BS EN 16846-1:2017

BSI Standards Publication

Photocatalysis — Measurement of efficiency of photocatalytic devices used for the elimination of VOC and odour in indoor air in active mode

Part 1: Batch mode test method in closed chamber

National foreword

This British Standard is the UK implementation of EN 16846-1:2017.

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English Version

Photocatalysis - Measurement of efficiency of photocatalytic devices used for the elimination of VOC and odour in indoor air in active mode - Part 1: Batch mode test method in closed chamber

Photocatalyse - Mesure de l'efficacité des dispositifs photocatalytiques servant à l'élimination, en mode actif, des COV et des odeurs dans l'air intérieur - Partie 1 : Méthode d'essai en enceinte confinée

Photokatalyse - Messung der Effizienz photokatalytischer Geräte im aktiven Modus zur Beseitigung flüchtiger organischer Verbindungen (VOC) und von Geruch in der Raumluft - Teil 1: Batch-Betrieb-Prüfverfahren mit einer geschlossenen Kammer

This European Standard was approved by CEN on 14 November 2016.

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European foreword

This document (EN 16846-1:2017) has been prepared by Technical Committee CEN/TC 386 “Photocatalysis”, the secretariat of which is held by AFNOR.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by September 2017, and conflicting national standards shall be withdrawn at the latest by September 2017.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN shall not be held responsible for identifying any or all such patent rights.

EN 16846, *Photocatalysis — Measurement of efficiency of photocatalytic devices used for the elimination of VOC and odour in indoor air in active mode*, is dedicated to photocatalytic devices for indoor air cleaning and is constituted by the following parts:

— *Part 1: Batch mode test method in closed chamber*;

— *Part 2: In situ test under real conditions*.

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1 Scope

This European Standard describes the methodologies to be used in a laboratory air tight chamber to test prototype or commercial air cleaner systems with a maximum flow rate of 1,000 m^3/h used for photocatalytic indoor air remediation.

It is applicable to the treatment of atmospheres that are representative of the air inside buildings and workplaces.

This protocol is applicable solely to photocatalytic systems alone or to combined systems that include a photocatalytic function. The photocatalytic function is demonstrated by verifying the mineralization of model VOCs to form CO_2.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 13725, *Air quality - Determination of odour concentration by dynamic olfactometry*

EN ISO 16017-1:2000, *Indoor, ambient and workplace air - Sampling and analysis of volatile organic compounds by sorbent tube/thermal desorption/capillary gas chromatography - Part 1: Pumped sampling (ISO 16017-1:2000)*

ISO 16000-3, *Indoor air — Part 3: Determination of formaldehyde and other carbonyl compounds in indoor air and test chamber air — Active sampling method*

ISO 16000-6:2011, *Indoor air — Part 6: Determination of volatile organic compounds in indoor and test chamber air by active sampling on Tenax TA sorbent, thermal desorption and gas chromatography using MS or MS-FID*

3 Terms and definitions

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

3.1
photocatalyst
substance that performs one or more functions based on oxidation and reduction reactions under photoirradiation, including decomposition and removal of air and water contaminants, deodorization, and antibacterial, self-cleaning and antifogging actions

3.2
volatile organic compounds
VOC
all three classes of VOC as per EN ISO 16000-6:2011, 3.1,3.2 and 3.3

3.3
system
commercial or prototype air cleaner system that includes at least one photocatalytic function with or without a fan function

3.4
chamber blank analysis
value of an analysis of the composition of the air inside the air tight chamber with no air cleaner system inside the chamber and after venting by taking sampling on special cartridge for VOC and aldehyde

3.5
test blank analysis

value of an analysis of the composition of the air inside the air tight chamber with an air cleaner system operating inside the chamber, but with no pollutant introduced, by taking sampling on special cartridge for VOC and aldehyde

3.6
cartridge blank analysis

value of an analysis of the sorbent cartridge prior to use for the analysis of reaction by-products

3.7
TWA

time-weighted average, measured or estimated over an 8-hour work schedule

3.8
Short-Term Exposure Limit

STEL

ceiling value that should never be exceeded in an occupational environment where these values are measured during a maximum period of 15 min

Note 1 to entry: TLV (threshold limit value) is replaced by STEL.

3.9
indoor air

air inside a closed environment

3.10
mineralization of model VOCs

oxidation of model VOCs to form CO_2

4 Symbols and abbreviations

ln : natural logarithm

PE : polyethylene

PMMA : Poly(methyl methacrylate)

ppbv : parts per billion in volumes [10^{-9}]

ppmv : parts per million in volumes [10^{-6}]

PTFE : Polytetrafluoroethylene

RH : relative humidity

5 Principle

The system is placed inside an air tight chamber and exposed to a model VOC mixture. Changes in pollutant concentrations due to operation of the system, as well as the production of CO_2 and the appearance of by-products, are measured against time.

6 Apparatus

Standard laboratory apparatus, in addition to the following elements:

6.1 Air tight chamber.

Air tight chamber with a volume of at least one m^3 fitted with an air homogenizing device with a nominal hourly flow rate (m^3/h) 100 times greater than the volume of the chamber. The ratio between the system volume and the chamber volume shall be less than or equal to 0,10 (see Figure A.1 in Annex A).

The chamber has sampling ports and throughputs for electrical connections.

The behaviour of the material used to build the chamber in relation to pollutants, UV radiation, sorption and degassing phenomena shall be known and controlled.

Examples of materials: glass, PMMA, PE, PTFE, stainless steel, etc.

6.2 Analysis apparatus.

All apparatus used for continuous monitoring of the air composition inside the chamber in the concentration range specified in Clause 6 can be used with a detection limit at around 5 ppbv for the test conditions stated in 7.1.2, or at 10 % of the initial concentration of the relevant pollutants as specified in 7.1.3.

Analyses of reaction by-products are performed according to the methods adapted to the characterization of the indoor air quality.

Reference will be made to the following standards: ISO 16000-3 and ISO 16000-6;

A description of a few sorbents are included in Annex B of this standard.

See also EN ISO 16017-1:2000, Annexes C, D and E.

Temperature and relative humidity are analysed on line by appropriate analysers.

7 Test performance

7.1 Pollutants and concentrations

7.1.1 General

There are two possible concentration ranges depending on the outcome of the test.

For the cleaning of indoor air, the test is carried out in the range ppbv to ppmv.

Where the issue is directly related to the exposure of workers, the concentration will be related to the TWA and STEL of the relevant products.

7.1.2 Indoor air

This standard requires the use of the following mixture (pollutants representative of the chemical families found in the indoor air pollution): Acetone, acetaldehyde, heptane, toluene and formaldehyde.

The test is to be run on both concentrations.

- test with *search for reaction by-products:*

  (50 ± 25 %) ppbv per compound at 22 °C and 1 atm.

- test used *to demonstrate the photocatalytic activity with monitoring of the mineralization of VOCs into* CO_2*:*

  (1 000 ± 10 %) ppbv per compound at 22 °C 1P_{atm}.

NOTE According to the present state of knowledge of analytical techniques, this test is the only means of monitoring the conversion into CO_2 against ambient concentration.

7.1.3 Industrial issue and challenge

Concentrations and pollutants will be chosen to reflect the issues and challenges currently facing the industrial sector. VOCs will undergo compound-by-compound analysis (e.g. by gas chromatography).

NOTE According to the present state of knowledge of analytical techniques, this test is the only means of monitoring the conversion into CO_2 against ambient concentration.

7.2 Validation of the chamber

The chamber is validated by measuring its leak tightness via its leakage rate of an inert gas or by pollutant mixture disappearance.

It is necessary to check that the air homogenizing fan does not generate VOCs.

The amount of VOCs released by the chamber prior to the test and captured on sorbent cartridges shall be less than 5 ppbv/compounds and less than 50 ppbv for the sum.

It is recommended that the chamber be validated by injecting the reaction mixture into the chamber with no system present and monitoring its behaviour during an 8-h period with the air homogenizing fan switched on.

Measured losses shall be less than 10 % of the initial concentration during this period.

The chamber shall be validated following each use of a new pollutant.

7.3 Test conditions

Initial test conditions are as follows:

- chamber temperature (22 ± 2) °C;
- relative humidity in the chamber of (50 ± 5) %.

NOTE The humidity level in the chamber is not regulated during the test. Temperature T (°C) and relative humidity RH (%) are recorded continuously.

The chamber is considered to be clean when the compounds to be analysed are not detected by the analysis system run prior injecting the pollutants (examples in Annexes B and C).

For industrial-sector issues, the total measured VOC concentration shall be less than 5 % of the VOCs injected into the chamber.

7.4 Test procedure

The system is placed in the centre of the chamber which is then flushed/vented with clean humidified air or with any other process that guarantees the RH conditions and blank quality specified in 7.3 for a period of one night.

The system is switched on during venting of the chamber in order to make sure that the system has been cleaned with clean air before taking any measurement. The system is operated for a period of 2 h during which data on T°, RH and VOCs is recorded prior injecting the pollutants. The system is then switched off.

The analysis systems that continuously monitor VOCs and CO_2 are operating prior the injection of the pollutants and throughout the whole period of analysis.

7.5 Mineralization test with continuous monitoring of CO_2 levels

The mixture at 1 000 ppbv per compound is injected into the chamber.

Any technique for generating the test atmosphere in the range of concentrations specified in 7.1 can be used.

EXAMPLE A simple technique for generating a polluted atmosphere is to prepare the mixture using an analytical balance, and then, using a micro-syringe, to inject a precise volume of this mixture through a septum into a glass weighing scoop making sure there is no contact with the materials making up the chamber.

The air is homogenized by the external fan.

Once the air has been homogenized, this homogenizing fan is switched off and the system is switched on.

NOTE It may be difficult to homogenize the mixture with certain systems, such as those that contain activated carbon for example. In this case, it will be necessary to determine the time required to homogenize the mixture in the empty chamber and then take this time as the reference for starting up the system.

The test is run until 90 % of VOCs are removed, with a maximum test time of 24 h.

7.6 Analysis of reaction by-products and ozone

A detection procedure targeting ozone and reaction by-products is run systematically for the mixture at 50 ppbv per compound (aldehydes, VOC, ozone).

By-products are analysed by the techniques used to characterize indoor air (see ISO 16000-3 and ISO 16000-6).

The following samples are taken:

- Chamber blank analysis prior to injection of the pollutants
- After the mixture has been homogenized and the system switched on

T0	interval 0 min to 15 min (system start-up)
T30	interval 30 min to 45 min
T120	interval 120 min to 135 min

The times at which the samples are taken are adapted to fit system efficiency. For example in Annex F, the time for removal is less than 30 min and times above shall be changed accordingly.

The total sample volume shall not exceed 5 % of the volume of the chamber.

Should it prove necessary to take several samples simultaneously, these samples shall be taken at separate sampling points. Use of the Y distribution pattern is prohibited.

Ozone is measured by a dedicated probe with a detection limit of 20 ppb, in order to detect ozone production/accumulation.

Reaction by-products for high concentrations (>ppmv) (industrial environment) will be sought if the investigation concerns occupational exposure to chemicals.

7.7 Olfactive efficiency of the system

The system's ability to eliminate odours may be studied by taking a sample at the beginning (following injection of the pollutants and homogenizing) and end of the test.

These samples are analysed by dynamic olfactometry in accordance with EN 13725.

8 Test report

The test report shall include at least the following information:

a) purpose of the investigation: information supplied by the person requesting the investigation;

b) methodology: reference to this standard, volume of the chamber, analysis techniques used, pollutant generation, etc.;

c) plot of the behaviour of pollutants and CO_2 against time (ppbv and/or μg/m^3); and a comparison graph between the CO_2 produced and the CO_2 expected from the VOC degradation (see Figure E.2);

d) plot of the development of T °C and % RH against time (see Figure E.1);

e) table of identified by-products (5 ppbv after subtracting the blank); this table shall have 3 columns: chamber blank analysis, sample, sample minus the blank (the cartridge blank analysis should be taken into account);

f) % mineralization at the end of the test; calculated from the CO_2 produced against the expected CO_2 concentration;

g) plot of the behaviour of ozone against time;

h) all test observations, such as changes over time in temperature and % RH outside the limits set by this standard;

i) apparatus quantification and detection limits;

j) give the CADR.

Clean Air Delivery Rate (CADR) is calculated at low concentration test, with a correlation coefficient (r2) equal to 0,98 or more. All chemical concentrations shall be expressed as mg of C (Carbon) /m^3 and time in hours. (See example in Annex F.)

NOTE If a correlation coefficient of 0,98 cannot be reached then the CADR cannot be determined.

$$ln\left(\frac{C}{C_0}\right) = -\left(k_n + \frac{CADR}{V}\right)t \text{ with } k_n = 0 \qquad (1)$$

where

C: chemical concentration at time t (mg C/m^3)

C_0: chemical concentration at time t_0

V: volume of the test chamber (m^3)

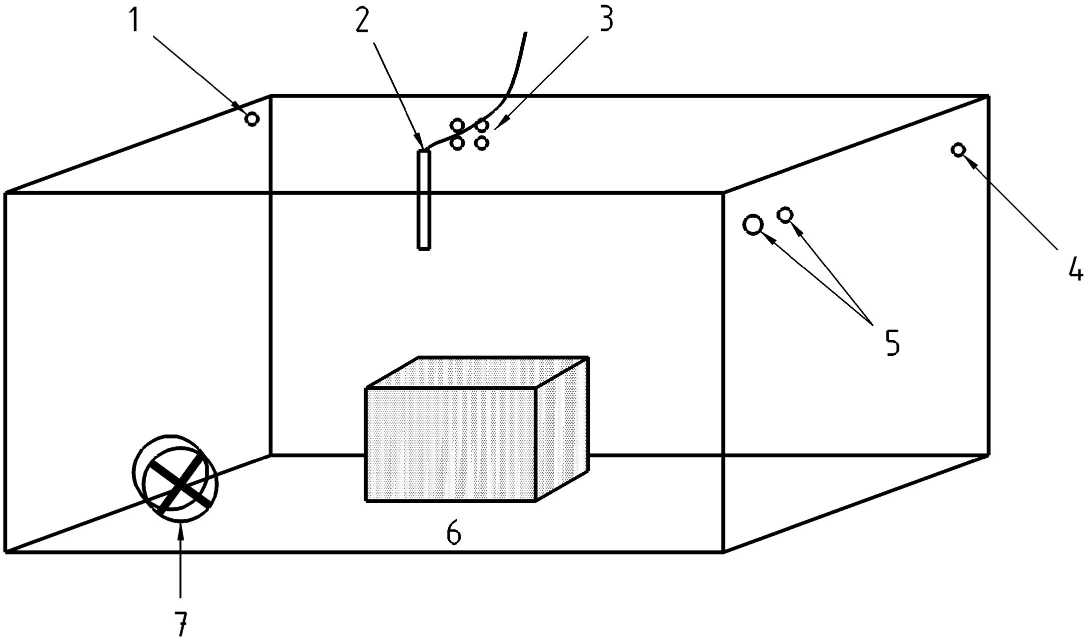
t: time (h)

CADR Clean Air Delivery Rate (m^3/h)

k_n: constant obtained from the blank test. $k_n = 0$ if no adsorption/leak are present.

Annex A
(informative)

Schematic diagram of an air tight chamber



Key

1	injection of the mixture
2	humidity and temperature probe
3	cartridge sampling
4	online sampling
5	electrical connection throughput
6	system
7	external fan

Figure A.1 — Schematic diagram of an air tight chamber

Annex B
(informative)

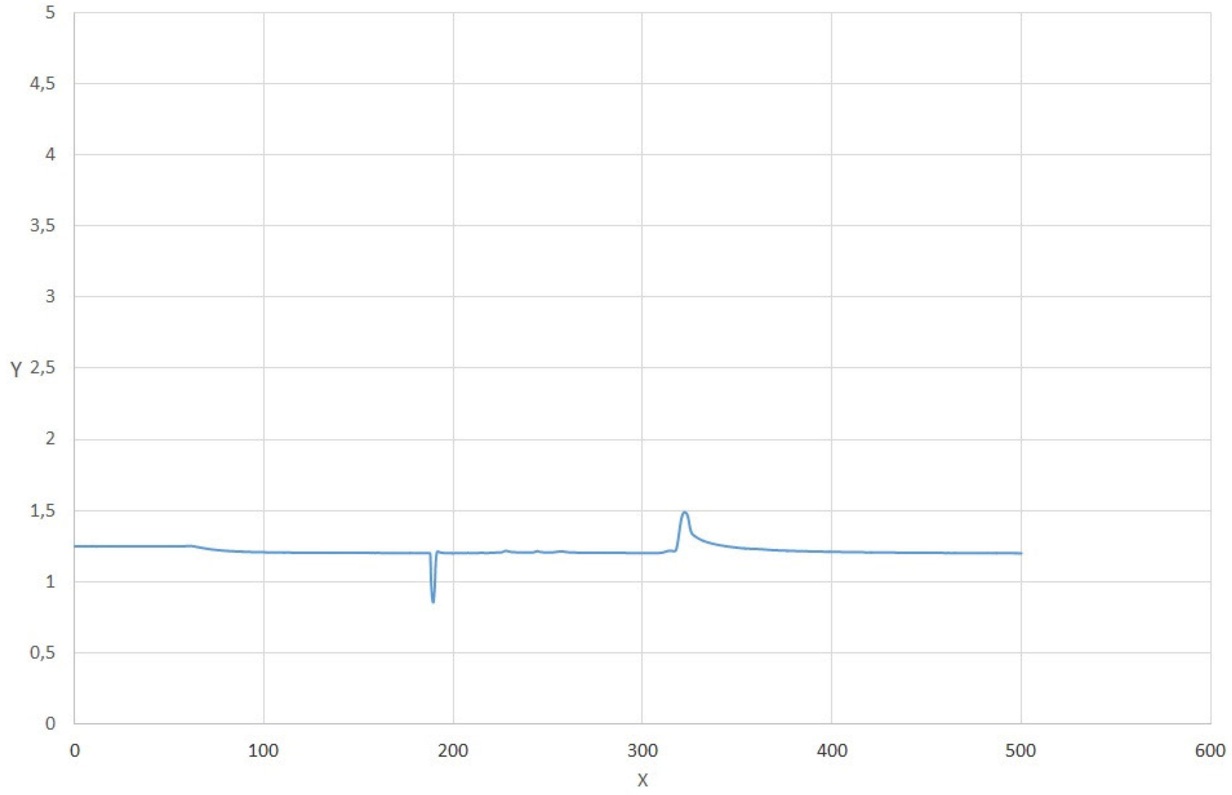
Types of sorbent apparatus for thermal desorption cartridges

Table B.1 — Types of sorbent apparatus for thermal desorption cartridges

Apparatus	**Molecule, volatility**	**Max. operating temp. °C**	**Specific surface m^2/g**	**Example of compounds**
CarbotrapC CarbopackC Ansortb GCB2	n-C_8 to n-C_{20}	> 400	12	Alkyl benzene and aliphatics
Carbotrap CaropackB Anasorb GCB1	(nC_4) nC_5 to nC_{14}	> 400	100	Large variety of VOC
Tenax TA	bp 100 °C up to 400 °C n-C_7 to nC_{30} C_2 to C_6 as per bp	350	35	Aromatics, possibility of interference during the heating phase: benzene, toluene
Tenax GR	bp 100 °C up to 400 °C n-C_7 to nC_{30}	350	35	Same as Tenax TA
Chromosorb 102	bp 50 °C up to 200 °C	250	350	Large variety of VOC including an oxygen-containing compound Significant background contribution
Chromosorb 106	bp 50 °C up to 200 °C	250	750	Large variety of VOC including an oxygen-containing compound Significant background contribution
Porapak Q	bp 50 °C up to 200 °C nC_5 to nC_{12}	250	550	Large variety of VOC including an oxygen-containing compound
Porapak N	bp 50 °C up to 200 °C nC_5 to nC_8	180	300	Specific to volatile nitriles: acrylonitrile, acetonitrile, propionitrile, also for pyridine and alcohol EtOH, MEK
Spherocarb	−30 °C 150 °C C_3 to n-C_8	> 400	1200	Suitable for very volatile compounds: ethylene oxide, CS, CHCl, and also for polar compounds
Carbosieve SIII Carboxene 1000 Anasorb CMS	−60 °C 80 °C C_2 to C_5	400	800	Suitable for very volatile compounds
Zeolite Molecular sieve 13X	−60 °C 80 °C	350		Used specifically for 1,3 butadiene and N_2O
Sorbent cartridges can be made of different sorbents (multi-bed).				

Annex C
(informative)

Examples of a chamber blanks analysis



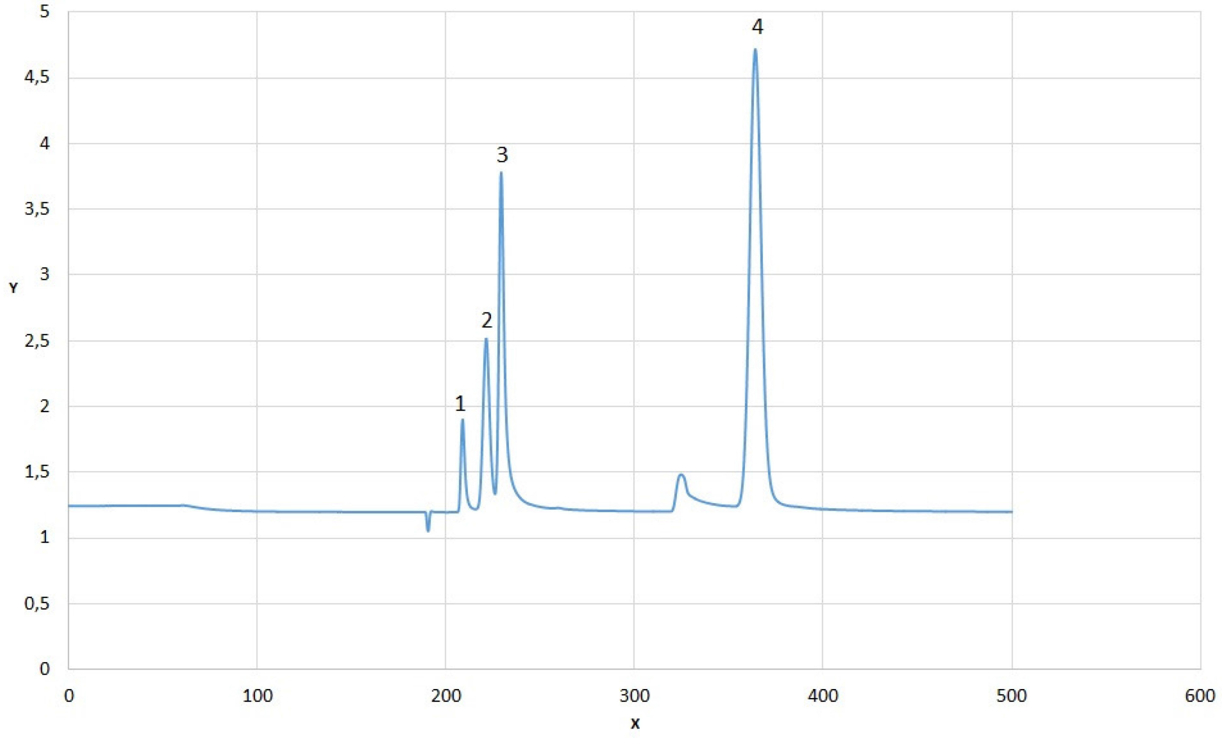
Key

X	time, expressed in second
Y	response (M counts)

Figure C.1 — Chamber blank analysis

Annex D
(informative)

Analysis of the reaction mixture



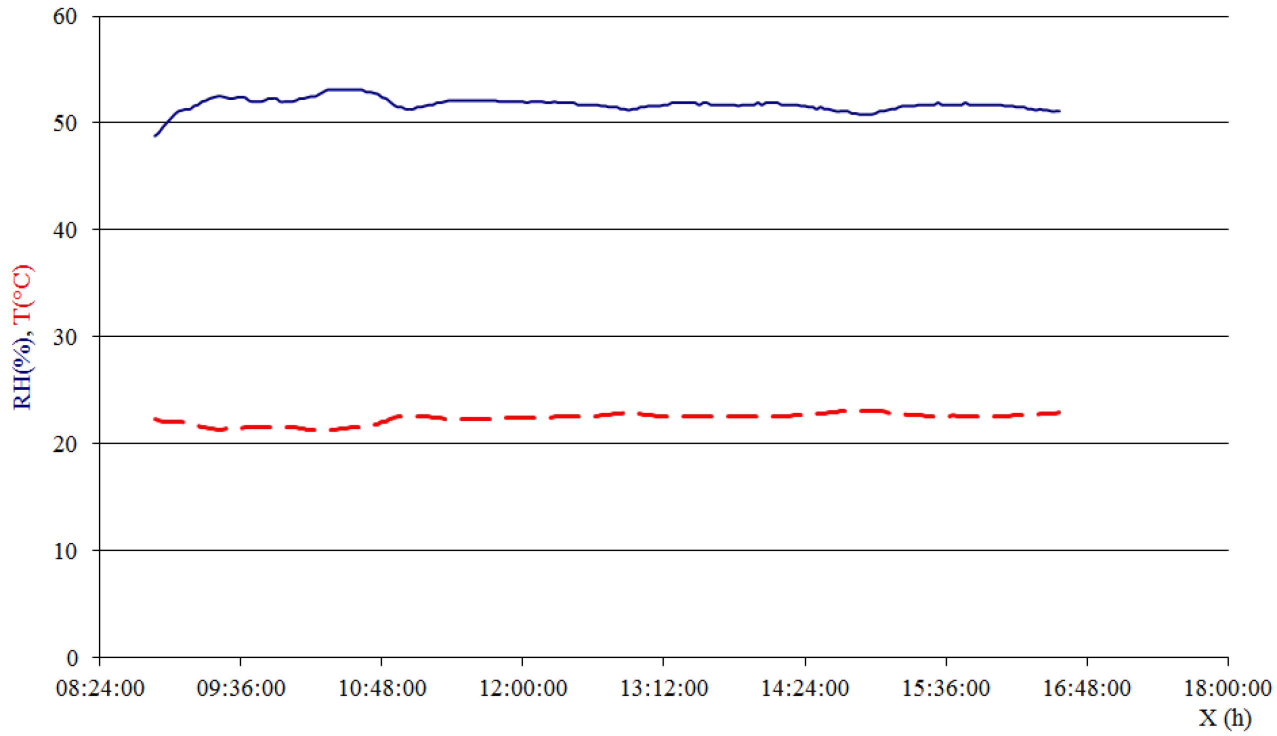
Key

X time, expressed in seconds
Y response (M counts)
1 acetaldehyde
2 n-heptane
3 acetone
4 toluene

Figure D.1 — Analysis of the reaction mix – Pollutant injection: acetaldehyde, n-heptane, acetone, and toluene

Annex E
(informative)

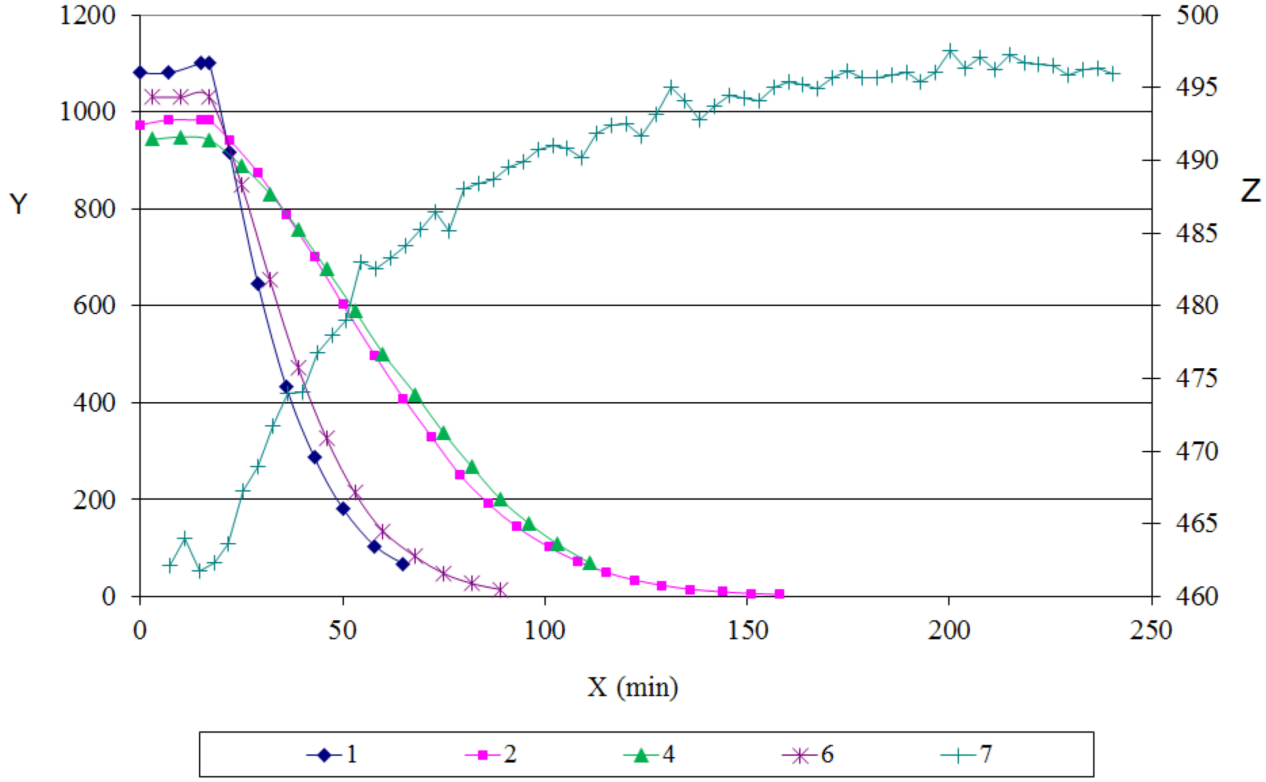
Example of a plot of temperature and relative humidity, as well as developments in pollutants and CO_2



Key

X	time, expressed in hours
Y	RH, expressed in % and T expressed in °C RH values in plain line T values in dotted line

Figure E.1 — Plot of temperature and relative humidity



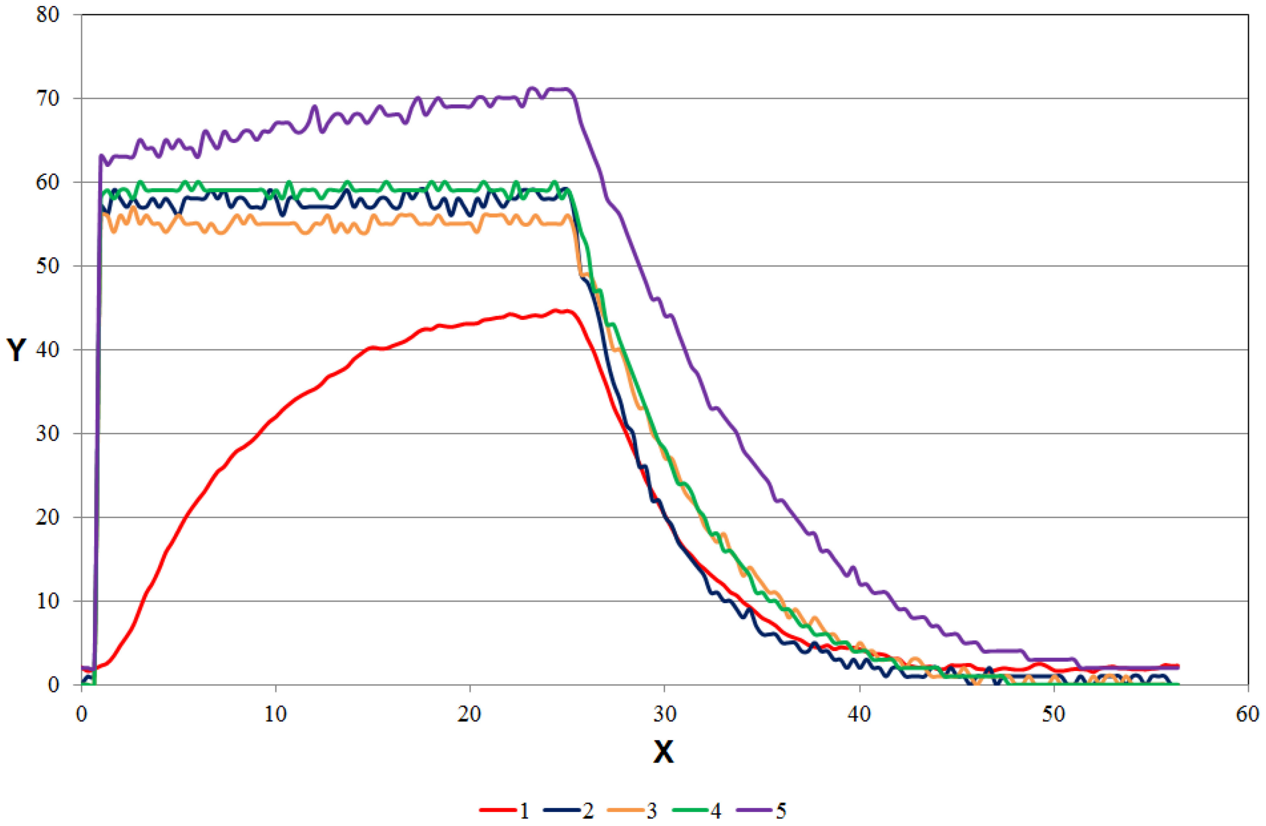
Key

X	time, expressed in minutes
Y	concentration, expressed in ppbv
Z	concentration of CO_2, expressed in ppmv
1	Acetaldehyde
2	Acetone
4	Heptane
6	Toluene
7	CO_2, expressed in ppmv

Figure E.2 — Development of pollutants and CO_2 against time

Annex F
(informative)

Example of test at low concentration with formaldehyde



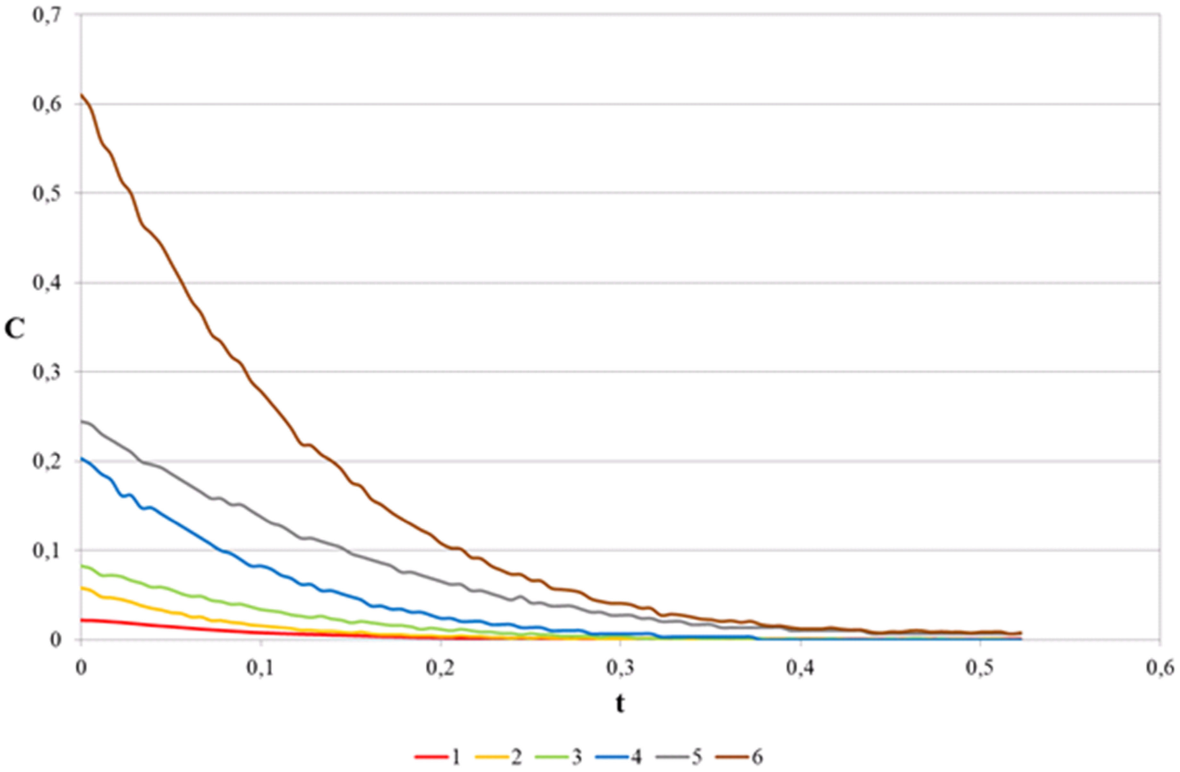
Key

X	time, expressed in minutes
Y	concentration, expressed in ppbv
1	Formaldehyde
2	Acetaldehyde
3	Acetone
4	Toluene
5	n-Heptane

Figure F.1 — Example of test at low concentration with formaldehyde

Annex G
(informative)

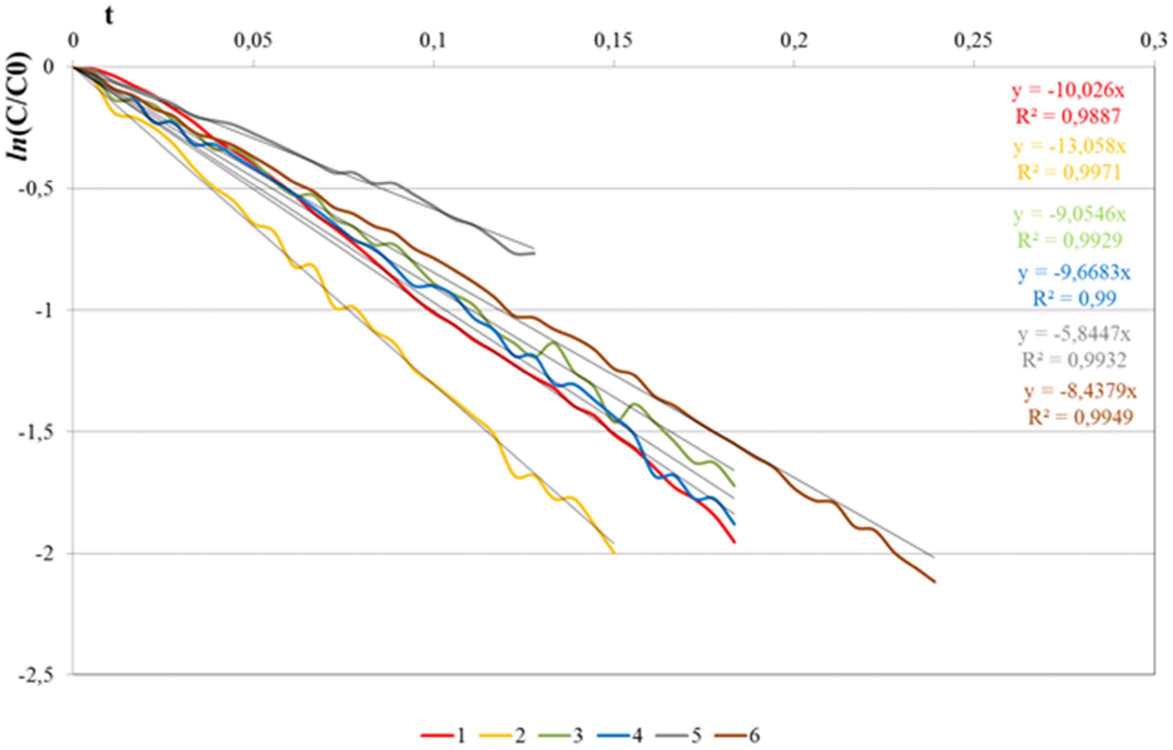
CADR calculation



Key

t	time, expressed in hours
C	concentration, expressed in mg C/m^3
1	Formaldehyde
2	Acetaldehyde
3	Acetone
4	Toluene
5	n-Heptane
6	Sum

Figure G.1— Concentration (mg C/m^3) versus time



Key

t	time, expressed in hours
C	concentration, expressed in mg C/m^3
1	Formaldehyde
2	Acetaldehyde
3	Acetone
4	Toluene
5	n-Heptane
6	Sum

Figure G.2 — *ln*(C/C$_0$) versus time in hours

Annex H
(informative)

Calculation of CADR

$$ln\left(\frac{C}{C_0}\right)=-\left(k_n+\frac{CADR}{V}\right)t \text{ with } k_n = 0 \qquad \text{(H.1)}$$

where

C : chemical concentration at time t (mg C/m^3)
C_0 : chemical concentration at time t_0
V : volume of the test chamber (m^3)
t : time (h)
: *CADR* (m^3/h)
k_n : constant obtained from the blank test. (k_n = 0 if no adsorption/leak are present).

Table H.1 —calculation of CADR with a volume V = 1,2m^3

Compound	Formaldehyde	Acetaldehyde	Acetone	Toluene	n-Heptane	sum
CADR/V (1/h)	10	13	9	10	6	8
CADR (m^3/h)	12	16	11	12	8	10

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