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Report UN2-210311-T5599900-045A **Cleaning efficiency for different aerosol particles and ozone emissions of an air cleaner (OneLife X)**	
Customer: **OneLife GmbH** **Krefelder Straße 670** **41066 Mönchengladbach** **Germany**	IUTA, Managing Director Institut für Energie- und Umwelttechnik e.V. (IUTA) Bliersheimer Straße 60 47229 Duisburg Duisburg, 16 June 2021

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Cleaning efficiency for different aerosol particles and ozone emissions of an air cleaner (OneLife X)

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Contents

1. Introduction

OneLife GmbH contracted IUTA to determine the cleaning efficiency of an air cleaner according to GB/T 18801-2015 with cigarette smoke and in the particle size range of viruses and exhaled droplets. In addition, a one-hour measurement of ozone emission was to be performed in the style of UL 867-37. All tests were carried out in an approximately 30 m³ test chamber according to GB/T 18801-2015. To identify the cleaning efficiency of the air cleaner, the device was exposed to a defined initial concentration of particles in the standardized test chamber and the decay rate of the particles was measured while the air cleaner was running at the highest level. The clean air delivery rate (CADR) was then determined by comparing the exponential decay curves with and without the air cleaner operating.

Similarly, CADR was determined with particles of the size of viruses and potentially virus-laden droplets in a non-standardized test similar to GB/T 18801-2015. Here, the droplets were simulated with paraffin and the individual viruses by solid potassium chloride particles.

2. Tested air cleaner

OneLife GmbH supplied an air cleaner in the design of a tabletop device, hereinafter referred to as OneLife X (internal no. M 210526/123). The test sample did no show any visible damage and ran properly during a first functional test, which was carried out at IUTA together with one of the customer’s employees. A schematic sketch of the tested appliance is shown in Figure 1.

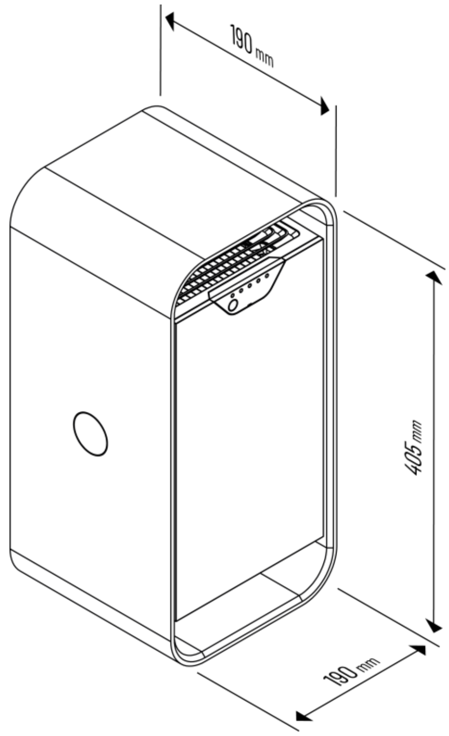


Figure 1: Schematic sketch of the tested OneLife X provided by the customer.

3. Measurements

3.1 Test chamber

All measurements were performed in the test chamber schematically shown in Figure 2 according to GB/T 18801-2015. The internal dimensions of the chamber are 3.45 m × 3.40 m × 2.50 m, corresponding to a volume of 29.3 m³. The walls of the test chamber were covered with an antistatic foil to minimize electrostatic particle losses. The test chamber has an active ventilation system to remove particles present prior to the start of measurements and an air conditioning system to set the required temperature. The relative humidity was adjusted with a portable humidifier.

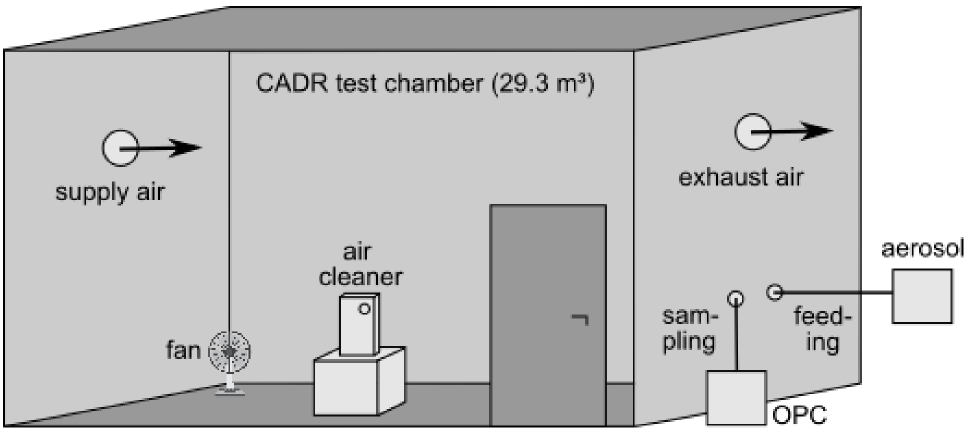


Figure 2: Schematic structure of the CADR test chamber according to GB/T 18801-2015.

Since the overall height of the air cleaner OneLife X was less than 70 cm and the device was designed as a tabletop appliance, the unit was placed on a pedestal of 70 cm height in the center of the test chamber as required by the standard. As a result, the effective volume of the chamber is reduced to 29.1 m³.

During the actual CADR measurements, the ventilation, air conditioning and humidifier were turned off. During the test, a fan ran on the floor of the chamber as required by air cleaner testing standard to homogenize the test aerosol. Sampling was performed by extracting a small flow rate from the chamber, which was fed to the respective measurement devices. The sampling point was located 0.50 m from the wall and 1.20 m above the floor, following the guidelines of GB/T 18801-2015.

With a volume in the range of 26.9 to 31.1 m³, a minimum wall length of 2.40 m and a maximum height of 3.00 m, the test chamber meets the requirements of UL 867-37 for determining ozone emissions. Likewise, the lining with polyethylene foil meets the requirements of this standard and the test chamber floor, which is made of stainless steel, meets the conditions for a non-porous material.

3.2 Ambient conditions

During the measurement the temperature was (25 ± 2) °C and the relative humidity were (50 ± 10) % in the test chamber.

3.3 Test and measurement equipment

The following test and measurement equipment was used:

- Cigarette smoke was generated as the test aerosol by burning 3R4F reference cigarettes in a 1 m³ acrylic cube. The smoke was introduced into the test chamber using a Venturi nozzle.
- KCl particles were generated with an atomizer (Palas AGK 2000) from an aqueous KCl solution (100 g KCl per liter of demineralized water) at a working pressure of 2 bar and dried by dilution with compressed air. The particles were then passed through an antistatic hose into the test chamber. No specific neutralization of the particles was carried out, since it is to be expected that the particles will reach a bipolar equilibrium state during the residence time in the test chamber by interaction with the ions naturally present.
- Paraffin droplets were dispersed with an atomizer (Palas AGF 2.0) at a working pressure of 2 bar and fed into the test chamber via an antistatic hose. As stated before, also here no specific neutralization of the particles was applied.
- The size range from 0.3 to 10 µm was measured with an optical aerosol spectrometer (OPC, Palas welas digital 3000 with aerosol sensor welas 2070) with a time resolution of 30 s.
- Monodisperse particles with a size of 0.12 µm were classified from the polydisperse test aerosol using a differential mobility analyzer (DMA, TSI 3080/3081) and then counted with a butanol-based condensation particle counter (CPC, Palas UF-CPC 100). The CPC was operated at a flow rate of 0.9 l/min and the veil air of the DMA was set to 9 l/min to achieve sharp classification. Data were recorded with a time resolution of 1 s and averaged over 30 s each for analysis.
- The size range from 0.5 to 20 µm was measured with an aerodynamic particle size spectrometer (APS, TSI 3321).
- Ozone emissions were measured using an online ozone monitor (2B Technologies 106-L). Data were recorded with a time resolution of 10 s and averaged over 1 min each for evaluation to minimize natural noise.

3.4 Measurement method for determination of the CADR with cigarette smoke

The cleaning efficiency of the air cleaner for cigarette smoke particles was measured in the size range from 0.3 to 10 µm according to GB/T 18801-2015. For this purpose, the smoke was introduced into the test chamber until the initial concentration of at least 2,000 particles per cm^3 (in the size range of 0.3 to 10 µm) was reached. The measurement of particle concentration ran over a total time of 70 min, with the air cleaner being switched on to the highest level 10 min after the initial concentration was reached. For the calculation of the CADR, the decay of the particle concentration during the first 20 min with the air cleaner running was evaluated according to the standard. As a reference, a natural decay curve was measured to separate the natural deposition from the effect of the air cleaner.

3.5 Measurement method for determination of the CADR with KCl and paraffin

The cleaning efficiency of the air cleaner in the particle size range of viruses and exhaled droplets was measured in a non-standardized test similar to GB/T 18801-2015. For this purpose, the KCl particles were first dispersed into the test chamber for 2 min. After a waiting period of 5 min to achieve homogeneous mixing, the natural decay curve was measured without operating the air cleaner for 30 min as a reference. Subsequently, the air cleaner was switched on and operated at the highest level for 30 min to record the decay curve with air cleaner. After completing the measurements with KCl, the room was cleaned and the same procedure was repeated with paraffin.

3.6 Measurement method for determination of the ozone emissions

The test chamber was first completely cleaned to minimize the background concentration of particulates and volatile organic compounds. Ozone sampling was performed 50 mm in front of the air cleaner outlet as required by UL 867-37. The sampling was oriented directly into the air stream. First, the natural background was recorded for 60 min without operating the air cleaner. The air cleaner was then switched on at the highest level and operated for a further 60 min.

4. Calculation of the Clean Air Delivery Rate (CADR)

The Clean Air Delivery Rate (CADR) described in GB/T 18801-2015 was used as a measure of purification performance. It describes the flow rate of cleaned air provided by the air purifier. Under ideal conditions, the CADR is equal to the product of the air cleaner's filtration efficiency and its flow rate.

The change in particle concentration C_t over time t follows the exponential function

$$C_t = C_0 e^{-kt}$$

with the initial particle concentration C_0. By linear regression of the natural logarithm of the particle concentration $\ln C_{t_i}$, the decay rate k can be determined as

$$k = -\frac{\left(\sum_{i=1}^{n} t_i \ln C_{t_i}\right) - \frac{1}{n}\left(\sum_{i=1}^{n} t_i\right)\left(\sum_{i=1}^{n} \ln C_{t_i}\right)}{\left(\sum_{i=1}^{n} t_i^2\right) - \frac{1}{n}\left(\sum_{i=1}^{n} t_i\right)^2}$$

where the time t_i corresponds to the ith data point and n to the number of data points. The natural decay rate k_{nat} and the total decay rate k_{tot} can be obtained from decay curves with and without operation of the air cleaner.

The correlation coefficient R^2 is a measure of the degree of linear relationship between the independent variable x_i and the dependent variable y_i. It is calculated according to

$$R^2 = \frac{\left[\sum_{i=1}^{n}\left(x_i - \frac{1}{n}\sum_{i=1}^{n} x_i\right)\left(y_i - \frac{1}{n}\sum_{i=1}^{n} y_i\right)\right]^2}{\sum_{i=1}^{n}\left(x_i - \frac{1}{n}\sum_{i=1}^{n} x_i\right)^2 \left(y_i - \frac{1}{n}\sum_{i=1}^{n} y_i\right)^2}$$

In this case, we have $x_i = t_i$ and und $y_i = \ln C_{t_i}$. Following GB/T 18801-2015, a correlation coefficient > 0.98 was assumed as the minimum criterion for a usable measurement. From the natural and total decay rate, the CADR is calculated to

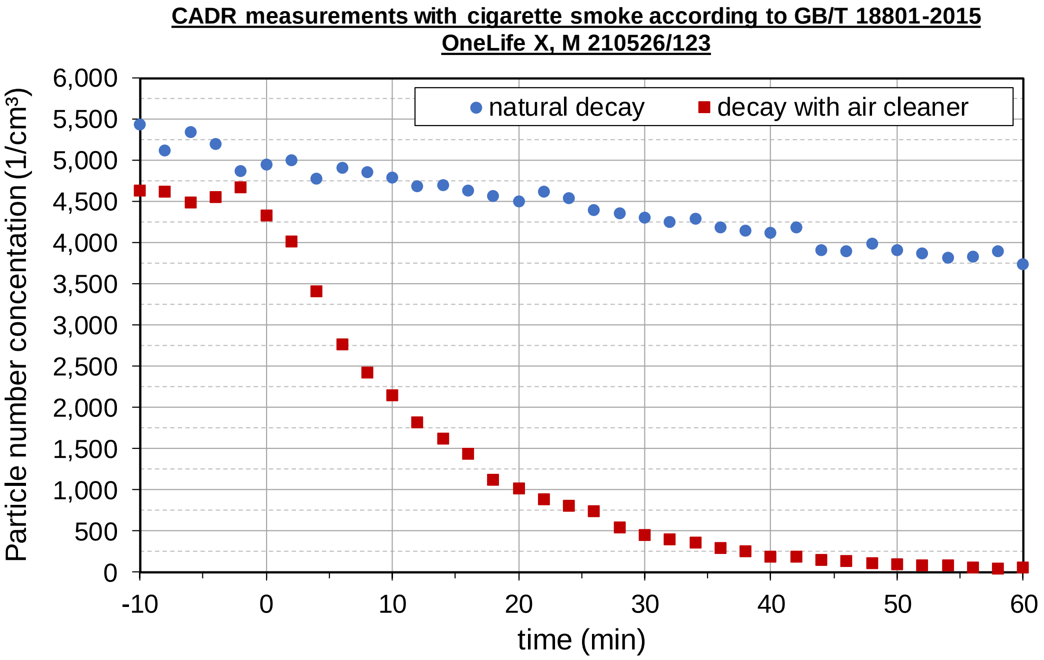
$$\text{CADR} = (k_{tot} - k_{nat}) \cdot V$$

with the effective volume V of the test chamber.

5. Results

5.1 Measurement of cigarette smoke

Figure 3 shows the decay curves for the integrated size range from 0,3 – 10 µm obtained with cigarette smoke without and with the air cleaner operating. The whole decay curves are shown in linear representation on the top and in logarithmic representation over the 20 min used for evaluation on the bottom.



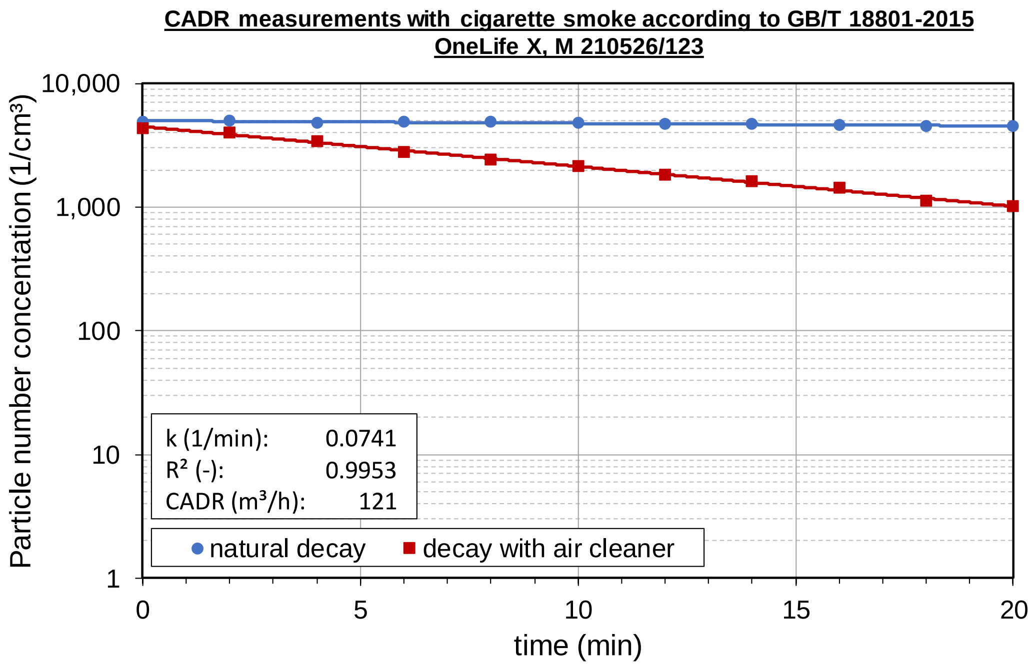


Figure 3: Natural decay curve and decay curve with air cleaner in normal (top) and logarithmic representation (bottom). The solid lines show the exponential fits to determine the decay rates.

Table 2 lists the CADR value obtained by fitting. In addition, the natural and total decay rates as well as the correlation coefficient for the measurement with the air cleaner switched on are given.

Table 1: Decay rates, correlation coefficients and CADR according to GB/T 18801-2015.

k_{nat} (min^{-1})	k_{tot} (min^{-1})	R^2_{tot}	CADR (m^3/h)
0.0048	0.0741	0.9953	121

5.2 Measurement of particles in the size range of viruses and exhaled droplets

Figure 4 shows a summary of the decay curves for the three size ranges 0.12 µm (DMA+CPC), 0.2 - 0.5 µm (OPC) and 0.5 - 1 µm (APS). Contrary to the original planning, the APS data were evaluated for KCl instead of paraffin, as this allowed a further size range to be covered. In the overlapping size range from 0.5 to 1 µm, however, there was good agreement with the measured values for paraffin. The decay curves are shown in linear representation on the left-hand side and in logarithmic representation on the right-hand side. The room air purifier was switched on after 30 min in each case. Black lines show the exponential fits used to determine the decay rates.

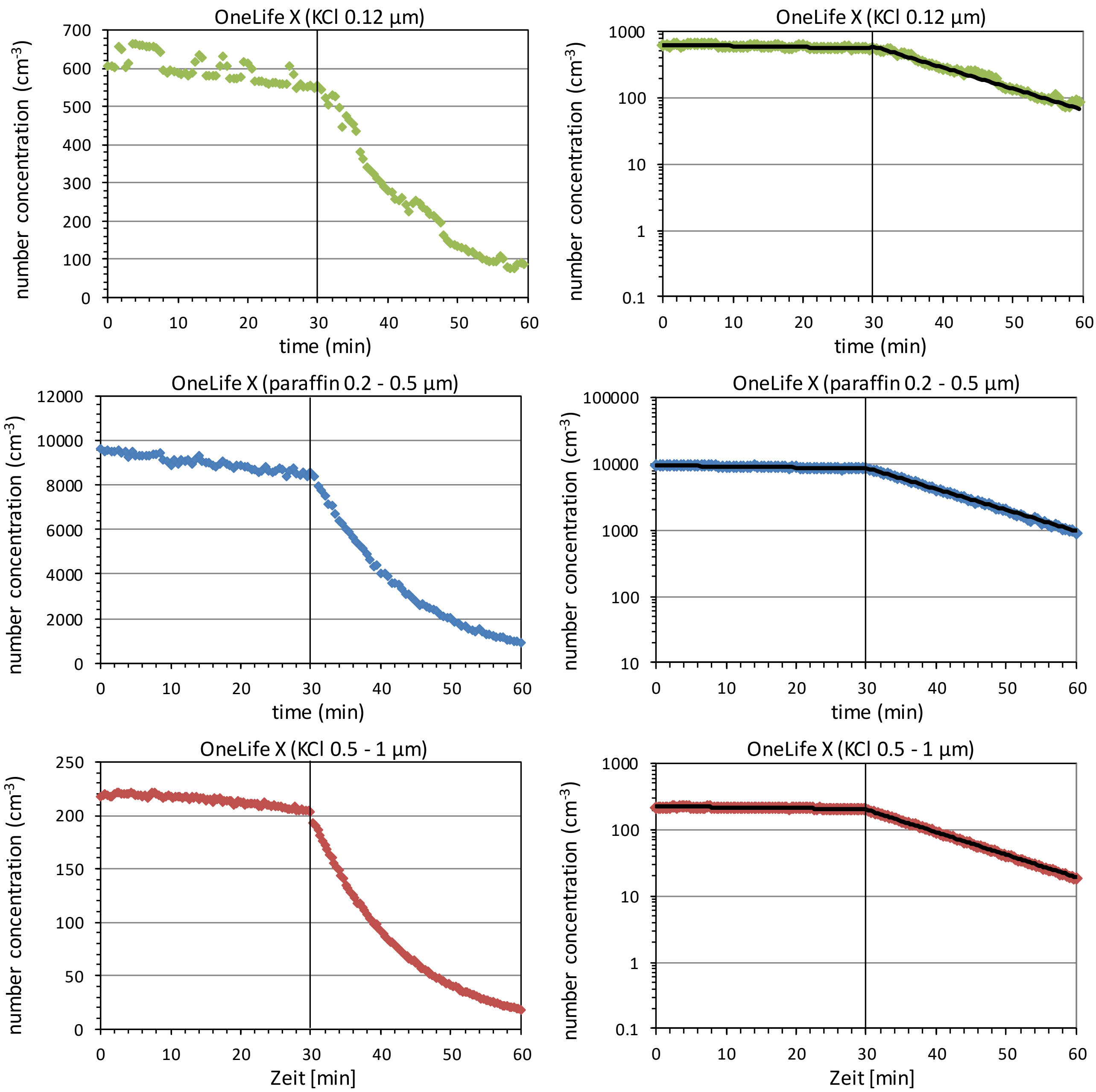


Figure 4: Decay curves for three different particle size ranges (30 min without and 30 min with air cleaner on) in linear and logarithmic order. The black lines are exponential fits to the data points.

Table 2 summarizes the integrated CADR values for the three size ranges. In addition, the respective test aerosol, the measurement technique used, the natural and total decay rates as well as the correlation coefficient for the measurement with the air cleaner switched on are given.

Table 2: Size-integrated CADR for particles in the size range of viruses and exhaled droplets.

Test aerosol	Particle size (µm)	Instrumen-tation	k_{nat} (min^{-1})	k_{tot} (min^{-1})	R^2_{tot}	CADR (m^3/h)
KCl	0.12	DMA + CPC	0.0044	0.0735	0.9479	121
Paraffin	0.2 – 0.5	OPC	0.0036	0.0730	0.9952	121
KCl	0.5 – 1.0	APS	0.0033	0.0784	0.9989	131

The size-dependent CADR determined from the decay curves of the individual size classes (summarized to 16 classes each per decade) over the entire size range under consideration from about approximately 0.12 to 2 µm is shown in Figure 5.

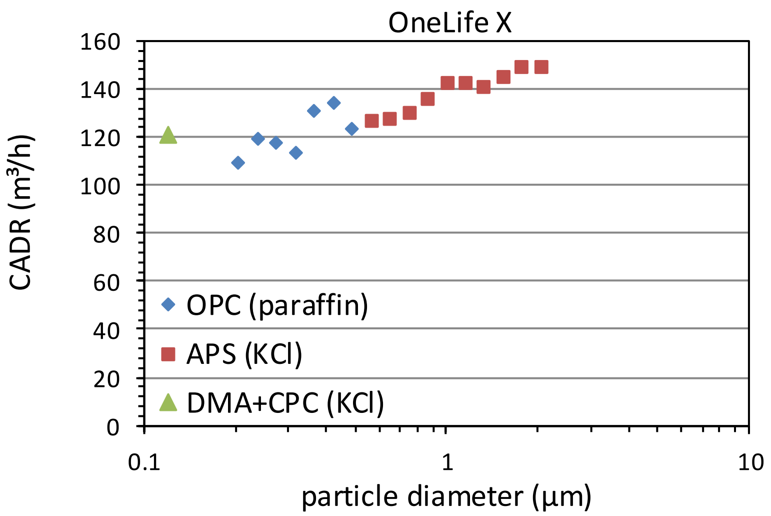


Figure 5: Size resolved CADR of the air cleaner.

5.3 Measurement of ozone emission

Figure 6 shows the course of the measured ozone concentrations with and without the air cleaner operating. The natural ozone background in the test chamber was in average (2.6 ± 1.4) ppb, which is within the typical expectations. After switching on the air cleaner, the ozone value increased slightly to (4.2 ±1.0) ppb on average and remained relatively constant. After subtraction of the natural background, this resulted in a maximum measured ozone concentration caused by the air cleaner of (1.6 ± 1.8) ppb. The limit value of 50 ppb specified by UL 867-37 was therefore significantly undercut.

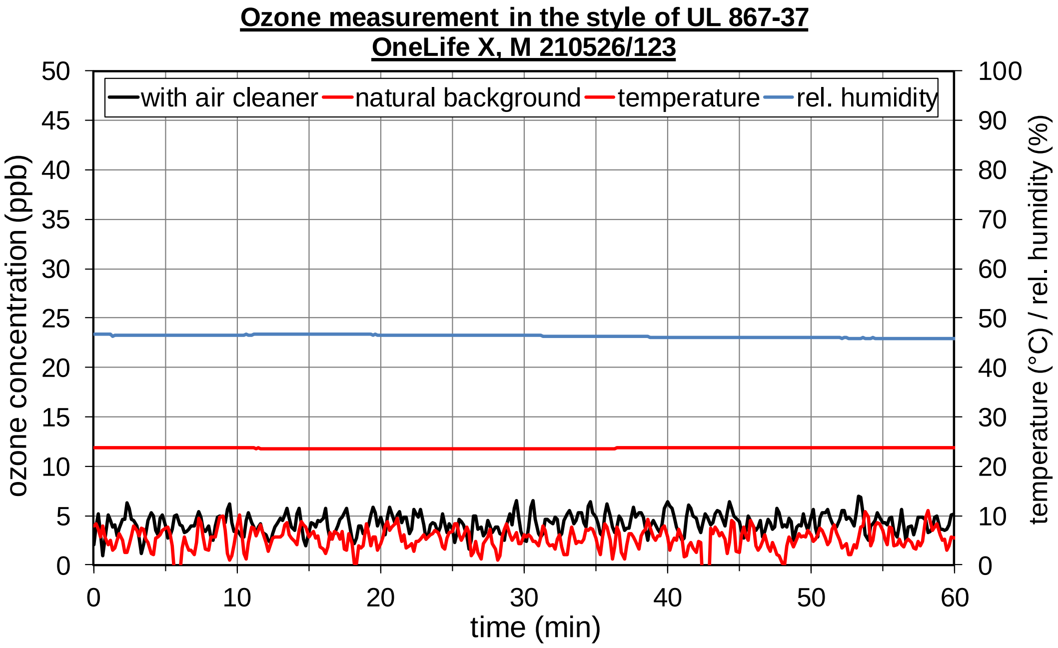


Figure 6: Measurement of natural background ozone and with air cleaner switched on over 60 min with temperature and relative humidity.

6. Summary

The test results show that the air cleaner OneLife X can provide per hour in average about 121 m³ air free of particles in the size range of viruses and small potentially virus-laden exhaled droplets. The filtration efficiency for larger exhaled droplets is even slightly larger, resulting in a CADR of 131 m³/h. The amount of emitted ozone lies with (1.6 ± 1.8) ppb substantially below the limit of 50 ppb specified by UL 867-37.

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