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Test report HoE-025/2021_EN

# Investigation of the emission behavior of an air cleaning device based on a plasma technology with respect to the formation of VOCs (volatile organic compounds), nitrogen oxides, and ozone

Conducted on behalf of

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Valley, August 16, 2021

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DAkkS accredited test laboratory
compliant with DIN EN ISO/IEC 17025:2018

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## 1 Examined air cleaner

| | |
|---|---|
| **Manufacturer:** | alphaklima GmbH<br>Ludwig-Erhard-Str. 2c<br>41564 Kaarst |
| **Product name:** | "Plasmagerät steckerfertig" 230 VAC |
| **Manufacturer specification:** | |
| General description: | Room air cleaning device, based on a plasma technology |
| Dimension: | 73 cm x 88 cm x 40 cm (W x H x D) |
| Plasma-Module: | ERDWELLE Technologies Inc. |
| Air flow rate: | Level 1: 980 m³/h<br>Level 2: 1390 m³/h (Setting during the test)<br>Level 3: 1540 m³/h<br>Level 4: 1580 m³/h<br>Level 5: 1630 m³/h |
| Area of application: | All public and private areas (e.g., hotels, classrooms, sports studios, offices, airports, churches, buses, etc.).<br>Exceptions: medical laboratories (environments where viruses etc., are bred or should survive) and environments with humidity above 70%. |

**Product pictures:**

## 2 Boundary conditions

| | |
|---|---|
| Installation room: | conference room „Helmut-Künzel-Saal"<br>(Fraunhofer-Institute for Building Physics, Valley) |
| Equipment: | furnished |
| Dimensions: | 10,6 m x 11,1 m<br>Volume 470 m³ |
| Position plasma-device: | decentralized, on one wall of the room (see Fig. 1) |
| Sampling position: | approx. in the middle of the room, height 1,2 m |
| Room temperature: | ca. 26 °C |
| Air humidity: | 40% r. F. |

Figure 1:
Conference room at IBP with the room air cleaning device to be tested.

# 3 Performance

## 3.1 Sampling

The internal reference number for the measurements performed is E3553.

Sampling was carried out following the specifications of DIN EN ISO 16000-5 [1] on July 21, 2021, between 10:00 a.m. and 2:00 p.m. in the conference room (see Fig. 3). The room was not used during the sampling. The prescribed ventilation regime before measuring process started was following: opening of all windows as wide as possible for at least 15 minutes at least 8 hours before the start of sampling and then close windows and doors until sampling. The background sampling (blank) was performed approximately 1½ hours after the instrument was switched on with plasma off and the fan on (stage 2, adjusted to the required air flow rate). Subsequently the the plasma was switched on and the device ran approx. 1½ hours before the second air sampling took place.

Fig. 2:
Air sampling in the conference room at IBP.

## 3.2 Measurement method

The sampling parameters [1] and the analytical methods applied ([2], [3]) are given in Table 1.

Table 1:
Sampling and analysis conditions

| Chemical category | Sample volume [NL] | Duration Sampling [h] | Adsorbent | Analytical methods |
|---|---|---|---|---|
| VOC | 3.0<br>5.0 | 0.50<br>0.83 | Adsorption tubes according to requirement Tenax TA® | Thermal desorption, GC-MS [1)] |
| Aldehyde & Ketone | 2 x 60 | 2 x 1.0 | DNPH-Cartridge "DNPH Silica" (Fa. Waters) | HPLC-DAD [2)] |
| Ozone[3)] | Ozone-Analyzer Modell O3 41M; Fa. ANSYCO<br>Measurement principle: UV-Absorption at 253.7 nm, Detection level 1 ppb | | | |
| Nitric oxides[3)] | NO/NOx/NO2 (Nitric oxide) Analyzer AC31M; Fa. ANSYCO<br>Measurement principle: Chemiluminescence, Detection level 1 ppb | | | |

1) Qualitative and quantitative analysis by TD-GC-MS (thermal desorption gas chromatography mass spectrometry) according to IBP - SAA 280/070, calibration via liquid spiking of the standards to Tenax TA™.

2) Investigated is the DNP hydrazone of the following substances (according to IBP - SAA 280/072): formaldehyde, acetaldehyde, acrolein, acetone, propionaldehyde, butyraldehyde, 2-butanone, crotonaldehyde, valeraldehyde, isovaleraldehyde, cyclohexanone, hexanal, benzaldehyde, o-tolualdehyde, and m-tolualdehyde, p-tolualdehyde, heptanal, octanal, nonanal, and decanal. The quantification is substance-specific via five-point calibration functions of DNP hydrazone in acetonitrile.

3) Ozone and nitrogen oxide measurement is not part of the accredited test methods.

# 4 Results

## 4.1 Volatile organic compounds

The measurement results obtained for the concentrations of VOCs before switching on the plasma module and during operation in the conference room are shown in Table 2. Only substances for which an increase in the room air concentration was recorded over the test period were taken into account.

Table 2:
Time-dependent, chemical-analytical measured values (mean values) for the substances with concentration increased and associated orientation values.

| Substance | CAS-No. | Substance concentration in the room air µg/m³] [1] | | | OW [2] [µg/m³] |
|---|---|---|---|---|---|
| | | with Plasma | without Plasma | Increase | |
| **VVOC** | | | | | |
| Formaldehyde [3] | 50-00-0 | 147 | 143 | 4 | 30 |
| Acetone [3] | 67-64-1 | 111 | 106 | 5 | 161 |
| Propanal [3] | 123-38-6 | 8 | 7 | 1 | 14 |
| Acetonitril [4] | 75-05-8 | 24 | 10 | 14 | -- [6] |
| **VOC** | | | | | |
| Heptanal [3] | 111-71-7 | 6 | 5 | 1 | 6.7 |
| Nonanal [3] | 124-19-6 | 13 | 11 | 2 | 19 |
| 1-Methyl-2-pyrrolidone [5] | 872-50-4 | 84 | 71 | 13 | 2.0 |
| Decamethylcyclopentasiloxane [5] | 541-02-6 | 13 | 9 | 4 | 22 |
| n-Octanoic acid [5] | 124-07-2 | 12 | 4 | 8 | 2.0 |
| Decanoic acid | 334-48-5 | 7 | 2 | 5 | -- [6] |
| n-Tridecane [5] | 629-50-5 | 3 | 2 | 1 | 5.0 |
| Lauric acid [4] | 143-07-7 | 1 | < 1 | 1 | -- [6] |
| Alcohol [4] | -- [8] | 3 | 1 | 2 | -- [6] |
| **Increase of VVOC** for $c_i \geq 1$ µg/m³ | | | | **24** | |
| **Increase of VOC (= TVOC)** for $c_i \geq 1$ µg/m³ | | | | **37** | |
| **Increase of SVOC** for $c_i \geq 1$ µg/m³ | | | | **0** | |

1 Without plasma = room air concentration before switching on the plasma module; the fan on level 2.
With plasma = room air concentration during the plasma module; the fan on level 2.
Increase = difference "with plasma" minus "without plasma, "i.e., increase due to the room air cleaner
2) AGÖF orientation values for volatile organic compounds in indoor air
(Updated version of 5 October 2013) [6].
3) Identification and quantification by HPLC/DAD reference substance.
4) Identification via GC-MS spectral library, quantification as toluene equivalent.
5) Identification and quantification by reference substance, GC/MS.
6) Substance not available in the AGÖF orientation values VOC list [6].
7) Identification via GC-MS spectra library, substance-like quantification.
8) No CAS number available.

## 4.2 Ozone

The course of the ozone concentration in the conference room before switching on the plasma module and during the operation of the plasma module is shown in Figure 3.

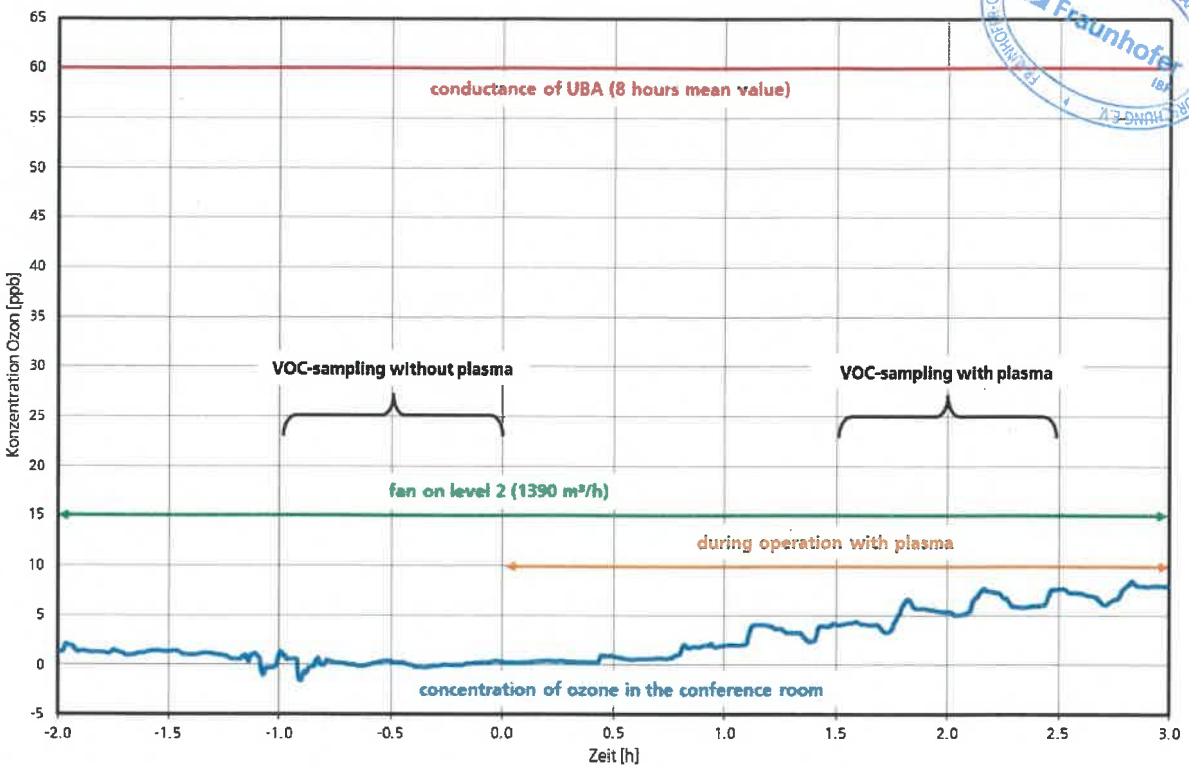


Fig. 3:
Course of ozone concentration in the conference room before switching on the plasma module and during operation of the plasma module.

The operation of the device forms ozone. The ozone concentration is below 10 ppb after 3 hours of operation. There are no reference values for ozone in indoor air. However, according to UBA [7], in the long term, the 8-hour average value of 60 ppb (120 µg/m³) should no longer be exceeded in outdoor air during a calendar year.

## 4.3 Nitric oxide

The courses of the nitrogen oxide concentrations in the conference room before switching on the plasma module and during the operation of the plasma module are shown in Figure 4.

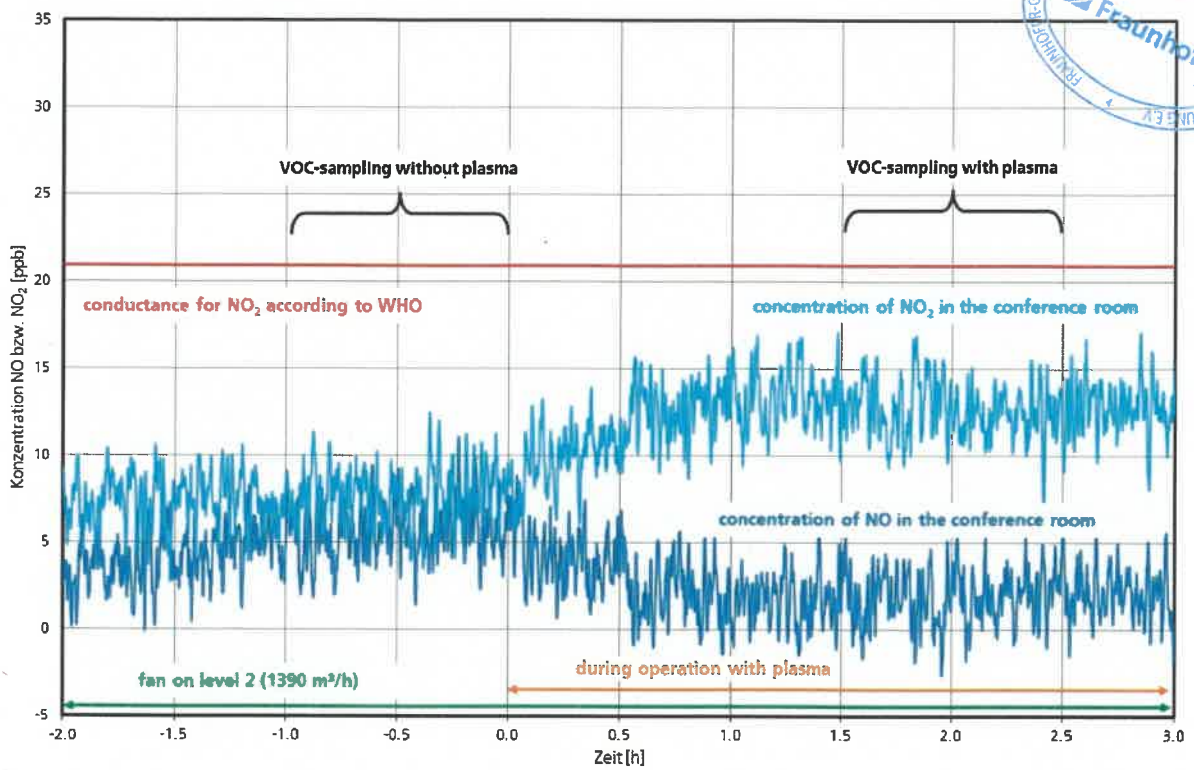


Fig. 4:
Course of NO and $NO_2$ concentration in the conference room before switching on the plasma module and during operation of the plasma module.

**Summary:**

- The operation of the device forms no NO (nitrogen monoxide).
- The concentration of $NO_2$ (nitrogen dioxide) in the conference room increases when the plasma module is switched on. The concentration increases by approx. 5 ppb to approx. 13 ppb. The "long-term reference value" for outdoor air set by the WHO in 2005 is 21 ppb (40 µg/m³) [8] and is also used as guideline value for indoor air [9].

# 5 Comparison of the measurement values

## 5.1 Reference values of the Committee for Indoor Reference values (AIR)

The volatile organic compounds formed by the air cleaner in the conference room (Table 2, "Increase" column), if present by June 2021, are compared to the guideline recommendations of the AIR [4 (Table 3). The AIR is an association of federal and state experts appointed by the Arbeitsgemeinschaft der Obersten Landesgesundheitsbehörden (AOLG). The UBA sends additional experts to support the committee.

There are two reference value categories: Reference value II (RW II) is an effect-related value based on current toxicological and epidemiological knowledge of the effect threshold of a substance, taking into account uncertainty factors. It represents the concentration of a substance which, if reached or exceeded, requires immediate action. This increased concentration can lead to adverse health effects, especially for sensitive persons who spend longer periods in such rooms. The reference value I (RW I) describes the concentration of a substance in indoor air at which, according to the current state of knowledge, no health effects are to be expected, even if a person is exposed to this substance for a lifetime. RW I can serve as a target value for remediation. The Reference values refer to individual substances and do not include any statement about possible combination effects of different substances.

Table 3:
Comparison of the volatile organic substances formed by the air cleaner (Table 2, column "Increase") with the existing reference value recommendations of the AIR ].

| Substance/Substance group | [µg/m³] | | Formed by air cleaner VOCs [µg/m³] |
|---|---|---|---|
| | RW II | RW I | |
| Formaldehyde | -- | 100 | 4 |
| 1-Methyl-2-pyrrolidone | 1000 | 100 | 13 |
| Total saturated acyclic aliphatic C4- to C11-aldehydes | 2000 | 100 | 3 |
| Total Cyclic dimethyl siloxanes (D3 - D6) | 4000 | 400 | 4 |
| Total low-aromatic hydrocarbon mixtures (C9 - C14) | 2000 | 200 | 1 |

## 5.2 TVOC-Guide value

Another parameter for assessing indoor air hygiene is the so-called TVOC guide value (total VOC). The TVOC value considers that it has only been possible to derive guide values for a small number of substances and substance groups but that a large number of organic substances can appear in indoor air. Since the TVOC value is calculated from the sum of the individual substance concentrations without considering, for example, the reactivity of the individual substances, no concentration values but concentration ranges are given for the assessment levels in Table 4.

Table 4:
Conductance for TVOC in the indoor air [5].

| Level | Concentration range [mg TVOC/m³] | Hygienic evaluation, notes |
|---|---|---|
| 1 | ≤ 0.3 mg/m³ | Hygienically harmless; Target value |
| 2 | > 0.3 to 1 mg/m³ | Hygienically still harmless; increased need for ventilation |
| 3 | > 1 to 3 mg/m³ | Hygienically conspicuous; temporary (< 12 months) as upper limit for rooms intended for longer-term stay |
| 4 | > 3 to 10 mg/m³ | Hygienically questionable; room usable for a limited period (maximum 1 month) and with increased ventilation |
| 5 | > 10 mg/m³ | Unacceptable from a hygienic point of view; at best, the room can be used temporarily daily (by the hour) and with increased regular ventilation activities. |

## 5.3 Orientation values (according to AGÖF])

The orientation values of the AGÖF are statistically derived. They are based on an updated data pool from the years 2006 to 2012, which was obtained as part of the research project "Conflict of objectives: energy-efficient construction and good indoor air quality - data collection for volatile organic compounds in the indoor air of residential and office buildings (solutions)" [10]. The list of AGÖF orientation values includes over 300 individual compounds. It also contains substances outside the TVOC range (C6 - to C16) but were recorded using the methods mentioned and are relevant for the assessment. For each substance, the statistical parameters sample size (n), 50th percentile (P 50), and 90th percentile (P 90) are given regarding the results of the current AGÖF research project.
The AGÖF orientation value corresponds in most cases to the conspicuity value and thus to the 90th percentile. Orientation values can be used to classify measurement results for a statistical probability and thus to weigh them in terms of their relevance for the search for causes of health complaints. However, the evaluation of concrete health risk is not possible with the orientation values. The orientation value indicates the measured value above which a substance in indoor air is to be evaluated based on statistical conspicuity or toxicological findings.

# 6 Conformity assessment

## TVOC

Despite the increase in the TVOC value (37 µg/m³) due to the air cleaners operation with the plasma module switched on, the air quality in the investigated room can be classified in level 1 "hygienically harmless."

## RW I-/RWII-Values

For all detected substances for which an increase in indoor air concentration was recorded over the test period and for which guideline recommendations of the AIR exist, the RW I and RW II values are clearly undercut.

## Guide values

Orientation values (OV) exist for 9 of the 13 substances listed in Table 2. For two substances (1-methyl-2-pyrrolidone and n-octanoic acid), an increase in the indoor air concentration was recorded over the test period and for which orientation values exist, the orientation values were recorded are exceeded by more than 50%.

For the evaluation of conformity, the measured values were considered together with the measurement uncertainty. The decision rule applied is documented in SAA 280/081. In addition, the decision rule and the calculated measurement uncertainty can be provided on request. Thus, the metrological traceability of the measurement results is ensured.

## Literature list


[1] DIN ISO 16000-5: Innenraumluftverunreinigungen – Teil 5: Probenahmestrategie für flüchtige organische Verbinden (VOC) (ISO 16000-5:2007).

[2] DIN ISO 16000-6: Innenraumluftverunreinigungen - Teil 6: Bestimmung von VOC in der Innenraumluft und in Prüfkammern, Probenahme auf TENAX TA®, thermische Desorption und Gaschromatografie mit MS oder MS//FID (ISO 16000-6:2012-11).

[3] DIN ISO 16000-3: Innenraumluftverunreinigungen - Teil 3: Messen von Formaldehyd und anderen Carbonylverbindungen in der Innenraumluft und in Prüfkammern; Probenahme mit einer Pumpe (ISO 16000-3:2013-01).

[4] Richtwertempfehlungen des AIR; Stand April 2021 https://www.umweltbundesamt.de/themen/gesundheit/kommissionen-arbeitsgruppen/ausschuss-fuer-innenraumrichtwerte-vormals-ad-hoc#hygienische-leitwerte-fur-die-innenraumluft; aufgerufen am 13. August 2021.

[5] Bekanntmachung des Umweltbundesamtes: Beurteilung von Innenraumluftkontaminationen mittels Referenz- und Richtwerten. In: Bundesgesundheitsblatt - Gesundheitsforschung – Gesundheitsschutz; 50(7); 2007; S. 990 – 1005.

[6] AGÖF-Orientierungswerte für flüchtige organische Verbindungen in der Raumluft (Aktualisierte Fassung vom 5. Oktober 2013)

https://www.agoef.de/orientierungswerte/agoef-voc-orientierungswerte.html; aufgerufen am 13. August 2021.

[7] Umweltbundesamt: Ozon-Belastung https://www.umweltbundesamt.de/daten/luft/ozon-belastung#zielwerte-und-langfristige-ziele-fur-ozon; aufgerufen am 13. August 2021.

[8] WHO Regional Office for Europe: Air quality guidelines: global update 2005 – Particulate matter, ozone, nitrogen dioxide and sulfur dioxide. Copenhagen: WHO Regional Office for Europe (Scherfigsvej 8, DK-2100 Copenhagen).

[9] WHO Regional Office for Europe: WHO guidelines for indoor air quality: selected pollutants; (2010); https://www.euro.who.int/__data/assets/pdf_file/0009/128169/e94535.pdf; aufgerufen am 13. August 2021.

[10] Arbeitsgemeinschaft Ökologischer Forschungsinstitute (AGÖF) e. V. UFOPLAN Vorhaben FKZ 3709 62 211: Zielkonflikt energieeffiziente Bauweise und gute Raumluftqualität - Datenerhebung für flüchtige organische Verbindungen in der Raumluft von Wohn- und Bürogebäuden (Lösungswege). https://www.agoef.de/forschung/fue-ll-voc-datenerhebung/abschlussbericht.html; aufgerufen am 13. August 2021.

**Note**

The test was carried out at the Emissions, Environment and Hygiene Testing Laboratory, which is accredited by DIN EN ISO/IEC 17025:2018 flexibly accredited by DAkkS with the No. D-PL-11140-11-05 (excluding ozone and nitrogen oxides).

The test report includes:

13 Pages text,
4 Tables
4 Figures



Valley, August 16, 2021

Technical manager of the testing laboratory

Christian Scherer

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