement were averaged over this period.

Table 2: Measurement of viral activity

Date of sampling	Measured reduction of viral activity (measurement data) [%]	Calculated reduction rate R without sedimentation */**	Calculated reduction rate R with sedimentation */**
P1	- ***	-	-
P2	0	-	-
P3	57,94	0,5387	0,3535
P4	99,91 ****	0,9962 ****	0,9925 ****
P5	99,91 ****	0,9958 ****	0,9891 ****

* Reduction rate R = 1-Ct/Ci (Ci for the air purifier not in operation and Ct with the air purifier in operation).
** Taking into account the natural half-life of viruses in indoor air (according to literature [2]), sedimentation coefficient was calculated using the decay curve in Fig. 3.
*** P1 Blank value before the virus dosing, no evidence in the room.
**** below statistical detection limit of 12%. Reduction rate R greater than 0.88 or reduction rate greater than 88%.

4 Study summary on the efficiency of the OXYTEC compact indoor air purifier (Freshair) on reducing and inactivating airborne viruses

An office with a size of 45 m³ was used for testing and was exposed to surrogate viruses (enveloped Phi6 bacteriophage with comparable structure, particle size and environmental stability to SARS-CoV-2) for 1 hour. Afterwards the air purifier Freshair (from OXYTEC air & water purification system) was switched on**. Within less than 2 hours of operation, the concentration of viruses in the room was reduced by over 99 %.**

It could be verified that no by-products (VOCs and aldehydes and ketones) were formed by the air purification device.

A maximum ozone concentration of 12 µg/m³ in the air was measured. This is 10 % of the legally defined limit value. The German Federal Emission Protection Act sets a level up to 120 µg/m³ as a non-hazardous limit (maximum target value). [15]

5 Literature

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[7] DIN ISO 16000-16:2009-12, Indoor air pollution - Part 16: Detection and enumeration of molds - Sampling by filtration (ISO 16000-16:2008).

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[12] DIN ISO 16000-6:2012-11 Indoor air - Part 6: Determination of VOCs in indoor air and in test chambers, sampling on Tenax TA®, thermal desorption and gas chromatography with MS or MS-FID.

[13] DIN ISO 16000-3:2013-01 Indoor air contaminants - Part 3: Measurement of formaldehyde and other carbonyl compounds in indoor air and test chambers - Sampling with a pump.

[14] Recommended Guideline AIR; as of October 2020 https://www.umweltbundesamt.de/themen/gesundheit/kommissionen-arbeitsgruppen/ausschuss-fuer-innenraumrichtwerte-vormals-ad-hoc#hygienische-leitwerte-fur-die-innenraumluft

[15] 39. BImSchV. Thirty-ninth Ordinance on the Implementation of the Federal Immission Control Act (Ordinance on Air Quality Standards and Emission Ceilings. Annex 7 (to §9) Target values and long-term objectives for ozone.