BS EN 13936:2014

BSI Standards Publication

Workplace exposure — Procedures for measuring a chemical agent present as a mixture of airborne particles and vapour — Requirements and test methods

...making excellence a habit.™

National foreword

This British Standard is the UK implementation of EN 13936:2014.

The UK participation in its preparation was entrusted to Technical Committee EH/2/2, Work place atmospheres.

A list of organizations represented on this committee can be obtained on request to its secretary.

ISBN 978 0 580 78057 8

ICS 13.040.30

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 January 2014.

Amendments issued since publication

Date	Text affected

EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN 13936

January 2014

ICS 13.040.30

English Version

Workplace exposure - Procedures for measuring a chemical agent present as a mixture of airborne particles and vapour - Requirements and test methods

Exposition sur les lieux de travail - Mesurage de l'agent chimique sous forme de mélange de particules aériennes et de vapeur - Exigences et méthodes d'essai

Exposition am Arbeitsplatz - Messung eines als Mischung aus luftgetragenen Partikeln und Dampf vorliegenden chemischen Arbeitsstoffes - Anforderungen und Prüfverfahren

This European Standard was approved by CEN on 30 November 2013.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and United Kingdom.

EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

CEN-CENELEC Management Centre: Avenue Marnix 17, B-1000 Brussels

Ref. No. EN 13936:2014 E

Contents

Page

Foreword

This document (EN 13936:2014) has been prepared by Technical Committee CEN/TC 137 “Assessment of workplace exposure to chemical and biological agents”, the secretariat of which is held by DIN.

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 July 2014, and conflicting national standards shall be withdrawn at the latest by July 2014.

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

According to the CEN-CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

Introduction

EN 482 specifies general requirements for the performance of procedures that methods for the measurement of the concentration of chemical agents in workplace atmospheres should meet. These performance criteria include maximum values of expanded uncertainty achievable under prescribed laboratory conditions for the methods to be used. Chemical agents in workplace air are often present in both gaseous and non-gaseous phases at the same time and therefore validated methods are required that can measure the combined concentration of the chemical agent in both phases. Examples include: processes that generate aerosols of volatile or semi-volatile liquids or solids such a paint spraying, metalworking with coolants and lubricants, acid pickling etc. and hot processes which generate vapours of chemical agents that are normally in the liquid or solid phase under ambient conditions, e.g. road surfacing with bitumen.

For health-related sampling of mixed-phase aerosols, it is necessary to measure the mass concentration of the inhalable fraction of hazardous chemical agents, regardless of whether they are present as airborne particles or vapour. This generally means drawing air through two or more collection media in series. If a chemical agent is collected in the form of airborne particles and it has a significant vapour pressure under ambient conditions, it will wholly or partly volatilise during sampling. Subsequently the resulting vapour needs to be collected so that the total mass of the chemical agent can be measured; the chemical agent can also be lost from the collected airborne particles after sampling if it is not stabilised.

In some cases, it might also be necessary to measure the distribution of chemical agents between the particulate and vapour phases as well as the mass concentration of the inhalable fraction. For example, there can be compounds whose toxicology is known to differ significantly depending on whether they exist as airborne particles or vapour. In addition, control measures in the workplace can depend on which phase dominates. Exposure limits can be phase-specific. However, the separate quantification of airborne particles and vapour is technically complex and subject to error using existing sampling technologies. For this reason, this European Standard is not applicable to methods that differentiate between the sampled airborne particles and vapour.

1 Scope

This European Standard specifies performance requirements and test methods for the evaluation of procedures for measuring a chemical agent present as a mixture of airborne particles and vapour in workplace air.

This European Standard establishes general principles to enable developers and users of mixed-phase samplers and methods to adopt a consistent approach to method validation and provides a framework for the assessment of method performance in accordance with EN 482.

Annex A of this European Standard gives guidance on possible approaches to sample mixtures of airborne particles and vapour and Annex B gives information about their physical behaviour.

This European Standard is not applicable to methods that differentiate between the sampled airborne particles and vapour.

This European Standard is not applicable to a chemical agent present in different chemical and physical forms (for example, mercury in the form of Hg (0) and Hg (II)).

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 481, *Workplace atmospheres - Size fraction definitions for measurement of airborne particles*

EN 482, *Workplace exposure - General requirements for the performance of procedures for the measurement of chemical agents*

EN 1076, *Workplace exposure - Procedures for measuring gases and vapours using pumped samplers - Requirements and test methods*

EN 1540:2011, *Workplace exposure - Terminology*

prEN 13205-1[1], *Workplace exposure — Assessment of sampler performance for measurement of airborne particle concentrations — Part 1: General requirements*

EN 13890, *Workplace exposure - Procedures for measuring metals and metalloids in airborne particles - Requirements and test methods*

EN ISO 13137, *Workplace atmospheres - Pumps for personal sampling of chemical and biological agents - Requirements and test methods (ISO 13137)*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 1540:2011 and the following apply.

3.1
single component aerosol

aerosol in which the airborne particles and vapour are composed of the same chemical agent

---

[1] To be published.

3.2
multiple component aerosol
aerosol containing more than one chemical agent, each of which can be present in the form of airborne particles and/or vapour

3.3
vapour sampler
pumped sampler or diffusive sampler that is used to collect vapour

4 Requirements

4.1 General

Regardless of the combination of samplers used, the measurement procedure used shall comply with the requirements of EN 482 and with the requirements of EN 1076, EN ISO 13137, prEN 13205-1 and EN 13890, as appropriate.

It is the responsibility of the manufacturer or of those who assemble mixed-phase samplers to ensure that the method complies with the requirements for expanded uncertainty under the specified laboratory conditions given in this document, including the environmental influences that can be expected to affect performance.

4.2 Sampler requirements

Measurement procedures shall specify the use of a mixed-phase sampler designed to collect the inhalable fraction of airborne particles, as defined in EN 481, and vapours. The sampler shall comply with prEN 13205-1 and with the performance requirements for pumped samplers prescribed in EN 1076.

The back pressure of the mixed-phase sampler shall not exceed the maximum values specified in EN ISO 13137.

A mixed-phase sampler may comprise of an inhalable sampler in combination with one or more vapour samplers. In such circumstances, the dead volume of the sampling train shall be kept to a minimum and any connection shall be made of an inert material that does not retain the chemical agent of interest.

NOTE When a mixed-phase sampler comprises a vapour sampler in combination with an inhalable sampler and there are flow rate compatibility issues, it is possible to split the air flow from the inhalable sampler through more than one vapour sampler.

4.3 Pumps

Measurement procedures shall specify the use of pumps complying with EN ISO 13137.

4.4 Measurement procedure requirements for mixtures of airborne particles and vapour

4.4.1 Storage test

When tested in accordance with the procedure prescribed in 5.3, the mean analytical recovery after storage shall be at least 90 %.

4.4.2 Expanded uncertainty

The expanded uncertainty of the measurement procedure as a whole, including the measurement of airborne particles and vapour, shall comply with the requirements of EN 482.

4.4.3 Method description

The method description shall contain at least the following information:

a) a general description of the principles of the method, the approach followed to sample mixtures of airborne particles and vapour and any relevant assumptions;

b) a detailed description and identification of the system components, including all collection substrates and, for commercial devices, the name of the manufacturer(s) and the product identification(s);

c) if applicable, the recommended shelf life of the collection substrate(s);

d) the design flow rate and the pressure drop across the mixed-phase sampler at the design flow rate;

e) the recommended sampling time and, if applicable, the sampler capacity for a specific analyte;

f) methods for handling, transport and storage of samples, including storage times;

g) information on analytical methods to be applied and instructions as to whether and how wall deposits are to be included in the analysis of the collected sample;

h) the recovery efficiency for specific analytes, including the effects of concentration, loading, temperature and humidity, where applicable;

i) any known interference.

5 Test methods

5.1 Sample distribution between the collection substrate for airborne particles and the collection substrate for vapour

5.1.1 Calculate the mass of analyte to be loaded onto the collection substrates in the sample distribution tests for each combination of concentration and time prescribed in Table 1.

Table 1 — Concentration and time used for calculation of mass of analyte

Reference period	Concentration	Time
long-term	0,1 times limit value	8 h or recommended sampling time
	2 times limit value	
short-term	1 time limit value	e.g. 15 min

5.1.2 Perform sample distribution tests under each of the following two combinations of test conditions:

— relative humidity: (50 ± 5) %;

— temperature: (10 ± 2) °C and (40 ± 2) °C;

— flow rate: recommended flow rate.

NOTE One way to obtain air with the required conditions of temperature and relative humidity is to use a climatic test chamber as defined in EN 60068–3–11.

5.1.3 Set up at least six mixed-phase samplers per test and add a known mass of analyte to each collection substrate or, where the mixed-phase sampler includes more than one collection substrate, to each of the first collection substrates. Add the analyte using a micropipette or syringe, if necessary, with the analyte diluted in a non-interfering solvent.

5.1.4 Immediately after adding the analyte, draw air through the mixed-phase samplers under the prescribed test conditions.

5.1.5 Repeat 5.1.3 and 5.1.4 for each of the sample loadings calculated in 5.1.1 and under each of the two combinations of test conditions prescribed in 5.1.2.

5.1.6 Analyse each collection substrate immediately after sampling and, for each sampler, calculate the distribution coefficients for vapour and airborne particles according to Formulae (1) and (2):

$$\gamma_{\mathrm{d,p}} = \frac{m_{\mathrm{p}}}{m_{\mathrm{v}} + m_{\mathrm{p}}} \cdot 100 \qquad (1)$$

$$\gamma_{\mathrm{d,v}} = 100 - \gamma_{\mathrm{d,p}} \qquad (2)$$

where

$\gamma_{\mathrm{d,p}}$ is the distribution coefficient for airborne particles, in percent;

$\gamma_{\mathrm{d,v}}$ is the distribution coefficient for vapour, in percent;

m_{p} is the mass determined on the collection substrate for airborne particles, in milligrams;

m_{v} is the mass determined on the collection substrate for vapour, in milligrams;

Calculate the mean and the coefficient of variation of the replicate samples.

Consider the distribution coefficients between the collections substrates used:

- if, in all cases, $\gamma_{\mathrm{d,p}}$ < 10 % the collection substrate for airborne particles does not need to be analysed;
- if, in any case 10 % ≤ $\gamma_{\mathrm{d,p}}$ ≤ 90 % the collection substrates for airborne particles and vapour shall be analysed.
- if, in all cases $\gamma_{\mathrm{d,p}}$ > 90 % only the collection substrate for airborne particles needs to be analysed;

5.2 Compliance with EN 1076

Perform the tests given in EN 1076 using the procedure described in 5.1.3 and 5.1.4 except for the storage test (see 5.3).

If it is not possible to generate a test atmosphere for a mixture of airborne particles and vapour, the best approach is to use the spiking method but with the spike applied to the collection substrate of the inhalable sampler rather than the vapour sampler. The spike should be distributed as even as possible on the collection substrate.

5.3 Storage

Perform storage tests on samples that have been stabilised as prescribed in the sampling method and verify that the analytical recovery determined from the combined results from the collection substrate for airborne particles and the collection substrate for vapour meets the requirements of 4.4.1.

NOTE For a chemical agent present as a mixture of airborne particles and vapour, sampled airborne particles cannot normally be stored without sample loss unless stabilised. See A.4 and B.3.2.

5.4 Uncertainty of the measurement

5.4.1 Calculation of the combined standard uncertainty

Calculate the combined standard uncertainty u_c taking into account the relevant uncertainty components associated with airborne particles and vapour, according to Annex C.

5.4.2 Calculation of the expanded uncertainty

Calculate the expanded uncertainty of the measuring procedure, U, using a coverage factor $k = 2$, according to Formula (3):

$$U = 2 \times u_\mathrm{c} \tag{3}$$

6 Test report

The test report shall contain at least the following information:

a) detailed description and identification of the sampling system components tested, including all collection substrates and for commercial devices name of manufacturer(s) and product identification(s);

b) complete identification of test atmospheres used plus details of independent measuring methods, where used;

c) details of the pump(s) used for testing;

d) details of analytical methods used for testing;

e) determined values for recovery efficiency, blank value, sampler capacity and storage losses;

f) statistical analyses of the test results and calculations of expanded uncertainty;

g) statement of whether the acceptance criteria are met;

h) any unusual features noted during the determinations;

i) any operations not included in this European Standard that can have influence on the results;

j) the technical justification for omitting any of the tests, if done.

Annex A
(informative)

Possible approaches to sample mixtures of airborne particles and vapour

A.1 General

General considerations for the sampling of mixtures of airborne particles and vapour have been reviewed by PEREZ and SODERHOLM (see [1]). Sampling mixtures of airborne particles and vapour require an efficient combination of an airborne particle collector placed in series with a vapour collector. According to EN 481, the aspiration characteristics of system inlets are required to follow the inhalable sampling convention. This limits the design flow rate of the devices and their inlet geometry. In general, it will not be possible to quantify the distribution of (airborne) particle and vapour components separately at the moment of sampling, unless specific conditions are met, e.g. the particle component is non-volatile.

For the sampling of mixtures of airborne particles and vapour, filter plus pumped sorbent tube (see A.2) and reagent-impregnated systems (see A.3) are most commonly used. Other systems, e.g. denuder and filter or impinger and filter, can be used alternatively for specific chemical agents.

A.2 Filter plus pumped sorbent tube

A.2.1 General

A filter is a particle collection substrate which is used in combination with a device that samples the inhalable fraction according to EN 481. A sorbent tube mounted in series is used to sample vapour.

This sampling train will require a specified design flow rate that cannot be altered unless it has been demonstrated to meet the performance requirements for inhalable samplers at other flow rates.

In general, a sorbent tube requires a lower flow rate in order to meet the performance requirements for pumped sorbent tubes (such as breakthrough volume). To combine the sorbent tube and the inhalable sampler, for example, the flow downstream of the filter can be split in order to achieve the desired value. The flow split can only be maintained without active flow control if the pressure drop across the sorbent tube remains constant during the sampling period.

Volatile and semi-volatile compounds (particles) collected on the filter can evaporate when air is drawn through the sampler. Some chemical agents in vapour form can also be adsorbed by the filter or particles collected on the filter. Thus the original separation of the chemical agents between the particle and vapour phases cannot always be preserved, only the sum of particles and vapour can be quantified.

A.2.2 Sampling flow rate

Inhalable samplers meeting the requirements of EN 481 often operate at flow rates of $2\ \mathrm{l} \cdot \mathrm{min}^{-1}$ or more. This flow rate is higher than for typical pumped sorbent tubes; channelling and therefore loss of sample can occur if these are used outside their recommended flow rate range.

Thermal desorption tubes also become very inefficient and lose capacity at over $500\ \mathrm{ml} \cdot \mathrm{min}^{-1}$ (depending on the size of the sorbent tube), which is also the maximum achievable flow rate due to back pressure.

To use filter plus pumped sorbent tube at flow rates of $2\ \mathrm{l} \cdot \mathrm{min}^{-1}$ or more, either a longer pumped sorbent tube should be used to counteract the loss of sampling efficiency, or a wider pumped sorbent tube should be used at a more optimal flow velocity, or the flow should be split.

NOTE A longer pumped sorbent tube increases the back-pressure, whereas a wider pumped sorbent tubes requires more sorbent.

A.3 Reagent-impregnated sampling system

Reagent-impregnated sampling systems usually collect airborne particles and vapour on the same sampling medium.

This methodology includes coated filters, coated foams, coated sorbent beds and other similar approaches and is only suitable for reactive substances. The type and amount of reagent used in a reagent-impregnated sampling system should be suitable for the intended purpose.

The coated substrate is used in an inhalable sampler which has a specified design flow rate that cannot be altered. In order to collect vapour efficiently, in some instances it might be necessary to combine more than one coated collection substrate to avoid sample loss.

A.4 Transport and storage

Compounds that can form mixtures of airborne particles and vapour at ambient temperature are difficult to handle after sampling, i.e. during transport and storage. Methods are required to ensure that there are minimal losses in total mass after sampling. If different sampling media are used to collect particles and vapours, the potential for losses or gains for each medium shall be addressed. The method description shall provide detailed information on the procedure used for stabilisation of the samples.

Several methods are available to minimise post-sampling changes. For example, samples can be cooled or stored in a fixing solution immediately after sampling. Clean air can be drawn through the sampler after workplace sampling in order to carry volatile constituents from the particle collection media of the sampling system onto the vapour collection media. Media containing volatile compounds should be transported and stored together with a sorbent medium to capture evaporative losses from the system.

Annex B
(informative)

Physical behaviour of a mixture of airborne particles and vapour

B.1 Generation of a mixture of airborne particles and vapour

The behaviour of a mixture of airborne particles and vapour is being widely studied by the environmental scientific community. Theoretical models which can calculate the behaviour of such a mixture can be found in the literature, but they are limited to the conditions underlying the mixture which are unknown in most cases of workplace atmospheres.

It is essential that the physical characteristics of the chemical agent of interest are known. Semi-volatile compounds are present as a mixture of airborne particles and vapour in workplace air. The sampling of a mixture of airborne particles and vapour is strongly influenced by the sampling conditions (e.g. sampling time, flow rate) and environmental conditions (temperature and pressure).

At room temperature most semi-volatile compounds are liquids but there are also solids with a significant vapour pressure (e.g. arsenic trioxide). At room temperature, semi-volatile compounds normally have quite a low vapour pressure; nevertheless, the way in which a compound is used in the workplace can result in vaporisation or condensation. There are two principal mechanisms by which a mixture of airborne particles and vapour is formed:

A: Partial evaporation of chemical agents used as a liquid or solid

EXAMPLES Processes in which liquids are nebulised during the machining of metals, ceramics etc., processes in which mists are generated by gas-bubbles breaking on the surface of liquids (e.g. electroplating) and liquid spraying processes (e.g. paint spraying).

B: Condensation of a chemical agent in thermal processes in which a semi-volatile compound evaporates and, subsequently cools down to ambient temperature

EXAMPLES Hot bitumen application, laser cutting and metalworking processes.

B.2 Sampling of chemical agents having a vapour pressure of more than 100 Pa at room temperature (process temperature)

For chemical agents having a vapour pressure of more than 100 Pa at room temperature, droplets evaporate in a short period of time (e.g. in a matter of seconds). These chemical agents are sampled as a vapour.

NOTE Chemical agents with a vapour pressure of greater than 100 Pa will in most cases have a boiling point below 180 °C.

B.3 Sampling of chemical agents having a vapour pressure of more than 0,001 Pa and less than or equal to 100 Pa at room temperature

B.3.1 For chemical agents having a vapour pressure of more than 0,001 Pa and less than or equal to 100 Pa at room temperature, droplets are stable for a significant period of time (e.g. from a few minutes to several hours). A mixture of airborne particles and vapour results and needs to be sampled as such.

NOTE Chemical agents with a vapour pressure of less than or equal to 100 Pa, but greater than 0,001 Pa, will in most cases have a boiling point in the range from 180 °C to 350 °C.

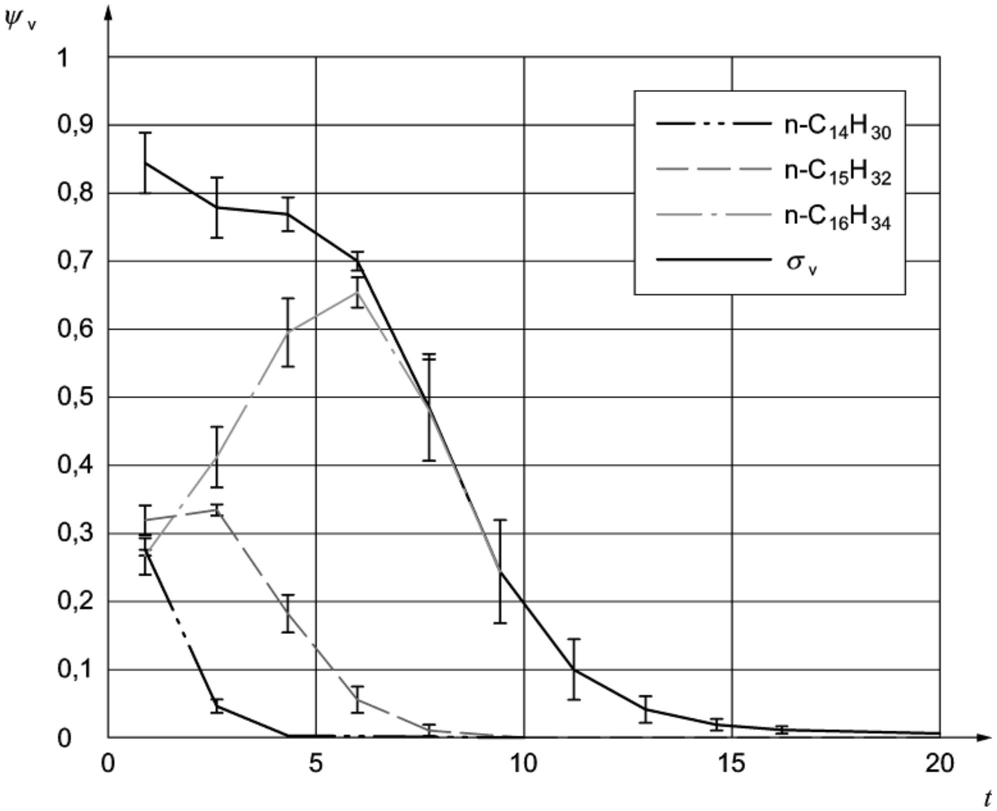
B.3.2 When mixtures of airborne particles and vapour are sampled with two separate collection substrates (e.g. a filter and subsequent sorbent tube), a fraction of the sampled airborne particles evaporates and is then sampled as a vapour. In order to avoid loss of airborne particles after sampling, the collection substrate for airborne particles needs to be subject to appropriate sample handling to ensure that no loss of analyte occurs.

EXAMPLE a) The sampling system can be sealed tightly, so that any vapour resulting from further evaporation of sampled airborne particles is retained by the vapour collection substrate.

b) Stabilisation of the collected airborne particles, e.g. by cooling or carrying out the dissolution process immediately after sampling.

Figure B.1 shows the situation where a mixture of three chemical agents with different vapour pressure are sampled. It clearly illustrates that compounds of different volatilities evaporate at different rates and semi-volatile compounds can form a stable aerosol for a certain time.

Approximately 500 µg of a liquid aerosol, consisting of a mixture of n-tetradecane (n-$C_{14}H_{30}$), n-pentadecane (n-$C_{15}H_{32}$) and n-hexadecane (n-$C_{16}H_{34}$) [1:1:1], was collected on a 37 mm high efficiency quartz filter. The mass median aerodynamic diameter of the aerosol was 4 µm, with a geometrical standard deviation of 2,2. Clean air was drawn through the filter at 5 cm · s^{-1} and the downstream air was adsorbed on a charcoal tube, desorbed and the vapour composition analysed by gas chromatography.



Key

ψ_v	ratio between the measured vapour concentration and its saturated vapour concentration at room temperature
σ_V	sum of the concentrations of the three components of the mixture
t	time, in minutes

Figure B.1 – Vapour concentrations downstream of a quartz fibre filter loaded with mixed liquid aerosol

B.4 Sampling of chemical agents having a vapour pressure of less than 0,001 Pa at room temperature

For chemical agents having a vapour pressure of less than 0,001 Pa at room temperature, airborne particles are stable. However, the process temperature needs to be taken into account.

a) Lower temperature processes (for example, ≤ 50 °C):

   For work processes performed at lower temperatures (for example, less than or equal to 50 °C), airborne particles are not significantly volatile and no vapour needs to be sampled.

b) Higher temperature processes (for example, > 50 °C):

   For work processes performed at higher temperatures (for example, greater than 50 °C), the volatility is significantly higher and, therefore, the sampling procedure needs to take into account both vapour and airborne particles.

EXAMPLES Hot bitumen application, laser cutting and metalworking processes.

Annex C
(informative)

Estimation of uncertainty of measurement

C.1 Uncertainty components

The following is a typical, but non-exclusive, list of uncertainty components:

a) air volume,

b) sampling efficiency,

c) sample storage,

d) effects of ambient conditions,

e) analytical recovery,

f) analytical variability,

g) calibration,

h) instrument response drift,

i) blank subtraction,

j) bias of sample distribution between the collection substrate for airborne particles and the collection substrate for vapour (distribution bias).

The estimation of these uncertainty components is based on those of EN 1076 and EN 13890 as given below.

C.2 Two collection substrates for airborne particles and vapour

C.2.1 Sampled air volume and sampling efficiency

The uncertainty associated with sampled air volume (flow rate measurement, pump flow stability and sampling time) and sampling efficiency for vapour can be determined according to EN 1076.

The uncertainty associated with sampling efficiency for airborne particles can be determined according to prEN 13205-1 and EN 13890, respectively.

C.2.2 Sample storage

The uncertainty associated with storage of airborne particles and vapour samples can be determined according to EN 13890 and EN 1076.

C.2.3 Effects of temperature and humidity

The fraction of a chemical agent in the vapour phase depends on the temperature and the humidity. It is not possible to estimate the effects of temperature and humidity on the collected masses of airborne particles and vapour separately.

Calculate the relative uncertainty components associated with temperature and humidity as follows:

Calculate the mean of the results for each exposure combination and the maximum difference between means. Divide the maximum difference by the mean results of vapour samples at the reference conditions. Calculate the relative standard uncertainties associated with temperature and humidity effects assuming rectangular distributions.

C.2.4 Analysis

The uncertainty components associated with the analysis (analytical recovery, analytical variability, calibration, instrument response drift and blank subtraction) can be estimated according to EN 13890 and EN 1076.

C.2.5 Bias of sample distribution between the collection substrate for airborne particles and the collection substrate for vapour (distribution bias)

If according to the results of the distribution test in 5.1, airborne particles or vapour are not analysed, the distribution bias is estimated and treated as an uncertainty component. Bias is taken to be the maximum value $B_{\text{d,max}}$ from the distribution test.

The relative standard uncertainty associated with the distribution bias u_{db} is given by Formula (C.1):

$$u_{\text{db}}^2 = \frac{B_{\text{d,max}}^2}{3} \qquad \text{(C.1)}$$

where

$B_{\text{d,max}}$ is the maximum bias of sample distribution between the collection substrate for airborne particles and the collection substrate for vapour, in percent.

C.2.6 Calculation of the relative combined uncertainty

C.2.6.1 Samples analysed separately

C.2.6.1.1 General

See ENV 13005:1999, 5.1.5 and 5.1.6 and [2] for calculation of combined uncertainty.

The mass concentration for the inhalable fraction of the mixture β_{mix} of airborne particles and vapour as final result is given by the Formulae (C.2) or (C.3) depending on whether the sampling volume is the same for both (see C.2.6.1.2 and C.2.6.1.3, respectively).

$$\beta_{\text{mix}} = \frac{m_{\text{p}} + m_{\text{v}}}{V_{\text{t}}} = \frac{m_{\text{mix}}}{V_{\text{t}}} \qquad \text{(C.2)}$$

$$\beta_{\text{mix}} = \frac{m_{\text{p}}}{V_{\text{p}}} + \frac{m_{\text{v}}}{V_{\text{v}}} = \beta_{\text{p}} + \beta_{\text{v}} \qquad \text{(C.3)}$$

where

m_{p}, m_{v} and m_{mix}	are the collected masses of airborne particles, vapour and mixture of both, respectively;
V_{p}, V_{v} and V_{t}	are the air volumes for airborne particles, vapour and both, respectively;
β_{p}, and β_{v}	are the mass concentrations of airborne particles and vapour, respectively.

C.2.6.1.2 Same sampling volume for airborne particles and vapour

Calculate separately the relative standard uncertainty associated with the collected mass of particles $u_{\mathrm{m,p}}$ and the relative standard uncertainty associated with the collected mass of vapour $u_{\mathrm{m,v}}$ in a similar way to that described in EN 13890 and EN 1076 without the uncertainty components associated with air volume.

Calculate the relative standard uncertainty associated with the collected mass of mixture of airborne particles and vapour $u_{\mathrm{m,mix}}$ using Formula (C.4):

$$u_{\mathrm{m,mix}}^2 = \frac{u_{\mathrm{m,p}}^2 \cdot m_{\mathrm{p}}^2 + u_{\mathrm{m,v}}^2 \cdot m_{\mathrm{v}}^2}{\left(m_{\mathrm{p}} + m_{\mathrm{v}}\right)^2} \tag{C.4}$$

where

$u_{\mathrm{m,p}}$ is the relative standard uncertainty associated with the collected mass of airborne particles;

$u_{\mathrm{m,v}}$ is the relative standard uncertainty associated with the collected mass of vapour;

m_{p} and m_{v} are the collected masses of airborne particles and vapour, respectively.

Calculate the relative combined standard uncertainty associated with the mass concentration of the mixture of airborne particles and vapour $u_{\mathrm{c,\beta mix}}$ using Formula (C.5):

$$u_{\mathrm{c,\beta mix}}^2 = u_{\mathrm{m,mix}}^2 + u_{\mathrm{V,s}}^2 \tag{C.5}$$

where

$u_{\mathrm{m,mix}}$ is the relative standard uncertainty associated with the collected mass of mixture of airborne particles and vapour;

$u_{\mathrm{V,s}}$ is the relative standard uncertainty associated with the sampled air volume.

C.2.6.1.3 Different sampling volumes for airborne particles and vapour

Calculate separately the relative combined standard uncertainty associated with the mass concentration of airborne particles $u_{\mathrm{c,\beta p}}$ and associated with the mass concentration of vapour $u_{\mathrm{c,\beta v}}$ similar as in EN 13890 and EN 1076.

Calculate the relative combined standard uncertainty associated with the mass concentration of the mixture of airborne particles and vapour $u_{\mathrm{c,\beta mix}}$ using Formula (C.6):

$$u_{\mathrm{c,\beta mix}}^2 = \frac{u_{\mathrm{c,\beta p}}^2 \cdot \beta_{\mathrm{p}}^2 + u_{\mathrm{c,\beta v}}^2 \cdot \beta_{\mathrm{v}}^2}{\left(\beta_{\mathrm{p}} + \beta_{\mathrm{v}}\right)^2} \tag{C.6}$$

where

$u_{\mathrm{c,\beta p}}$ is the relative combined standard uncertainty associated with the mass concentration of airborne particles;

$u_{\mathrm{c,\beta v}}$ is the relative combined standard uncertainty associated with the mass concentration of vapour;

β_p, and β_v are the mass concentrations of airborne particles and vapour.

C.2.6.1.4 Airborne particles or vapour collection substrate not analysed

If either the airborne particles or vapour collection substrate is not analysed, the relative combined standard uncertainty associated with the mass concentration of the mixture of airborne particles and vapour $u_{\mathrm{c},\beta_{\mathrm{mix}}}$ is given by the Formulae (C.7) and (C.8), respectively:

$$u_{\mathrm{c},\beta_{\mathrm{mix}}}^2 = u_{\mathrm{c},\beta_{\mathrm{p}}}^2 + u_{\mathrm{db}}^2 \tag{C.7}$$

$$u_{\mathrm{c},\beta_{\mathrm{mix}}}^2 = u_{\mathrm{c},\beta_{\mathrm{v}}}^2 + u_{\mathrm{db}}^2 \tag{C.8}$$

where

$u_{\mathrm{c},\beta_{\mathrm{p}}}$	is the relative combined standard uncertainty associated with the mass concentration of airborne particles;
$u_{\mathrm{c},\beta_{\mathrm{v}}}$	is the relative combined standard uncertainty associated with the mass concentration of vapour;
u_{db}	is the relative standard uncertainty associated with the distribution bias (see C.2.5).

C.2.6.2 Samples analysed together

Carry out the analysis of the particles and vapour samples together for all tests except for the distribution test.

Calculate the relative standard uncertainty components and combined uncertainty as given in C.3.

C.3 One collection substrate for airborne particles and vapour

C.3.1 General

In this case only the combined mass of airborne particles and vapour is obtained by the samples analysis. There is no possibility of knowing the distribution between airborne particles and vapour unless information from other sources was available.

It is assumed that the maximum sampling time for vapours is not exceeded so that the sampling efficiency of vapour is 100 % and the uncertainty component is zero.

C.3.2 Sampling

The relative uncertainty component associated with sampling can be estimated according to EN 13890, assuming that uncertainty component associated with sampling efficiency for vapour is zero.

The uncertainty components are the ones associated with sampled air volume, $u_{\mathrm{V,s}}$, sampling efficiency of the airborne particles, $u_{\mathrm{se,p}}$ and sample storage, u_{st}.

C.3.3 Analysis

The relative uncertainty component associated with analysis u_{a} can be determined according to EN 13890, adding the uncertainty components associated with temperature and humidity effects (u_{T} and u_{h}). These latter non-random uncertainty components can be calculated according to EN 1076 using the results of the analysis of the replicate samples collected in the tests of the temperature and humidity effects.

C.3.4 Calculation of the relative combined standard uncertainty

The relative combined standard uncertainty associated with the mass concentration of the mixture of airborne particles and vapour $u_{\mathrm{c},\beta_{\mathrm{mix}}}$ can be calculated according to Formula (C.9):

$$u_{\mathrm{c},\beta_{\mathrm{mix}}}^2 = u_{\mathrm{V,s}}^2 + u_{\mathrm{se,p}}^2 + u_{\mathrm{st}}^2 + +u_{\mathrm{T}}^2 + u_{\mathrm{h}}^2 + u_{\mathrm{a}}^2 \tag{C.9}$$

where

$u_{\mathrm{V,s}}$ is the relative standard uncertainty associated with sampled air volume;

$u_{\mathrm{se,p}}$ is the relative standard uncertainty associated with sampling efficiency of the airborne particles;

u_{st} is the relative standard uncertainty associated with sample storage;

u_{T} is the relative standard uncertainty associated with temperature effects;

u_{h} is the relative standard uncertainty associated with humidity effects;

u_{a} is the relative standard uncertainty associated with analysis.

Formula (C.9) likely overestimates the uncertainty because uncertainty components associated with sampling efficiency of airborne particles and with humidity and temperature effects are accounted for twice, both for airborne particles and vapour.

Bibliography

Documents referred to in the European Standard

[1] Perez C., Soderholm S.C. Some Chemicals Requiring Special Consideration when Deciding Whether to Sample the Particle, Vapour, or Both Phases of an Atmosphere. *Appl. Occup. Environ. Hyg.* 1991, **6** pp. 859–864

[2] EURACHEM. *EURACHEM/CITAC Guide Quantifying Uncertainty in Analytical Measurement* (QUAM 2000). Second Edition, (8.2.6)

[3] ENV 13005:1999[2] *Guide to the expression of uncertainty in measurement*

[4] EN 60068-3-11, *Environmental testing – Part 3-11: Supporting documentation and guidance – Calculation of uncertainty of conditions in climatic test chambers (IEC 60068-3-11)*

Further references of general interest for application of the European Standard

[5] Bemgård A., Colmsjö A., Melin J. Assessing Breakthrough Times for Denuder Samplers with Emphasis on Volatile Organic Compounds. *J. Chromatogr. A*. 1996, 723 pp. 301–311

[6] Bidleman T.F. Atmospheric Processes: Wet and Dry Deposition of Organic Compounds are Controlled by their Vapour-Particle Partitioning. *Environ. Sci. Technol.* 1988, 22 pp. 361–367

[7] Biswas P., Jones C.L., Flagan R.C. Distortion of Size Distributions by Condensation and Evaporation in Aerosol Instruments. *Aerosol Sd. Tech.* 1987, 7 pp. 231–246

[8] Brosseau L.M. C.-12. Fang C.-P., Snyder C and Cohen B.S.: Particle Size Distribution of Automobile Paint Sprays. *Appl. Occup. Environ. Hyg.* 1992, 7 pp. 607–612

[9] Caka F.M., Eatough D.J., Lewis E.A., Tang H., Hammond S.K., Leaderer B.P. et al. An Intercomparison of Sampling Techniques for Nicotine in Indoor Environments. *Environ. Sci. Technol.* 1990, 24 pp. 1196–1203

[10] Cohen B.S., Brosseau L.M., Fang C.-P., Bowers A., Snyder C. Measurement of Air Concentrations of Volatile Aerosols in Paint Spray Applications. *Appl. Occup. Environ. Hyg.* 1992, 7 pp. 514–521

[11] Cotham W.E., Bidleman T.F. Laboratory Investigations of the Partitioning of Organochlorine Compounds between the Gas Phase and Atmospheric Aerosols on Glass Fiber Filters. *Environ. Sci. Technol.* 1992, 26 pp. 469–478

[12] Coutant R.W., Brown L., Chuang J., Lewis R.G. Field Evaluation of Phase Distribution of PAH. Proceedings of the 1986 EPA JAPCA Symposium on Measurement of Toxic Air Pollutants, *U.S. Environmental Protection Agency, Report No. 60019- 86-013*, p. 146-155 (1986)

[13] Demange M., Gendre J.C., Hervé-Bazin B., Carton B., Peltier A. Aerosol Evaluation Difficulties Due to Particle Deposition on Filter Holder Inner Walls. *Ann. Occup. Hyg.* 1990, 34 pp. 399–403

[14] Gotfelty D.E., Seiber J.X., Liljedahl L.A. Pesticides in Fog. *Nature*. 1987, 325 pp. 602–605

---

[2] Re-issued as ISO/IEC Guide 98-3:2008, *Uncertainty of measurement – Part 3: Guide to the expression of uncertainty in measurement* (GUM:1995).

[15] GUNDEL L.A., DAISEY J.M., MAHANAMA D.R.R., LEE V.C., STEVENS R.X. Polycyclic Aromatic Hydrocarbons in Indoor Air and Environmental Tobacco Smoke Measured with a New Integrated Organic Vapour-Particle Sampler. *Proceedings of Indoor Air '93, July 5-8, 1993*, Helsinki, Finland

[16] GUNDERSON E.C., ANDERSON C.C. Collection Device for Separating Airborne Vapour and Particulates. *Am. md. Hyg. Assoc. J.* 1987, 48 pp. 634–638

[17] HART K.M., PANKOW J.F. Comparison of n-Alkane and PAH Concentrations Collected on Quartz Fiber and Polytetrafluoroethylene (PTFE) Membrane Filters in an Urban Environment. *J. Aerosol Sci.* 1990, 21 (Supp. 1) pp. 377–380

[18] HART K.M., ISABELLE L.M., PANKOW J.F. High-Volume Air Sampler for Particle and Gas Sampling. 1. Design and Gas Sampling Performance. *Environ. Sci. Technol.* 1992, 26 p. 1048-1052

[19] HILL R.H. JR., ARNOLD J.E. A Personal Air Sampler for Pesticides. *Arch. Envirorim. Contam. Toxicol.* 1979, **8** pp. 621–628

[20] KAUPP H., UMLAUF G. Atmospheric Gas-Particle Partitioning of Organic Compounds: Comparison of Sampling Methods. *Atmos. Environ.* 1992, 26A pp. 2259–2267

[21] KONIG J., FUNKE W., BALFANZ E., GROSCH B., POTT F. Testing a High Volume Air Sampler for Quantitative collection of Polycyclic Aromatic Hydrocarbons. *Atmos. Environ.* 1980, 14 pp. 609–613

[22] KIRTON P.J., ELLIS J., CRISP P.T. Investigation of Adsorbents for Sampling Compounds Found in Coke Oven Emissions. *Fuel*. 1991, 70 pp. 4–8

[23] KIRTON P.J., ELLIS J., CRISP P.T. The Analysis of Organic Matter in Coke Oven Emissions. *Fuel*. 1991, 70 pp. 1383–1389

[24] KNEGER M.S., HITES R.A. Diffusion Denuder for the Collection of Semivolatile Organic Compounds. *Environ. Sci. Technol.* 1992, 26 pp. 1551–1555

[25] KOGAN V., KUHIMAN M.R., COUTANT R.W., LEWIS R.G. Aerosol Filtration by Sorbent Beds. *J. Air Waste Manage. Assoc.* 1993, 43 pp. 1367–1373

[26] KOUTRAKIS P., FASANO A.M., SIATER J.I., SPENGLER J.D., MCCARTHY J.F., LEADERER B.P. Design of a Personal Annular Denuder Sampler to Measure Atmospheric Aerosols and Gases. *Atmos. Environ.* 1989, 23 pp. 2767–2773

[27] KOUTRAKIS P., SIOUTAS C., FERGUSON S.T., WOFFSON J.M. Development and Evaluation of a Glass Honeycomb Denuder-Filter Pack System to Collect Atmospheric Gases and Particles. *Environ. Sci. Technol.* 1993, 27 pp. 2497–2501

[28] KULMALA M., VESALA T. Condensation in the Continuum Regime. *J. Aerosol Sci.* 1991, 22 pp. 337–346

[29] LAFONTAINE M., VU DUC T., DELSAULT P., MORELE Y. Aerosol deposits on the inner cassettte walls during PAH sampling: underestimation of the inhaled part and of the occupational risk. *Polycyclic Aromatic Compounds*. 1999, 17 (3) pp. 221–228

[30] LEVIN J.−O AND FANGMARK I.: High-Performance Liquid Chromatographic Determination of Hexamethylenetetramine in Air. *Analyst (Lond.)*. 1988, 113 pp. 511–513

[31] LICHTENSTEIN N., HENNIG M., FRIEDRICH C., AUFFARTH J., HEBISCH R., et al: Meßmethoden zur Bestimmung der Exposition gegenüber Lackaerosolen und Lösemitteldämpfen beim Spritzlackieren (Methods for Determining Exposure to Lacquer Aerosols and Solvent Vapours During Spray Painting). *Gefahrstoffe - Reinhaltung der Luft 57*, (1997), pp. 39-48

[32] MALEK R.F., DAISEY J.M., COHEN B.S. The Effect of Aerosol on Estimates of Inhalation Exposure to Airborne Styrene. *Am. md. Hyg. Assoc. J.* 1986, 47 pp. 524–529

[33] MCDOW S.R., HUNTZICKER J.J. Vapour Adsorption Artifact in the Sampling of Organic Aerosol: Face Velocity Effects. *Atmos. Environ.* 1990, 24A pp. 2563–2571

[34] NAIR P.V.N., VOHRA K.G. Growth of Aqueous Sulphuric Acid Droplets as a Function of Relative Humidity. *J. Aerosol Sci.* 1975, 6 pp. 265–271

[35] PANKOW J.F. An Absorption Model of Gas / Particle Partitioning in the Atmosphere. *Atmos. Environ.* 1994, 28 pp. 185–188

[36] PANKOW J.F., BIDLEMAN T.F. Interdependence of the Slopes and Intercepts from Log-Log Correlations of Measured Gas-Particle Partitioning and Vapour Pressure - 1. Theory and Analysis of Available Data. *Atmos. Environ.* 1992, 26A pp. 1071–1080

[37] PANKOW J.F., BIDLEMAN T.F. Effects of Temperature, TSP and Per Cent Nonexchangeable Material in Determining the Gas-Particle Partitioning of Organic Compounds. *Atmos. Environ.* 1991, 25A pp. 2241–2249

[38] PANKOW J.F. Review and Comparative Analysis of the Theories on Partitioning Between the Gas and Aerosol Particulate Phases in the Atmosphere. *Atmos. Environ.* 1987, 21 pp. 2275–2283

[39] PERRINO C., DESANTIS F., FEBO A. Criteria for the choice of a Denuder Sampling Technique Devoted to the Measurement of Atmospheric Nitric and Nitrous Acids. *Atmos. Environ.* 1990, 24A pp. 617–626

[40] POON W.S., PUI D.Y.H., LEE C.-T., LIU B.Y.H. A Compact Porous Denuder for Atmospheric Sampling of Inorganic Aerosols. *J. Aerosol Sci.* 1994

[41] POSSANZINI M., FEBO A., LIBERTI A. New Design of a High-performance Denuder for the Sampling of Atmospheric Pollutants. *Atmos. Environ.* 1983, 17 pp. 2605–2610

[42] PRATSINIS S.E., XU M., BISWAS P., WILLEKE K. Theory for Aerosol Sampling through Annular Diffusion Denuders. *J. Aerosol Sci.* 1989, 20 pp. 1597–1600

[43] SIEKMANN H., BLOME H., HEISIG W. Probenahmesysteme: Spezielle Anforderungen und Entwicklungstendenzen. *Staub Reinhalt. Luft*. 1988, 48 pp. 89–94

[44] SIOUTAS C., KOUTRAKIS P. Development of a Low Cutpoint Size Slit Virtual Impactor for Sampling Ambient Fine Particles. *J. Aerosol Sci.* 1994

[45] SIOUTAS C., KOUTRAKIS P. Development of a Low Cutpoint Slit-Nozzle Virtual Impactor for Collection of Semi-Volatile Organic Compounds. *J. Aerosol Sci.* 1993, 24 (Supp. 1) pp. 363–364

[46] SLANINA J., DE WILD P.J., WYERS G.P. The Application of Denuder Systems to the Analysis of Atmospheric Components. Chapter 3, *Gaseous Pollutants: Characterization and Cycling*, edited by J.0. Nriagu, Wiley, New York, 129-154 (1992)

[47] SODERHOLM S.C., ANDERSON D.A., UTELL M.J., FERRON G.A. Method of Measuring the Total Deposition Efficiency of Volatile Aerosols in Humans. *J. Aerosol Sci.* 1991, 22 pp. 917–926

[48] SODERHOLM S.C., FERRON G.A. Estimating Effects of Evaporation and Condensation on Volatile Aerosols during Inhalation Exposures. *J. Aerosol Sci.* 1992, 23 pp. 257–277

[49] SODERHOLM, S.C.: Aerosol Instabilities. *Appl. Ind. Hyg. 3*:3 5-40 (1988)

[50] STREICHER R.P., KENNEDY E.R., LORBERAU C.D. Air Sampling Strategies for the Simultaneous Collection of Vapours and Aerosols. *Analyst (Lond.)*. 1994, 119 pp. 89–97

[51] SVENDSEN K. BJORSETH O., BORRESEN E.: Sampling Petroleum Oil Mist and Vapour; Comparison of Methods. *Am. Ind. Hyg. Assoc. J.* 1996, 57 pp. 537–541

[52] TANNER R.L., HARRISON R.M. Acid-base Equilibria of Aerosols and Gases in the Atmosphere. Chapter 2, Environmental Particles, Vol. 1, edited by J. Buffle and H.P. van Leeuwen, *Environmental Analytical and Physical Chemistry Series*, Lewis Publishers, Boca Raton, 75-106 (1992)

[53] TURPIN B.J., LIU S.P., PODOISKE K.S., GOMES M.S.P., EISENREICH S.J. AND MCMURRY P.H.: Design and Evaluation of a Novel Diffusion Separator for Measuring Gas/Particle Distributions of Semivolatile Organic Compounds. *Environ. Sci. Technol.* 1993, 27 pp. 2441–2449

[54] WANG H.-C., JOHN W. Characteristics of the Berner Impactor for Sampling Inorganic Ions. *Aerosol Sci. Technol.* 1988, 8 pp. 157–172

[55] WEXIER A.S., SEINFELD J.H. The Distribution of Ammonium Salts Among a Size and Composition Dispersed Aerosol. *Atmos. Environ.* 1990, 24A pp. 1231–1246

[56] YAMASAKI H., KUWATA K., MIYAMOTO H. Effects of Ambient Temperature on Aspects of Airborne Polycyclic Aromatic Hydrocarbons. *Environ. Sci. Technol.* 1982, 16 pp. 189–194

[57] YE Y., TSAI C.A., PUI D.Y.H., LEWIS C.W. Particle Transmission Characteristics of an Annular Denuder Ambient Sampling System. *Aerosol Sci. Technol.* 1991, 14 pp. 102–111

[58] ZHANG X.Q., MCMURRY P.H. Theoretical Analysis of Evaporative Losses from Impactor and Filter Deposits. *Atmos. Environ.* 1987, 21 pp. 1779–1789

This page deliberately left blank

British Standards Institution (BSI)

BSI is the national body responsible for preparing British Standards and other standards-related publications, information and services.

BSI is incorporated by Royal Charter. British Standards and other standardization products are published by BSI Standards Limited.

About us

We bring together business, industry, government, consumers, innovators and others to shape their combined experience and expertise into standards -based solutions.

The knowledge embodied in our standards has been carefully assembled in a dependable format and refined through our open consultation process. Organizations of all sizes and across all sectors choose standards to help them achieve their goals.

Information on standards

We can provide you with the knowledge that your organization needs to succeed. Find out more about British Standards by visiting our website at bsigroup.com/standards or contacting our Customer Services team or Knowledge Centre.

Buying standards

You can buy and download PDF versions of BSI publications, including British and adopted European and international standards, through our website at bsigroup.com/shop, where hard copies can also be purchased.

If you need international and foreign standards from other Standards Development Organizations, hard copies can be ordered from our Customer Services team.

Subscriptions

Our range of subscription services are designed to make using standards easier for you. For further information on our subscription products go to bsigroup.com/subscriptions.

With **British Standards Online (BSOL)** you'll have instant access to over 55,000 British and adopted European and international standards from your desktop. It's available 24/7 and is refreshed daily so you'll always be up to date.

You can keep in touch with standards developments and receive substantial discounts on the purchase price of standards, both in single copy and subscription format, by becoming a **BSI Subscribing Member**.

PLUS is an updating service exclusive to BSI Subscribing Members. You will automatically receive the latest hard copy of your standards when they're revised or replaced.

To find out more about becoming a BSI Subscribing Member and the benefits of membership, please visit bsigroup.com/shop.

With a **Multi-User Network Licence (MUNL)** you are able to host standards publications on your intranet. Licences can cover as few or as many users as you wish. With updates supplied as soon as they're available, you can be sure your documentation is current. For further information, email bsmusales@bsigroup.com.

Revisions

Our British Standards and other publications are updated by amendment or revision.

We continually improve the quality of our products and services to benefit your business. If you find an inaccuracy or ambiguity within a British Standard or other BSI publication please inform the Knowledge Centre.

Copyright

All the data, software and documentation set out in all British Standards and other BSI publications are the property of and copyrighted by BSI, or some person or entity that owns copyright in the information used (such as the international standardization bodies) and has formally licensed such information to BSI for commercial publication and use. Except as permitted under the Copyright, Designs and Patents Act 1988 no extract may be reproduced, stored in a retrieval system or transmitted in any form or by any means – electronic, photocopying, recording or otherwise – without prior written permission from BSI. Details and advice can be obtained from the Copyright & Licensing Department.

Useful Contacts:

Customer Services
Tel: +44 845 086 9001
Email (orders): orders@bsigroup.com
Email (enquiries): cservices@bsigroup.com

Subscriptions
Tel: +44 845 086 9001
Email: subscriptions@bsigroup.com

Knowledge Centre
Tel: +44 20 8996 7004
Email: knowledgecentre@bsigroup.com

Copyright & Licensing
Tel: +44 20 8996 7070
Email: copyright@bsigroup.com

BSI Group Headquarters

389 Chiswick High Road London W4 4AL UK

bsi.

...making excellence a habit.™