SLOVENSKI STANDARD
oSIST prEN 13205-2:2012

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Zrak na delovnem mestu - Ocenjevanje lastnosti merilnikov za merjenje koncentracij lebdečih delcev - 2. del: Preskušanje usposobljenosti laboratorija na osnovi učinkovitosti vzorčenja

Workplace exposure - Assessment of sampler performance for measurement of airborne particle concentrations - Part 2: Laboratory performance test based on determination of sampling efficiency

Exposition am Arbeitsplatz - Bewertung der Leistungsfähigkeit von Sammlern für die Messsung der Konzentration luftgetragener Partikel - Teil 2: Laborprüfung der Leistungsfähigkeit basierend auf der Bestimmung des Probenahmewirkungsgrades

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English Version

Workplace exposure - Assessment of sampler performance for measurement of airborne particle concentrations - Part 2: Laboratory performance test based on determination of sampling efficiency

Exposition am Arbeitsplatz - Beurteilung der Leistungsfähigkeit von Sammlern für die Messung der Konzentration luftgetragener Partikel - Teil 2: Laborprüfung der Leistungsfähigkeit basierend auf der Bestimmung des Probenahmewirkungsgrades

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Foreword

This document (prEN 13205-2:2012) has been prepared by Technical Committee CEN/TC 137 “Assessment of workplace exopsure to chemical and biological agents”, the secretariat of which is held by DIN.

This document is currently submitted to the CEN Enquiry.

This document together with prEN 13205-1, FprCEN/TR 13205-3, prEN 13205-4, prEN 13205-5 and prEN 13205-6 supersedes prEN 13205:2010 and will supersede EN 13205:2001.

EN 13205 *Workplace exposure – Assessment of sampler performance for measurement of airborne particle concentrations* consists of the following parts:

— *Part 1: General requirements;*

— *Part 2: Laboratory performance test based on determination of sampling efficiency;*

— *Part 3: Analysis of sampling efficiency data;*

— *Part 4: Laboratory performance test based on comparison of concentrations;*

— *Part 5: Aerosol sampler performance test and sampler comparison carried out at workplaces;*

— *Part 6: Transport and handling tests.*

Introduction

EN 481 defines sampling conventions for the particle size fractions to be collected from workplace atmospheres in order to assess their impact on human health. Conventions are defined for the inhalable, thoracic and respirable aerosol fractions. These conventions represent target specifications for aerosol samplers, giving the ideal sampling efficiency as a function of particle aerodynamic diameter.

In general, the sampling efficiency of real aerosol samplers will deviate from the target specification, and the aerosol mass collected will therefore differ from that which an ideal sampler would collect. In addition, the behaviour of real samplers is influenced by many factors such as external wind speed. In many cases there is an interaction between the influence factors and fraction of the airborne size distribution of the environment in which the sampler is used.

EN 13205 enables manufacturers and users of aerosol sampling instruments to adopt a consistent approach to sampler validation, and provide a framework for the assessment of sampler performance with respect to EN 481 and EN 482.

It is the responsibility of the manufacturer of aerosol samplers to inform the user of the sampler performance under the laboratory conditions[1)] specified in this part of EN 13205. It is the responsibility of the user to ensure the actual conditions of intended use are within what the manufacturer specifies as acceptable conditions according to the performance test.

1) The inhalable convention is undefined for particle sizes in excess of 100 µm or for wind speeds greater than 4 m/s. The tests required to assess performance are therefore limited to these conditions. Should such large particle sizes or wind speeds actually exist at the time of sampling, it is possible that different samplers meeting this document give different results.

1 Scope

This European Standard specifies a laboratory performance test for samplers for the inhalable, thoracic and respirable aerosol fractions, based on determining the sampling efficiency curve of a candidate sampler at a minimum of nine particle sizes. It specifies methods for testing aerosol samplers under prescribed laboratory conditions in order to test whether the performance of a candidate sampler fulfils the requirements of prEN 13205-1:2012.

This part of EN 13205 is applicable to all samplers used for the health-related sampling of particles in workplace air.

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 1232, *Workplace atmospheres — Requirements and test methods for pumps used for personal sampling of chemical agents in the workplace*

EN 1540, *Workplace exposure — Terminology*

EN 12919, *Workplace atmospheres — Pumps for the sampling of chemical agents with a volume flow rate of over 5 l/min — Requirements and test methods*

prEN 13205-1:2012, *Workplace exposure — Assessment of sampler performance for measurement of airborne particle concentrations – Part 1: General requirements*

prEN 13205-5:2012, *Workplace exposure — Assessment of sampler performance for measurement of airborne particle concentrations – Part 5: Aerosol sampler performance test and sampler comparison carried out at workplaces*

3 Terms and definitions

For the purpose of this document, the term and definitions given in EN 1540, prEN 13205-1:2012 and the following apply.

NOTE With regard to EN 1540, in particular, the following terms are used in this document: total airborne particles, respirable fraction, sampling efficiency, static sampler, thoracic fraction, measuring procedure, non-random uncertainty, random uncertainty, expanded uncertainty, standard uncertainty, combined standard uncertainty, expanded uncertainty, uncertainty (of measurement), coverage factor and precision.

3.1
relative concentration
concentration expressed as a fraction of the total airborne concentration

3.2
total airborne particle concentration
concentration of aerosol particles present in the air before the particles are affected by the presence of the sampler, or in the case of a personal sampler by the presence of the person wearing the sampler

4 Symbols and abbreviations

4.1 Symbols

4.1.1 Latin

$A(D_A, \sigma_A, D)$ relative lognormal aerosol size distribution, with mass median aerodynamic diameter D_A and geometric standard deviation σ_A, [1/µm]

NOTE The word "relative" means that the total amount of particles is unity [-], *i.e.* $\int_0^\infty A(D_A, \sigma_A, D)\mathrm{d}D = 1$.

C_{std} target sampled relative aerosol concentration, expressed as a fraction of the total airborne aerosol concentration, that would have been sampled using an ideal sampler with a sampling efficiency identical to the sampling convention, $F(D)$, for aerosol size distribution A, [-]

$\bar{C}_i$ mean sampled relative aerosol concentration, expressed as a fraction of the total airborne aerosol concentration, calculated to be obtained when using the candidate sampler, for aerosol size distribution A at influence variable value ζ_i, [-]

c candidate sampler correction factor for bias correction, either prescribed by sampler manufacturer or measuring procedure, or assigned the value c=1.00, [-]

D aerodynamic diameter, [µm]

D_A mass median aerodynamic diameter of a lognormal aerosol size distribution A, [µm]

D_{A_a} mass median aerodynamic diameter a of a lognormal aerosol size distribution A, [µm]

D_{max} diameter of the end of the integration range of the sampled aerosol, [µm]

D_{min} diameter of the beginning of the integration range of the sampled aerosol, [µm]

D_p aerodynamic diameter of test particle p (p=1 to N_P), [µm]

$\bar{E}_i(D_p)$ mean sampling efficiency of the candidate sampler for test particle size p at influence variable value ζ_i, [-] – (polygonal approximation method)

$\bar{E}_i(Q, D_p)$ mean sampling efficiency curve of the candidate sampler at flow rate Q for test particle size p at influence variable value ζ_i, [-] – (polygonal approximation method)

$^{est}E_{is}(D)$ fitted sampling efficiency curve of the candidate sampler individual s at influence variable value ζ_i, [-] – (curve-fitting method)

$^{est}E_{is}(Q, D)$ fitted sampling efficiency curve of the candidate sampler individual s at flow rate Q for influence variable value ζ_i, [-] – (curve-fitting method)

$e_{ipr[s]}$ and $e_{ips[r]}$ experimentally determined efficiency value, with notation for polygonal approximation and curve-fitting methods, respectively. The subscripts are for influence variable value ζ_i, particle size p (p=1 to N_P), sampler individual s (s=1 to N_S) and

repeat r (r=1 to N_R), [-] – (notation for polygonal approximation and curve-fitting methods, respectively)

$F(D)$ target sampling convention, [-]

$g_{ipr[s]}$ and $g_{ips[r]}$ aerosol concentration sampled by the candidate sampler. The subscripts are for influence variable value ς_i, particle size p (p=1 to N_P), sampler individual s (s=1 to N_S) and repeat r (r=1 to N_R), [mg/m^3] or [1/m^3] – (notation for polygonal approximation and curve-fitting methods, respectively)

h_{ipr} and $h_{ips[r]}$ corresponding total airborne aerosol concentration estimated from the sharp-edged probe values. The subscripts are for influence variable value i (i=1 to N_{IV}), particle size p (p=1 to N_P), sampler individual s (s=1 to N_S) and repeat r (r=1 to N_R), [mg/m^3] or [1/m^3] – (notation for polygonal approximation and curve-fitting methods, respectively)

$m_i(D_A, \sigma_A, Q)$ mean sampled aerosol mass, expressed as a fraction of the total airborne aerosol mass, calculated to be obtained when using the candidate sampler with flow rate Q, to sample aerosol size distribution A at influence variable value ς_i, [-]

N_{IV} number of values for the other influence variables at which tests were performed,

N_P number of test particle sizes

N_{Rep} number of repeats at particle size p for candidate sampler individual s at influence variable value ς_i – (in the polygonal approximation method N_{Rep} equals the number of repeats, whereas in the curve-fitting method it equals the number of repeats per candidate sampler individual)

N_S number of candidate sampler individuals – (In the polygonal approximation method N_S equals the number of sampler individuals tested per repeat, whereas in the curve-fitting method it equals the total number of sampler individuals tested.)

Q actual flow rate of candidate sampler, [l/min]

Q^0 nominal flow rate of sampler, [l/min]

q_0 parameter expressing whether the nominal or actual flow rate is used for the calculation of sampled respirable and thoracic aerosol fractions, [-]

$q_i(D_A, \sigma_A)$ flow rate dependence of sampled mass for aerosol size distribution A at influence variable value ς_i, [-]

$s_{\text{CandSampl-Flow}_{ia}}$ non-random uncertainty (of measurement) of the calculated sampled concentration, due to excursion from nominal flow and/or deviation from initial flow, for the a^{th} aerosol size distribution A at influence variable value ς_i, [-]

$s_{(\delta_{\text{FlowSet}} + \delta_{\text{Pump}})}$ random uncertainty for combined rectangular distribution based on allowed initial flow deviation from nominal flow rate and pump flow deviation, [-]

$U_{\text{CandSampl}}$ expanded uncertainty (of measurement) of the calculated sampled concentration due to the candidate sampler, [-]

$u_{\text{CandSampl}}$ combined uncertainty (of measurement) of the calculated sampled concentration due to the candidate sampler, [-]

$u_{\text{CandSampl}_i}$ combined uncertainty (of measurement) of the candidate sampler, at influence variable value ζ_i, [-]

$u_{\text{CandSampl-Bias}_i}$ standard uncertainty (of measurement) due to bias (non-random errors) in relation to the sampling convention of the candidate sampler at influence variable value ζ_i, [-]

$u_{\text{CandSampl-Calibr}_i}$ standard uncertainty (of measurement) (non-random and random errors) of the calculated sampled concentration, due to the calibration uncertainty of the experiment, calculated as the RMS of the corresponding relative uncertainties over all N_{SD} aerosol size distributions A at influence variable value ζ_i, [-]

$u_{\text{CandSampl-Flow}_i}$ standard uncertainty (of measurement) of the calculated sampled concentration, due to flow rate deviation at influence variable value ζ_i, [-]

$u_{\text{CandSampl-ModelCalc}_i}$ standard uncertainty (of measurement) of the calculated sampled concentration (random errors), due to the uncertainty of the fitted model, calculated as the RMS of the corresponding relative uncertainties over all N_{SD} aerosol size distributions A at influence variable value ζ_i, [-]

$u_{\text{CandSampl-nR}}$ combined uncertainty (of measurement) of the sampled concentration (non-random errors) due to the candidate sampler, [-]

$u_{\text{CandSampl-nR}_i}$ combined uncertainty (of measurement) of the sampled concentration (non-random errors) due to the candidate sampler, at influence variable value ζ_i, [-]

$u_{\text{CandSampl-R}}$ combined uncertainty (of measurement) of the sampled concentration (random errors) due to the candidate sampler, [-]

$u_{\text{CandSampl-R}_i}$ combined uncertainty (of measurement) of the sampled concentration (random errors) due to the candidate sampler, at influence variable value ζ_i, [-]

$u_{\text{CandSampl-Variability}_i}$ standard uncertainty (of measurement) of the sampled concentration (random errors) due to differences among candidate sampler individuals at influence variable value ζ_i, [-]

W_p weighted average of integration of aerosol size distribution A between two particle sizes, [-] – (polygonal approximation)

4.1.2 Greek

Δ_i bias or relative error in the aerosol concentration measured using the candidate sampler, for aerosol size distribution A, at influence variable value ζ_i, [-]

δ_{FlowSet} maximum relative error allowed in setting the flow rate, [-]

δ_{Pump} maximum relative change in flow rate allowed by pump flow rate stability, [-] $\varepsilon_{ipr[s]}$ and $\varepsilon_{ips[r]}$ Random experimental error at particle size p, repeat r and

candidate sampler s at influence variable value ς_i, [-] – (notations for polygonal approximation and curve-fitting methods, respectively)

ς value of other influence variable values, as for example wind speed and mass loading of sampler, with values for i=1 to N_{IV}, [various dimensions]

ς_i i^{th} value of any other influence variable

NOTE The dimension of each ς_i depends on the influence variable. The dimension selected, however, is not critical, as the values are never part in any calculation.

σ_A geometric standard deviation of a lognormal aerosol size distribution A from Table A.2, [-]

σ_{A_a} geometric standard deviation a of a lognormal aerosol size distribution A, [µm] –

4.2 Enumerating subscripts

a for test aerosols

I for selected value of distinguishable values of an influence variable

i for influence variable values, ς,

$i0$ for selected value of non-distinguishable values of an influence variable which causes the largest combined standard uncertainty for the candidate sampler

p for test particle size

r for repeats

s for candidate sampler individual

4.3 Abbreviations

RMS Root Mean Square

5 Principle

The test method described in this part of EN 13205 is based on the measurement of the candidate sampler's sampling efficiency as a function of particle aerodynamic diameter, whether all aspirated particles are part of the sample (as for most inhalable samplers) or if a particle size-dependent penetration occurs between the inlet and the collection substrate (as for thoracic and respirable samplers). The bias versus the sampling convention is calculated based on the measured sampling efficiencies. Other sampling errors due on-random and random sources of error are also determined, e.g. individual sampler variability, excursion from nominal flow rate, estimation of sampled concentration and experimental errors.

The purpose of the laboratory experiments is to determine the sampling efficiency as a function of particle aerodynamic diameter over the relevant size range, and also as a function of any other relevant variables (as determined in the critical review, see prEN 13205-1:2012, 6.2). Mathematical modelling is used to estimate the concentrations that would be sampled from a range of ideal log-normally distributed aerosols, using both the measured sampler efficiency and the target sampling convention. From these data, the sampler performance is estimated.

6 Test method

6.1 General

The sampling efficiency values are calculated by dividing the aerosol concentrations measured using the candidate sampler, by measured values of the total airborne particle concentration. An experimental design shall be devised that gives due attention to randomisation and to estimation of the main effects. The design, and its associated statistical model, shall be explained in the test report. An example of a suitable design is given in FprCEN/TR 13205-3:2012.

6.2 Test conditions

Experiments to test samplers for the inhalable fraction shall be carried out in a wind tunnel or in an aerosol chamber. Personal inhalable samplers for the inhalable particle fraction, intended for use outdoors or in environments with strong forced ventilation (i.e. wind speeds in excess of 0,5 m/s), shall be tested while mounted on a life-size mannequin, or on a simulated torso. The mannequin or simulated torso set-up shall reproduce the aerodynamic effects of the presence of a life-size, human-shaped head and torso[2)]. In a wind-tunnel of size (1,2 × 1,8) m it has been shown that a simulated torso with the width, height and depth equal to 33 cm, 21 cm and 21 cm, respectively, with samplers mounted on all four vertical planes has been demonstrated to give similar results as a life-size mannequin[3)]. The size and nature of the mannequin/ simulated torso used shall be described in the test report. If a candidate sampler is tested as a personal sampler in moving air, the results do not apply to its use as a static sampler (and vice versa).

The sampling efficiencies of samplers for the thoracic or the respirable fractions are combinations of the samplers' inlet efficiency and of the internal penetration. They may be tested as a whole as described above, except that the particle size range for testing is restricted to that specified for the fraction of interest in Table 1. Alternatively the sampling efficiencies in these cases may be measured by combining the results from two separate experiments, one to test the sampler's inlet efficiency, and one to determine its internal penetration. For tests of the inlet efficiency the same considerations apply as for inhalable samplers, except that the particle size range for testing is restricted to that specified for the fraction of interest in Table 1. Tests of the penetration may be carried out in a low-wind aerosol chamber using isolated samplers.

6.3 Test variables

6.3.1 General

The laboratory tests of sampling efficiency shall be designed to quantify the effects of those influence variables which the critical review indicates are important for the sampler under test. Table 1 lists the most important influence variables and identifies those for which testing is compulsory (C), compulsory for some sampler types or uses only (C*), or optional (O). Excluded variables shall be clearly identified in the section of the test report that describes the scope of the test.

Table 1 — Influence variables to be tested

Variable	Status	Range	Number of values	Clause
Particle aerodynamic diameter	C C C	Inhalable: 1 µm to 100 µm Thoracic: 0,5 µ to 35 µm Respirable: 0,5 µm to 15 µm	≥ 9: spaced to cover important features of the efficiency curve	6.3.2
Wind Speed	C	Indoor workplaces only:	1: ≤ 0,1 m/s	6.3.3
	C	Indoor or outdoor workplaces, 0 m/s to 4,0 m/s:	2: ≤ 0,1 m/s and 1 m/s	

2) For examples of performance evaluations of personal inhalable samplers, see Bibliography, references [2] to [5].

3) See for example Bibliography, references [6] and [7], for reported experiments.