IEC PAS 63086-3-1

Edition 1.0 2023-05

PUBLICLY AVAILABLE SPECIFICATION

Household and similar electrical air cleaning appliances – Methods for measuring the performance
Part 3-1: Method for assessing the reduction rate of key bioaerosols by portable air cleaners using an aerobiology test chamber

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INTERNATIONAL
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HOUSEHOLD AND SIMILAR ELECTRICAL AIR CLEANING APPLIANCES – METHODS FOR MEASURING THE PERFORMANCE –

Part 3-1: Method for assessing the reduction rate of key bioaerosols by portable air cleaners using an aerobiology test chamber

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IEC PAS 63086-3-1 has been processed by subcommittee 59N: Electrical air cleaners for household and similar purposes, of IEC technical committee 59: Performance of household and similar electrical appliances, in co-operation with ISO technical committee 142: Cleaning equipment for air and other gases.

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Draft PAS	**Report on voting**
59N/28/DPAS	59N/33/RVDPAS

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Words in **bold** type in the text are defined in Clause 3.

A list of all parts in the IEC 63086 series, published under the general title *Household and similar electrical air cleaning appliances*, can be found on the IEC website.

IMPORTANT – The "colour inside" logo on the cover page of this document indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

This Publicly Available Specification (PAS) contains test procedures for measuring the reduction by the air cleaner of micro-organisms suspended in the air in the specified test chamber. It also prescribes a method for measuring the operating power and stand-by power of the air cleaner. The test procedures may be applied to any brand or model of household and similar electrical air cleaners within the stated confines of the standard limits of measurability for measuring performance.

The annexes to this PAS are included for informative purposes only unless the annexes are noted as normative.

Warning – The tests given in this document shall be performed by expert staff trained to handle microorganism-related techniques and in properly equipped laboratories under the supervision of a skilled microbiologist. Some of the test micro-organisms might be facultative pathogens for humans, animals and plants and require a laboratory of an appropriate bio-safety level. National and international safety procedures for working with infectious biomaterials shall be followed to prevent any contamination of laboratory staff, apparatus, working place or environment in compliance with national standards or regulations. This document does not purport to address all of the safety aspects, if any, associated with its use. It is the responsibility of the user to establish appropriate safety and health practices and ensure compliance with any national, regional or international regulatory conditions.

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HOUSEHOLD AND SIMILAR ELECTRICAL AIR CLEANING APPLIANCES – METHODS FOR MEASURING THE PERFORMANCE –

Part 3-1: Method for assessing the reduction rate of key bioaerosols by portable air cleaners using an aerobiology test chamber

1 Scope

This part of IEC 63086 specifies a method to evaluate the capability of portable household air cleaners to reduce the concentration and viability of key experimentally generated bioaerosols in a specified chamber.

Indoor air free of harmful microbes is important to the health of occupants. This is particularly relevant with regard to increased time spent indoors.

Air cleaners are used to reduce the concentrations of microorganisms in indoor air.

The efficiency of such air cleaners to reduce airborne microorganisms can be assessed in test chambers at controlled air temperature and relative air humidity.

The test is applicable to portable air cleaners commonly used in single room spaces such as those based on mechanical filtration, ultraviolet (UV), ionizers, photocatalytic oxidation, and ozone generators in-unit technology.

If the air cleaner does not claim to have the function of reducing microorganisms, this document may not be applicable unless it is being used to simply evaluate the performance.

This document deals with measurement procedures regarding the reduction of the microbial contamination related to electrical air cleaner appliances for household and similar use.

This document does not apply to appliances intended to be used in medical, veterinary, or pharmaceutical applications.

This document does not address sanitization, disinfection, or sterilization measures.

This document does not support, by itself any health-related claims or conclusions about prevention or treatment of a disease or health improvement.

NOTE 1 IEC 63086-3-1 is created for household and similar electrical air cleaners and is not intended to conflict with or replace standards for commercial or industrial consumers.

NOTE 2 In this document, we do not suggest performance test methods that measure the by-products of either the interaction between microbes or between the air cleaner and the microbes tested in this document. The formation of by-products is an important subject. The subject of measuring by-products is under study, and AHAM will address this in future documents.

NOTE 3 This document does not apply to appliances intended for use in medical treatment locations, such as surgical suites, laboratories, medical treatment rooms, etc.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 63086-1:2020, *Household and similar electrical air cleaning appliances − Methods for measuring the performance − Part 1: General requirements*

ASTM E741-11:2017, *Standard Test Method for Determining Air Change in a Single Zone by Means of a Tracer Gas Dilution*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at https://www.electropedia.org/
- ISO Online browsing platform: available at https://www.iso.org/obp

3.1
air cleaner
electrically powered household, or similar, appliance that employs one or multiple technologies to reduce, destroy, and/or inactivate one or more types of indoor air pollutants

Note 1 to entry: The term "air purifier" is defined as an Electrically powered device that is basically built of a fan and a set of components possessing the ability to capture and/or (partially or totally) destroy air pollutants [Source: ISO 16000-36] but PAS 63086-3-1 has chosen to not use this term in this document as it may not be possible to totally destroy an air pollutant.]

[Source: IEC 63086-1:2020, 3.1, modified – "destroy, and/or inactivate" and the note to entry have been added]

3.2
background concentration
quantity of **microbes** in the chamber after the chamber has undergone cleaning and prior to any testing or addition of **microbes** via nebulization

3.3
bacteria
prokaryotic, single-celled, microscopic organism with peptidoglycan cell wall

3.4
bacteriophage or phage
group of **viruses** that infect **bacteria** or **fungi**

3.5
bioaerosol
airborne particle that is composed of or derived from biological matter (such as a bacterial cell, fungal or bacteria spore, **virus**, or endotoxin)

3.6
biological safety levels
BSL
series of protections relegated to autoclave-related activities that take place in particular biological labs

Note 1 to entry: This includes individual safeguards designed to protect laboratory personnel, as well as the surrounding environment and community. For BSL level expectations, a lab should follow the most recent version of the WHO Laboratory Biosafety Manual, the CDC Biosafety in Microbiological and Biomedical Laboratories (BMBL) or the Canadian Biosafety Standards and Guidelines.

3.7
CADR
clean air delivery rate
measure of **air cleaner** performance by this test procedure

Note 1 to entry: Clean Air Delivery Rate (CADR) is defined as the measure of the delivery of contaminant-free air, within the defined particle size range, by an **air cleaner**, expressed in cubic feet per minute (cfm) or cubic meters per hour. Clean Air Delivery Rates are the rates of contaminant reduction in the test chamber when the **air cleaner** is turned on, minus the rate of **natural decay** when the **air cleaner** is not running, multiplied by the volume of the test chamber as measured in cubic feet or cubic meters (see 8.5). CADR values are always the measurement of an **air cleaner** performance as a complete system, and they have no linear relationship to air movement per se or to the characteristics of any particular particle removal methodology.

Note 2 to entry: For this document, we use the designation of m-CADR which is the clean air delivery rate for microbes.

3.8
colony forming units for bacteria and fungi
CFU
unit of measurement by which the number of culturable **microbes** (***Bacteria*** *and* ***fungi****)* is expressed

3.9
device under test
DUT
test sample of the **air cleaner** undergoing examination

3.10
fungi
multicellular eukaryotic organisms without chlorophyll and with cell walls

3.11
impaction
sampling of the airborne **microbe** by inertial separation on a semisolid agar surface

3.12
impinger method
glass or plastic device for the collection of air samples into a liquid medium through a scrubbing action.

Note 1 to entry: The liquid volume is subsequently utilized for dilution and inoculation of counting plates.

3.13
initial concentration
concentration of **microbes** inside the chamber immediately at the start time of sampling of either the **natural decay** or the total decay

3.14
maximum performance mode
through manual operation the DUT is set to the highest flow rate with all air cleaning functions switched on, set to maximum, where applicable, and with all filters in place

Note 1 to entry: If the DUT has zero flow rate, the m-CADR is measured with all air cleaning functions switched on.

3.15
microbes
microorganisms
microscopic living beings that cannot be seen with the naked eye, including **bacteria**, protozoa, **viruses** and **some fungi**/fungal components

Note 1 to entry: They are common in the environment as well as in/on our own bodies.

3.16
microbial reduction
reduction rate of viable **microbe** is measured by comparing the concentration of the microbe after nebulizing a microbial suspension inside the chamber with the concentration determined after a defined running time (testing time) of the **air cleaner**

Note 1 to entry: The microbial reduction rate is expressed as natural log reduction over time.

3.17
natural decay
rate of reduction of the airborne concentration of viable microbiological contaminants as measured without an air-cleaning device operating in an aerobiology chamber

Note 1 to entry: The **natural decay** rate is expressed as natural log reduction over time.

3.18
plaque forming units
PFU
unit of measurement by which the number of viable **viruses** is expressed

3.19
virus
group of microorganisms with a simple structure composed of RNA or DNA and protein outer coat which are specialized in intracellular infection and replication

4 Principle

The efficiency of **air cleaners** is tested using one or more nebulized and homogeneously distributed microbial suspensions inside an enclosed test chamber at controlled air temperature and relative air humidity. The efficacy is calculated by the **reduction** rate of the test **microbe** in a defined period of time, considering the rate of **natural decay** of the test **microbe**.

5 Apparatus and materials

5.1 Apparatus

NOTE As a wide variety of specialized pieces of equipment exist and are commercially available, the following list gives only the preferred list of equipment that have the desired primary critical characteristics. Alternates are allowed when they have been shown to be equivalent. Equivalency specifications or data should be included showing the alternate equipment can be considered equivalent.

5.1.1 Test chamber

The chamber shall be constructed to the following characteristics:

- Be accepted by OSHA (U.S. Occupational Safety and Health Administration) or other national bodies;
- The chamber size is (30 ± 1,5) m^3; Height = (2,5 ± 0,1) m. The width shall be within 85 % and 100 % of the length;
- The walls should be made from a suitable smooth non-porous material that emits minimal levels of volatile organics, is corrosion-resistant, and is repeatedly washable (i.e., constructed of stainless steel, epoxy, glass or other documented nonreactive material with minimum volatile organic hydrocarbon emission potential). The material should not quench ionization, be non-reflective for visible and ultraviolet light (which is measured as between 5 % and 20 % reflectance at the operational wavelength of the device under test), and be well-grounded;
- It shall maintain sufficient airtight capacity. The test chamber air exchange rate is to be less than 0,05 air changes per hour (ACH) as determined by ASTM E741 (Standard Test Method

for Determining Air Change in a Single Zone by Means of a Tracer Gas Dilution) or an equivalent method;

- The test environment shall be kept clean and free from extraneous microbial contamination. It shall have a suitable environmental control system to maintain a controlled level of air temperature and humidity. To achieve this, the test chamber should include the following:
  - A system capable of removing contamination and maintaining aseptic condition inside the chamber, such as an UV lamp;
  - A facility to transfer items into and out of the chamber without cross-contamination (this can include a special system, such as a glove box, etc.);
  - The chamber may be fitted with an anteroom to allow for staging;
  - A facility to control the power inside the chamber from outside;
  - The chamber should be equipped such that tests can be witnessed externally;
  - A facility to generate an aerosol of test **microbe** inside the chamber and to ensure its homogeneity (this can be achieved by using a nebulizing inlet through which **microbes** are nebulized, connected to an atomizing nozzle in the chamber, with a fan to ensure homogeneous distribution of the **microbe** inside the chamber);
  - A sampling port should be 1,20 m (± 0,12 m) high from the floor. The port should be a minimum of 0,305 m (± 0,03 m) from the wall and a minimum of 0,914 m (± 0,09 m) away from the device and out of the airflow of the **air cleaner** exhaust or intake. See 7.2.2. for unit positioning;
  - An air conditioning system inside the chamber capable of controlling air temperature and relative humidity in a stable and precise manner; the air conditioning system shall be switched off during the test. No other external temperature or humidity manipulating equipment for the chamber shall be operated during the test:
    - the initial test air temperature and acceptable range of variation shall be (20 ± 3) °C;
    - the initial test relative humidity and acceptable range of variation shall be (50 ± 10) %;
    - the test chamber shall be equipped to continuously monitor and record humidity and temperature;
  - A facility to use negative pressure airflow to flush the chamber post-testing;
  - A filter to prevent contamination from the outside during ventilation. A HEPA filter is recommended to be used in the incoming and outgoing air to prevent lab contamination from entering the chamber or residual **microbes** contaminating the surrounding space.

See graphics of an example test chamber in Annex A.

5.1.2 Nebulizer

The nebulizer shall be capable of nebulizing microbial suspensions into particles (0,05 µm to 5 µm) to produce, as far as possible, discrete particles. It typically comprises a pump to generate a defined air pressure to nebulize, a clean air supply unit and a dehumidifier to remove excess water from the generated culture medium. A compressed air cylinder can also be used to operate the nebulizer.

- Collison 6-jet nebulizer (BGI Inc. Waltham MA), or equivalent, driven by purified filtered house air supply or equivalent

5.1.2.1 Nebulizer fluid

The nebulizer reservoir should be filled with a combination of test microbial suspension, deionized water, antifoaming agent and phosphate-buffered saline (PBS). The concentrations in the mixture the lab uses should be specified in the report (see Clause 9).

5.1.3 SKC bio sampler or equivalent for the sampling of microbes

The recommended impinger tube size is 20 mL. See Figure 1.

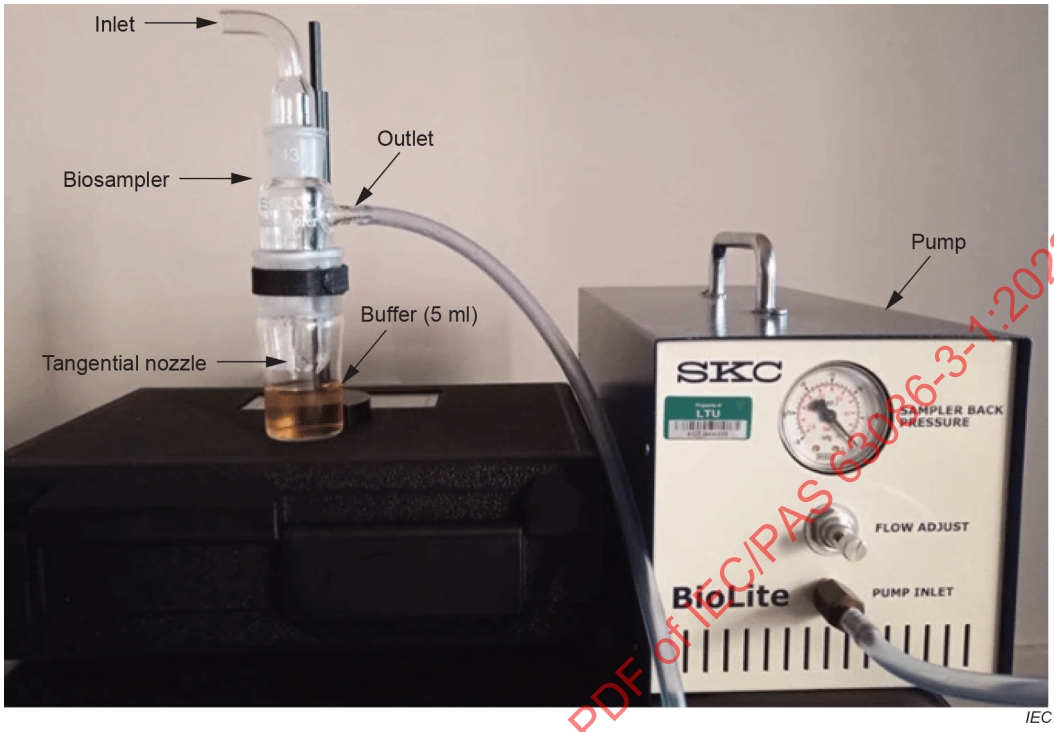


Figure 1 – SKC biosampler

5.1.4 Other test chamber apparatus

a) Flow calibration – SKC checkmate or equivalent

b) Stand, to position the sample tube per 5.1.1.

c) Autoclave, thermostatically controlled at (121 ± 3) °C and pressure of (103 ± 5) kPa.

d) Incubator, thermostatically controlled at the appropriate temperature depending on the microbe under test.

e) Deep freezer, thermostatically controlled at (–80 ± 10) °C.

f) Microbiological safety cabinet class II.

g) Balance, capable of weighing to ±0,01 g.

h) Inoculating loop, 4 mm in ring diameter, sterile.

i) Petri dishes, vented, sterile, 90 mm to 150 mm diameter.

j) Disinfectant, ethanol (70 % volume fraction) or bleach (3 % by volume).

k) UV-C Light (254 nm to 265 nm wavelength with a minimum of 2 mW/cm^2).

l) pH-meter, capable of measuring to ±0,2 unit.

m) Timer.

n) Stirrer – A high volume ceiling fan used to mix the test chamber during contaminant aerosol generation.

o) Ceiling fan available from W.W. Grainger:

3 blade, 0,91 m, ceiling fan 395 RPM

Stock No. 36201 or equivalent

Amps 0,65, Volts 110-120

Weight 9,07 kg (20 lbs.)

NOTE It is acceptable to use multiple fans replacing the ceiling fan. Evaluation is needed to show the mixing is equivalent. Make sure the multiple fans are not artificially impacting the decay rate.

p) Recirculation fan − a fan capable of producing an air volume in the chamber of 250 $m^3 h^{-1}$ (± 170). This fan is used for the purpose of maintaining a homogeneous environment within the test chamber.

q) Refrigerator (5 ± 3) °C. This refrigerator is used for storage of culture media, culture plates and reagents.

5.2 Key bioaerosols

The preferred **microbes** for testing are noted below, and their associated American Type Culture Collection (ATCC) catalog numbers are noted below (www.atcc.org). See Annex C for Alternate **microbes** and Annex D for justification for the particles listed below. Any of the alternates in Annex C can also be used but need to be noted in the report.

- For testing of **bacteria**, interactions are different, so we recommend testing more than one. For example: U.S. EPA and this test method recommend both a Gram-Positive and a Gram-Negative (see 5.2.1 and 5.2.2). See 5.2.3 for source of bacterial endospores.
- For testing of **virus**, susceptibility based on their relative resistance to inactivation is different, so we recommend testing more than one type of **bacteriophage** as surrogates for human pathogenic **viruses** (see U.S. EPA classification as noted in Annex D).
  - See 5.2.4 and the alternates in the Annex C.
- For testing of mold, mold spores are recommended (see 5.2.5).

5.2.1 Test bacteria (Gram-positive)

- Staphylococcus epidermidis (BSL-1) ATCC 12228

5.2.2 Test bacteria (Gram-negative)

- Acinetobacter baumannii (BSL-2) ATCC 19606

5.2.3 Test bacteria (Spore forming)

- Geobacillus stearothermophilus (BSL-1) ATCC 12980

5.2.4 Test bacteriophages (Non-enveloped)

- MS2 (preferred) (BSL-1) ATCC15597-B1
  with host Escherichia coli ATCC 15597

5.2.5 Test mold spores

- Aspergillus brasiliensis (BSL-1) ATCC 16404

For specific questions, other **microbes** may be used. All strains used shall be listed in the test report.

6 Preparation of the stock cultures and working cultures of the test microbes

Culture method is per ATCC recommendations or equivalent for a defined culture method for each **microbe**. The same agar from the same source should be used throughout the same evaluation.

7 Procedures

7.1 General

In order to prevent any extraneous microbial contamination, prepare and handle the test **microbes** using a certified biological safety cabinet (BSC). The lab should also have a laboratory safety plan that is adequate to handle the specified **BSL** for the chosen **bioaerosols**.

WARNING – The test method given in this document shall be performed by expert staff trained and certified to handle microorganism-related techniques and in properly equipped laboratories under the control of a skilled microbiologist. Some of the suggested test micro-organisms can be pathogens for humans, other animals and plants. Great care should be taken in the disposal of all incubated test materials and surfaces exposed to aerosolization of the micro-organisms. National and international safety procedures for working with infectious biomaterials shall be followed to prevent any contamination of laboratory staff, apparatus, working place or environment. The examination and preparation of the cultures should be carried out in a microbiological safety cabinet or chamber at the appropriate bio-safety level (**BSL**) in compliance with national standards or regulations. This document does not purport to address all of the safety aspects, if any, associated with its use. It is the responsibility of the user to establish appropriate safety and health practices and ensure compliance with any national, regional or international regulatory conditions.

The test is performed in two steps. In Step 1 (see 7.2), the concentration of the nebulized test **microbe** in the chamber's air is measured without operating the **air cleaner**, then in Step 2 (see 7.3 the concentration of the nebulized test **microbe** in the chamber's air is measured with the **air cleaner** operating.

The test is only valid if the conditions in 8.2 are met. If these conditions are not met, the test (Step 1 and Step 2) shall be repeated.

7.1.1 Electrical Supply

Standard frequency and voltage for the m-CADR testing and operating power test are listed in 7.1.1.1 and 7.1.1.2. Other frequencies and voltages may be used to produce m-CADR values. The specific electrical supply conditions shall be concurrently reported with the applicable m-CADR values.

7.1.1.1 Frequency

Operate **air cleaner** at Nameplate frequency ± 1 % Hertz.

7.1.1.2 Voltage

Operate **air cleaner** at Nameplate voltage ± 1 % Volts.

7.2 Step 1 – Measurement of the concentration of airborne microbe, c_i, without operating the air cleaner

7.2.1 General

In Step 1, the concentration of the airborne test **microbe** is measured without operating the **air cleaner**.

7.2.2 Preparation of the air cleaner and the test chamber

Prior to the initial test, the **air cleaner** motor shall be properly broken in by running the **air cleaner** per manufacturer instructions up to but not to exceed 48 hours. Installation of a UV-C device and configuration of the lamp assembly within the **device under test** shall be as designated by the manufacturer or equipment provider. The burn-in time for lamps shall be 100 hours.

The **air cleaner** is installed per the manufacturer's instructions, placing the **air cleaner** (or test fixture containing the **air cleaner**) in a position where the inlet and outlet flow is not occluded and where it is not in the airflow of the recirculation fan. The best location would be centrally located within the chamber unless the **air cleaner** cannot be operated remotely, then it needs to be placed within reach of the glove box. It is highly recommended that a cart or device be present for glove box applications to move the product to as close to the centre of the room as possible. For **air cleaners** that discharge air in a specific direction, the air discharge shall not

be pointed toward the aerosol collection device and the air discharge shall not be directly on the wall or at least 2 feet (61 cm) from the wall. Air cleaners using UV technology should be positioned such that UV light shall not be illuminated directly on the air sampling port. If the manufacturer's instructions do not specify, place the **air cleaner** on a table for test. (Refer to IEC 63086-1:2020, 5.7.1 or 5.7.7 for positioning of specific types of **air cleaners** in the test chamber.)

Air cleaners are adjusted to the **maximum performance mode** setting for testing. The product shall be operated on a consistent operating parameter (non-adjustable) for the duration of the test. Other performance settings may be concurrently reported with the applicable m-CADR values.

The air temperature and relative humidity inside the test chamber shall be recorded:

- temperature: (20 ± 3) °C;
- humidity: (50 ± 10) % RH.
  - The humidity level shall not be artificially manipulated through supplemental equipment beyond the DUT during the test to purposefully improve performance.

Before the test, decontaminate the interior space of the chamber and test apparatus, i.e., by using an UV-C lamp (see 5.1.4 k)), 70 % ethanol or appropriate disinfectant (see 5.1.4 j)), or adopting other decontamination methods in order to reduce the risk of contamination from the previous testing.

7.2.3 Measurement of microbial background concentration in the test chamber

Measure the **background concentration** after placing the **air cleaner** and prior to nebulizing test **microbe** into the chamber.

NOTE Assure that the air in the chamber has no chemical residue from the decontamination process. This can require its own measurement or demonstration that the Laboratory Standard Operating Procedure used by the lab for cleaning provides no residuals.

The microbial **background concentration** shall be maintained at < 4 CFU m^3 h^{-1} or PFU m^3 h^{-1} over multiple sampling periods or a level deemed acceptable through laboratory standard operating procedures. If higher concentrations are detected, ventilate and decontaminate the chamber, i.e., by using an UV-C lamp, and repeat the measurement.

7.2.4 Nebulizing test microbial suspension

Add a defined volume of microbial suspension (see Clause 6) into the nebulizer. The volume of the microbial suspension can vary depending on the type of nebulizer, the concentration of the microbial suspension used, the method to reach the minimum concentration in 7.2.5. The chamber's stirrer is turned on during **bioaerosol** dissemination to assure a homogeneous **bioaerosol** concentration in the test chamber prior to taking the first **impinger** sample.

NOTE A particle counter can be run in the room to understand the particle size of the nebulized suspension and ensure the right size particle is in the test chamber.

Prior to first use and after each use, clean and decontaminate/sterilize the nebulizer according to the manufacturer's instructions.

7.2.5 Measurement of the initial concentration of airborne microbe inside the test chamber after nebulizing

Measure the **initial concentration** of **microbes** inside the chamber immediately after nebulizing the microbial suspension (see Clause 6) using the air sampler (i.e., **impinger** tube). Measurement time and volume vary depending on the microorganism and expected microbial concentration. The minimum **initial concentration** may vary depending on the **microbe** and

the required log reduction but shall be between 5,0 × 10^6 CFU m^3 h^{-1} or PFU m^3 h^{-1} and 2,1 × 10^9 CFU m^3 h^{-1} or PFU m^3 h^{-1}.

7.2.6 Measurement of the concentration of airborne microbe inside the test chamber after a defined time

To determine the **microbe's natural decay**, measure the microbe's concentration inside the test chamber after a defined time period without operating the **air cleaner**. Choose the time period based on the intended operation testing time of the **air cleaner** (see 7.3). The concentration should be measured with at least three-time points every twenty minutes to have aa acceptable **natural decay** curve (see Clause 8). Measure the complete **natural decay** at least once as sampling with the **air cleaner** will also happen in 7.3.

Use a SKC Biosampler filled with 20 ml of phosphate-buffered saline (PBS) solution (pH of 7,2-7,4) as the collecting solution. Collect airborne test **microbes** by sampling air in the chamber with a sampling rate of 12,5 l per minute for one minute (= 12,5 l) as one collection. Calibrate the flow using a NIST traceable certified calibrator (see 5.1.4) and document the value to be used in calculations.

Multiple **impingers** (example: four **impingers** in series) may be used to increase collection efficiency with the condition that collecting volume in the former **impingers** is more than that in the later ones. The number of **impingers** shall be unchanged in a test.

NOTE 1 For control and **air cleaner** trials, the **impingers** are filled with 20 ml of sterilized PBS (pH of 7,2) (addition of 0,005 % v/v polysorbate 80) for **bioaerosol** collection. The addition of polysorbate 80 is to increase the **impinger** collection efficiency and de-aggregates the microbial clumps. The PBS may cause foaming and can be reduced if there is too much foaming or bubbling.

All **impinger** samples are serially diluted, plated and enumerated in triplicate to yield viable **bioaerosol** concentration at each sampling point and time. Utilize dilution schemes that will provide a plate count greater than 200 on a 100 mm plate and greater than 400 on a 150 mm plate to reduce the amount of measurement error.

NOTE 2 See Annex D for information on SIT-sampler operation.

7.2.7 Post-test actions

Decontaminate the interior space of the test chamber using an UV-C lamp (see 5.1.4 k)), spraying 70 % ethanol or bleach (see 5.1.4 j)), appropriate disinfectant or adopting another decontamination method in order to remove any contamination after a test. It is very important that no residue from the decontamination be on the surface or in the air. Adequate air exchanges to flush the chamber may be sufficient to decontaminate the chamber. Sanitizing the chamber between different test **microbes** will require more effort compared to sanitizing between tests with the same **microbes**.

7.3 Step 2 – Measurement of the concentration of airborne test microbe, c_t, after operating the air cleaner

Prepare the test chamber and measure the microbial **background concentration** as described in 7.2.2 and 7.2.3.

Nebulize the test microbial suspension (see 7.2.4) and measure the **initial microbial concentration** inside the chamber with the air sampling device (see 7.2.5).

Operate the **air cleaner** after measuring the **initial microbial concentration** in the chamber's air. The operation time can be changed according to the **air cleaner**'s characteristics. The operation time for a high m-**CADR air cleaner** could be less than 10 min but may need to be extended to 60 minutes for a lower m-**CADR** unit. See Figure 2 for a process table.

Once the **air cleaner** starts, take air samples from the chamber every 4 minutes for a duration of 20 minutes from the chamber in order to quantify the reduction speed and capabilities of the **air cleaner** on the test. Air samples can also assess the device's performance at 30 and 45 minutes depending on the **air cleaner** capabilities as a minimum of five valid sampling points are needed. All **impinger** samples are serially diluted as required, plated and enumerated in triplicate to yield viable **bioaerosol** concentration at each sampling point and time. Due to the lack of measurable **microbes**, the lab may need to extend the final measurement beyond 1 minute to capture a valid sample (however, this does have mathematical implications for how a value versus time is considered).

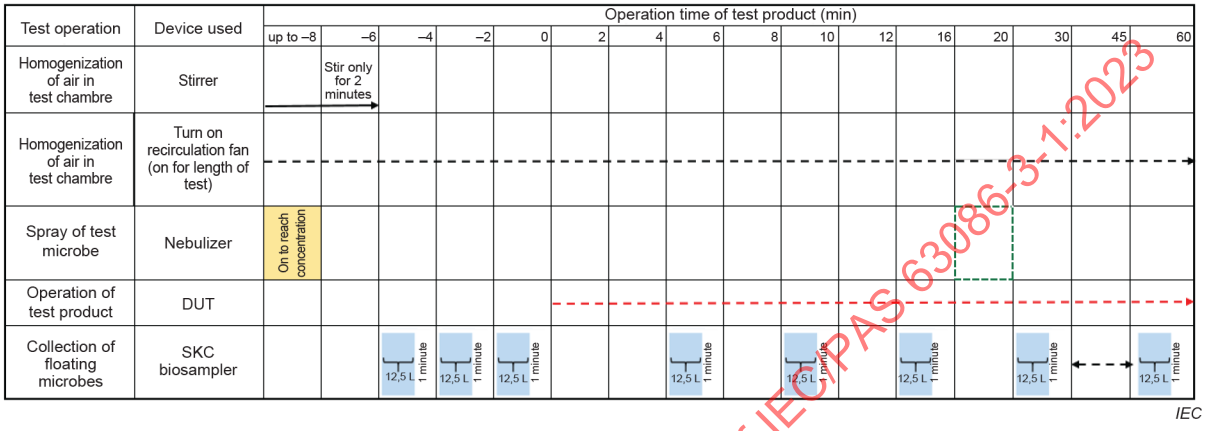


Figure 2 – Process table

Alternate sampling method for very high CADR units. Once the **air cleaner** starts, take air samples from the chamber every 2 minutes for a duration of 10 minutes from the chamber in order to quantify the reduction speed and capabilities of the **air cleaner** on the test. Additional samples can be taken up until 30 minutes using a 2- or 4-minute interval.

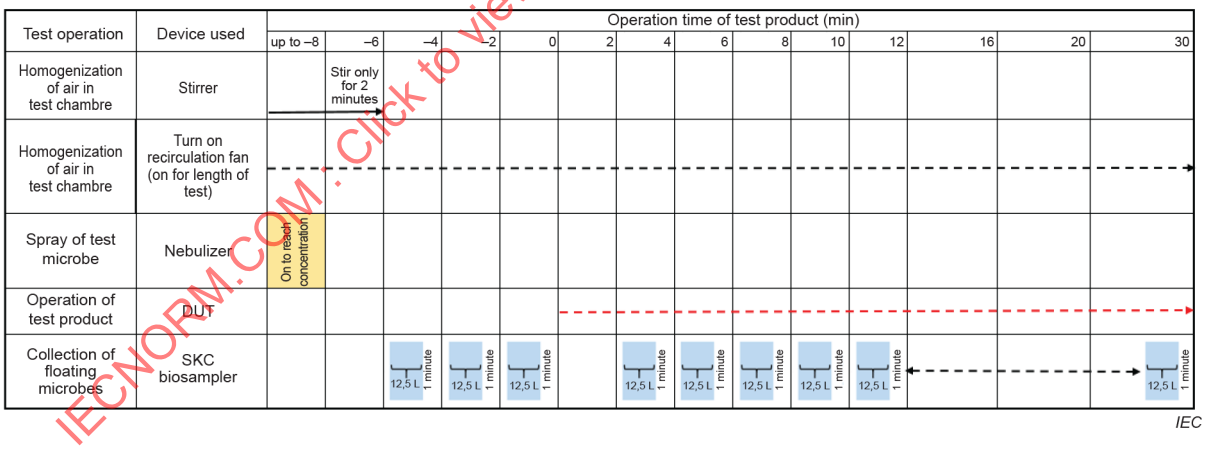


Figure 3 – Alternate process table

8 Calculation and expression of results

8.1 Conditions for a valid test

The **initial microbial concentration** in the air of the chamber immediately after nebulizing and prior to conducting the test shall be a minimum of $5{,}0 \times 10^6$ CFU $m^3\ h^{-1}$ or PFU $m^3\ h^{-1}$.

8.1.1 Criteria for elimination of data points from an IEC 63086-3-1 run

There are four criteria for eliminating a data point from an IEC 63086-3-1 run. The first is operator error. The second is equipment error either in the sensing, recording, or reporting of information. The third is the data point is not within the 95 % prediction limit of the regression line. The fourth is decay below the limit of instrument measurability.

Criterion 1:

Any noted operator error results in the elimination of the data point whether or not the data point (corresponding to the time the error is noted) is found within acceptable concentration ranges.

Criterion 2:

Any noted equipment error will result in the elimination of the data point (corresponding to the time the error is noted) whether or not the data point is found within acceptable or anticipated concentration ranges. Typically, this type of error invalidates the entire run.

Criterion 3:

Any data point found to be outside the 95 % prediction limits of the regression slope line will result in the elimination of the data point. The cause of the outlier data may or may not be due to test chamber instrumentation, air cleaner inconsistency, or other test chamber effects.

Criterion 4:

Any data point resulting in a reported concentration below the instrument measurability limit will be eliminated along with all subsequent data points in the run. Subsequent data points are eliminated based on the anticipated theoretical reduction of concentration with time. Any data point taken after one rejected for Criterion 4 would theoretically expect to also be eliminated by Criterion 4.

8.2 Calculation of the concentration of airborne microbe

Calculate the concentration of airborne **microbe** by counting the ***CFU*** or ***PFU*** on the incubated cultured plates and by applying the serial dilution factor for the respective **impinger** and collected air volume according to Formula (1):

$$C = \frac{N \times V_{samp} \times V_{dil}}{F \times r \times t \times V_{pip} \times V_{innoc}} \quad (1)$$

where

C is the concentration ***CFU*** or ***PFU*** per m^3, ***CFU*** m^3 h^{-1} or ***PFU*** m^3 h^{-1};

N is the number of ***CFU*** or ***PFU*** counted per plate;

V_{samp} is the volume of total sample from **impinger** and wash, l;

V_{pip} is the volume pipetted for dilution, l;

V_{dil} is the volume into which V_{pip} is diluted, l;

F is the volumetric conversion factor, m^3 /1 000 l;

r is the volumetric flowrate of sampled air, l/min;

t is the sampling time, min;

V_{inoc} is the volume of inoculation to the plate, l.

If no **colony** appears on the agar plates, the result is expressed as "< 1 ***CFU*** or ***PFU***" in the sampled air volume. For example, "< 1 ***CFU*** or ***PFU***/m^3" indicates that there were no viable **microbes** on the incubated agar plates after sampling 1 000 l of air. For **virus** calculations, ***PFU*** is used in place of ***CFU***.

8.3 Reduction of microbes

The **microbial reduction**, R, can be calculated according to Formula (2) at a specified time:

$$R = \frac{C^*_{\text{initial}} - C^*_{\text{measured at time t}}}{C^*_{\text{initial}}} = 1 - \frac{C^*_{\text{t}}}{C^*_{\text{i}}} \quad (2)$$

NOTE This is only used for internal review as various variables are not included in this equation, making it not transferrable from product to product (i.e., room size, target **initial concentration** versus measured **initial concentration**, etc.). It is recommended to use m-CADR as calculated in 8.4.

8.4 Calculating the decay constant

Since the test chamber is sealed, air exchange is negligible, and thus the air exchange rate is not included in the calculation.

8.4.1 The decay constant, k, for **microbes** is based on Formula (3):

$$\boldsymbol{C}_{t_i} = \boldsymbol{C}_{\text{i}} \boldsymbol{e}^{-\boldsymbol{k}\boldsymbol{t}_{\text{i}}} \quad (3)$$

where

C_{ti} is the concentration at time t_{i} (microbes (CFU or PFU/m^3));

C_{i} is the concentration at t = 0 minutes;

k is the decay rate constant (minutes^{-1});

t_{i} is the time (minutes);

e is Euler's number, 2.718…

8.4.2 The decay constant, k, is obtained using the linear regression on the lnC_{ti} and t_{i} using Formula (4):

$$k = \frac{S_{xy}}{S_{xx}} \quad (4)$$

where

$$S_{xy} = \sum_{i=1}^{n} t_i \ln C_{t_i} - \frac{1}{n}\left(\sum_{i=1}^{n} t_i\right)\left(\sum_{i=1}^{n} \ln C_{t_i}\right) \quad (5)$$

$$S_{xx} = \sum_{i=1}^{n} (t_i)^2 - \frac{1}{n}\left(\sum_{i=1}^{n} t_i\right)^2 \quad (6)$$

When the above calculations are used for **natural decay** measurements in 7.2, the results represent the **natural decay** rate in test chamber air.

When the above calculations are used for the total microbial removal measurements in 7.3, the results represent the **air cleaner** microbial removal rate or **microbial reduction**, including the **natural decay** rate.

8.5 Computation of the standard deviation estimate for the slope of one regression line

Step 1: Calculation of standard deviation of a regression line. An estimate of the standard deviation about the regression line is calculated as in Formula (7):

$$S_{\text{reg}} = \sqrt{\frac{1}{n-2}\sum_{i=1}^{n}\left(\ln C_{t_i} - b - mt_i\right)^2} \quad (7)$$

where

S_{reg} is the estimated value of the overall standard deviation;

n is the number of pairs of data points used in the regression;

b is the intercept of the regression line (equivalent to an estimated **initial concentration**); expressed as ln (**microbes** (CFU or PFU/m^3));

m is the slope of the regression line expressed as min^{-1};

t_{i} is the time (in minutes) at data point "i";

$\ln C_{\text{ti}}$ is the natural logarithm of the concentration at time t_{i}.

Step 2: Calculation of standard deviation estimate of the regression line slope. The standard deviation estimate of the slope of the regression line is calculated as in Formula (8):

$$S_{\text{slope}} = \sqrt{\frac{S_{\text{reg}}^2}{S_{xx}}} \quad (8)$$

8.6 Performance calculation

The performance of an **air cleaner** is represented by an m-clean air delivery rate (m-**CADR**). The method for calculating the clean air delivery rate is given in Formula (9):

$$\text{m-CADR} = V\,(k_{\text{td}} - k_{\text{nd}}) \quad (9)$$

where

m-CADR is the clean air delivery rate for microbes(m^3/h);

V is the volume of test chamber, m^3;

k_{td} is the total decay rate with operating the **air cleaner**, hour^{-1};

k_{nd} is the **natural decay** rate without operating the **air cleaner**, hour^{-1}.

8.7 Calculation of the standard deviation estimate of the CADR for a single test

The standard deviation estimate as described above for each of the natural and total decay lines can be combined using error propagation analysis on the equation used to compute the m-CADR in 8.6.

The test chamber volume is taken as a constant and the following equation is used to estimate the standard deviation for the m-CADR computed for the pair of regression lines. See Formula (10)

$$S_{CADR} = 30\sqrt{S^2_{(\text{slope},k_e)} + S^2_{(\text{slope},k_n)}} \quad (10)$$

where

S_{CADR} is the estimated standard deviation for m-CADR (m^3/h);

$S(\text{slope},k_e)$ is the estimated standard deviation of the total decay rate ($hour^{-1}$);

$S(\text{slope},k_n)$ is the estimated standard deviation of the natural decay rate ($hour^{-1}$);

30 is the volume of the test chamber in m^3, treated as a constant, which is used to put the estimated standard deviation value in m-CADR units.

NOTE For companies that want to convert to the English system, a simple conversion method can be used between the English system of measurement and metric system: 1 cfm = 1,699 $m^3\ h^{-1}$.

9 Test report

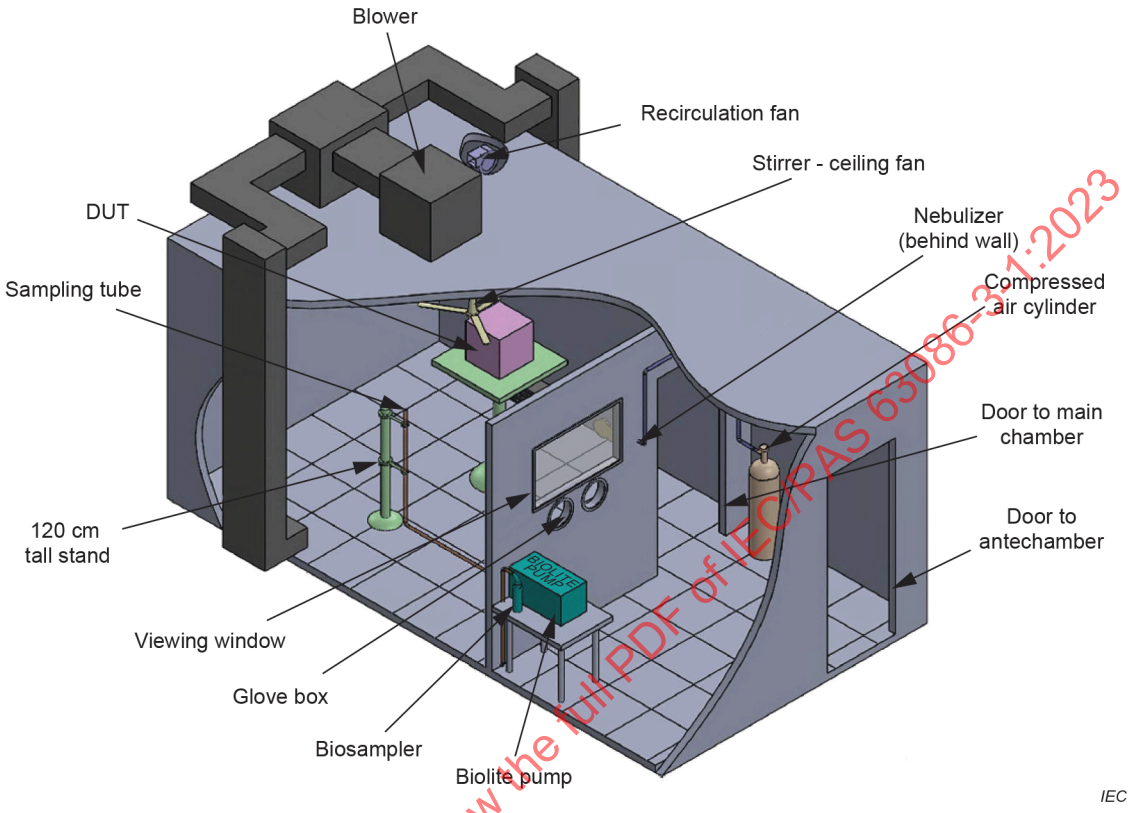
The test report shall include the following:

1) the standard name of the test;
2) the **Microbe**(s) used, and nebulization fluid characteristics/specifications;
3) volume of the test chamber, name and flow rate of the used air sampler, the volume flow rate of the stirrer, and the volume flow rate of the recirculation fan;
4) room setup diagram including the direction of the fan airflow, and the DUT in relation to the sampling port;
5) test conditions, including the **air cleaner** operating mode, test time and operation levels for component technology (i.e., Ozone generation or hydroxyl radical levels, etc.) The test may be performed under other conditions. These conditions shall be clearly documented;
6) the rate of **natural decay** of airborne test **microbe**;
7) test result as stated by elements of m-CADR, such as natural decay and total decay concentration, by **microbe** used. Clearly state which units were used in the calculation (m^3/h or ft^3/min)
8) the volume of air from the extraction,
9) dilution information,
10) all the details necessary for the identification of the test laboratory,
11) the name(s) and signature(s) of the person(s) in charge of testing,
12) product-related information (client, model, etc.)
    - Catalog number (i.e. Model number),
    - Serial number,
    - Electrical ratings of **DUT** from data submitted or from the rating plate (i.e. Nameplate) affixed to the **DUT**.

Please see Annex E for a suggested test report using this method.

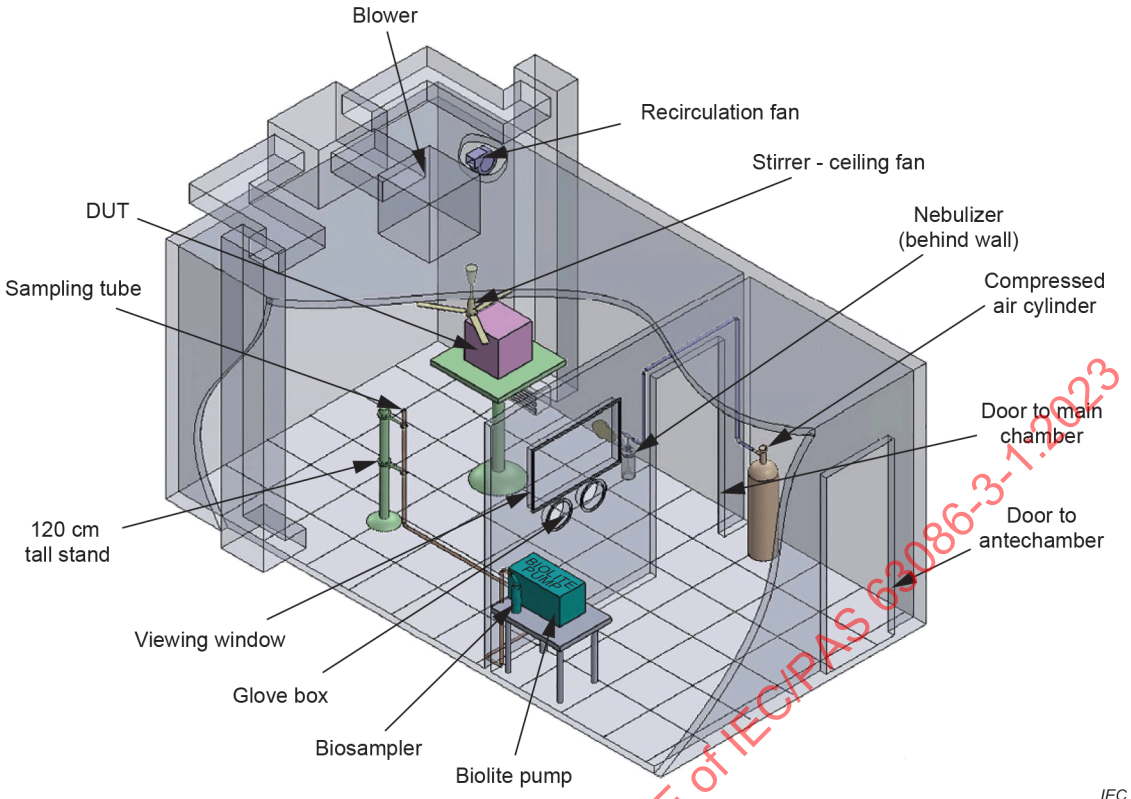
Annex A
(informative)

Test chamber



NOTE Part labelled "Glove box" is the opening through which gloves may be placed.

Figure A.1 – Example – Main chamber with a glove box for external operation



NOTE Part labelled "Glove box" is the opening through which gloves may be placed, if needed.

Figure A.2 – See-through of example chamber

Annex B
(informative)

Example calculations for machine decay

Figure B.1 gives a graphical representation for decay curves. Subtract natural decay from total decay to calculate machine decay.

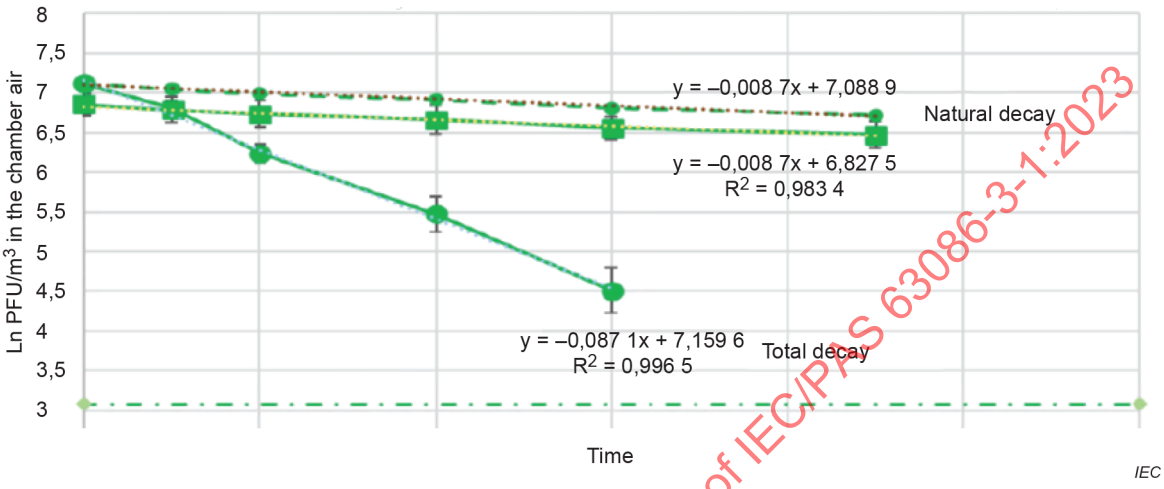


Figure B.1 − Graphical representation for decay curves