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Zrak na delovnem mestu - Izraļunavanje koncentracije z zdravjem povezanih frakcij aerosolov iz koncentracije, izmerjene z vzorļevalnikom znanih delovnih karakteristik

Workplace atmospheres - Calculation of the health-related aerosol fraction concentration from the concentration measured by a sampler with known performance characteristics

Arbeitsplatzatmosphäre - Berechnung der gesundheitsbezogenen Fraktion der Aerosolkonzentration anhand der mit einem Probenahmegerät mit bekannten Leistungseigenschaften gemessenen Konzentration

Atmosphères des lieux de travail - Calcul de la concentration en fractions d'aérosols liées a la santé a partir de la concentration mesurée a l'aide d'un dispositif de prélevement ayant des caractéristiques de performances connues

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Foreword

This document (CEN/TR 15547:2007) 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.

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Introduction

Exposure assessment of workers to particulate matter dispersed into the air at the workplace is generally achieved through aerosol sampling by using instruments designed for measuring health-related aerosol fractions as defined in EN 481. EN 13205 gives a methodology to evaluate sampler performance. The knowledge of the sampling efficiency of a sampler is used to calculate the bias and the accuracy in concentration for log-normally distributed aerosols. Bias and accuracy maps give an overall indication on sampler performance when sampling health-related aerosol fractions. This performance varies with particle size distribution of sampled aerosol.

Many different samplers can be used for the same purpose, depending on local circumstances or the current practice in the country where these measurements have to be performed. Even with samplers whose performances are quite similar, some significant differences in measured concentrations can occur between these samplers, depending on the aerosol measured. Furthermore, the concentration measured by a sampler is not actually the conventional concentration even if the sampler fulfils the performance criteria stated in EN 13205. This is due to the fact that the particle-size selectivity of the sampler does not generally coincide exactly with the conventional sampling curve over the whole particle-size range.

In the revision of EN 482 presently under way, the uncertainty estimate of a measurement procedure should be expanded to meet the requirements of ENV 13005 complying with GUM (ISO Guide to the expression of Uncertainty in Measurements). This requires that all uncertainties encountered by the use of a measurement procedure (except interlaboratory variation) have to be accounted for. For the special case of aerosol sampling this means that the uncertainty in an expected bias of the sample due to non-ideal collection characteristics will only be estimated for a very wide range of size distributions. The calculations presented in this Technical Report can help to significantly reduce this uncertainty by first estimating a restricted range of size distributions in which the sampler was actually used, and then estimate the bias uncertainty only over this narrow range of size distributions. For an aerosol sampler, the variability due to bias is in many cases a major component of the uncertainty.

1 Scope

This Technical Report specifies a method for calculating and expressing the relevant aerosol fraction concentration and its confidence interval, rather than the actually measured concentration. This can be done for any sampler satisfying EN 13205:2001, Annex A.

The calculation method follows the way developed and described in EN 13205:2001, Annex A and Annex F. This Technical Report explains practically how to perform the calculation.

2 Normative references

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

EN 13205:2001, *Workplace atmospheres — Assessment of performance of instruments for measurement of airborne particle concentrations.*

3 Method to produce improved concentration data

The method is based on the knowledge of sampler's particle size-selectivity and the estimation of the aerosol size distribution. The results with lowest uncertainty are obtained when the concentration measurements are accompanied by measurement of aerosol size distribution. When the size distribution is not known, an estimate can be used. The accuracy of this estimation will have a direct influence on the confidence interval of the concentration value. The estimation of particle size distribution is not an easy exercise, however in many cases the knowledge of the aerosol nature (mineral dust, fumes, oil mists, etc.) allows an approximate estimation to be made.

This approach facilitates a comparison measured health-related aerosol concentrations obtained in different European countries, whatever the samplers used.

The method cannot be used to calculate the respirable aerosol fraction from the thoracic aerosol fraction, or vice versa.

Using the aerosol concentration measured by a sampler and the information provided by the application of EN 13205, it is possible to calculate the concentration of the aerosol conventional fraction of interest and therefore to assess the exposure as mentioned in EN 689 independently of the sampler used. This calculation method leads to less bias relative to the intended conventional health-related aerosol fraction (see [1]).

Using the calculation described in this document is not compulsory. However, there are several circumstances when using the proposed method could help to obtain higher quality results from routine aerosol measurements. Of course, there is no need to use this calculation when the selectivity of the aerosol sampler meets exactly the conventional target curve, i.e. its performance is ideal for all particle sizes.

More accurate values of aerosol concentrations related to some conventional fraction can be needed in some special cases:

— in epidemiological studies consistent exposure data from old and recent periods of time are simultaneously required in order to be correlated with human health effects;

— when data from various sampling techniques and different countries need to be interpreted. The proposed method helps to make the results of measurements more consistent by recalculating them in terms of concentrations of the relevant health-related aerosol fraction. The method allows a comparison of exposures measured at different times and work places provided the performances of the samplers used are known.

Another case where the proposed method can be useful is the measurement of aerosol concentrations in the vicinity of Limit Values. A Limit Value for an aerosol concentration in the workplace is not defined as concentration measured by some sampling device but precisely as a concentration of one of three conventional health-related aerosol fractions (see EN 481). The method is an approach to assess the right concentration to be compared with its Limit Value.

In the case of simultaneous measurements with two or several different samplers, the measured values from all techniques can be processed with the proposed calculation method. The common part of the individual confidence intervals represents a narrower confidence interval of the conventional concentration than that of any individual measurement. The confidence interval improvement is achieved even when the sampler performances are rather poor.

The calculations suggested in this document will not reduce the variability in measured concentration due to the inherent variability of the concentration at a workplace

4 Data needed to calculate the concentration of a health-related aerosol fraction

a) Data from the laboratory evaluation of the sampler performance according to EN 13205:2001, Annex A. The evaluation gives the particle size dependent sampling bias (Δ) along with its standard deviation due to the experimental method $\sigma(\Delta)$.

b) Workplace sampling data as sampled particle mass (M), sampling flow rate (Q) and time of sampling (t) along with the standard deviation of the analytical method e.g. weighing, $\sigma(M)$, and the relative standard deviation of the flow rate, $RSD(Q)$.

c) Distribution of particle mass vs. particle aerodynamic diameter of sampled aerosol, measured or estimated. This could be a log-normal distribution expressed by parameters *MMAD* and *GSD* (Mass Median Aerodynamic Diameter and Geometric Standard Deviation) as written in EN 13205. When the aerosol size distribution is measured at the workplace (e.g. using a cascade impactor), single values of the *MMAD* and the *GSD* will be determined. When the size-distribution measurement cannot be provided, the estimation of these parameters can be expressed as intervals: [$MMAD_{min}$ – $MMAD_{max}$] and [GSD_{min} – GSD_{max}], where $MMAD_{max}$ < 25 µm.

NOTE In some cases the workplace aerosol is better represented by a bi-modal particle size distribution. The bi-modal distribution can be modelled by two combined uni-modal distributions and a parameter "k" from the range [0;1] representing the relative weight of each mode . If the distribution function of the first mode is $Y_1=f(D)$ and the distribution function of the second mode is $Y_2=f(D)$, the bi-modal aerosol distribution Y can be written as:

$$Y = kY_1 + (1-k)Y_2 \tag{1}$$

The more precise the knowledge of the sampler performance and aerosol size-distribution data is, the less uncertainty there will be in the estimated concentration of the health-related aerosol fraction. Quality of sampling performance data may vary with the sampled aerosol fraction. Sampling the respirable and thoracic fractions is less wind-dependent and therefore, the experimental sampling efficiency measurements are generally of higher quality for these fractions than for the inhalable fraction. This is due to the high inertia of coarse particles involved in the inhalable aerosol sampling.

5 Calculation method

The concentration C^* of a specified conventional fraction of an aerosol is given by:

$$C^* = C\int_0^\infty f_M(D)E^*(D)dD \tag{2}$$

where

C is the total aerosol concentration;

f_M the particle-size mass distribution;

E^* is the function defining the conventional probability for particles to penetrate some compartments of the respiratory airways (see EN 481).

f_M and E are functions of particle aerodynamic diameter D. Any actual sampler (index i) is characterized by its own particle-size selectivity that can be represented by a similar function E_i; the concentration measured by this sampler C_i can be deduced from the equation above by simply replacing E^* by E_i:

$$C_i = C\int_0^\infty f_M(D)E_i(D)dD \quad (3)$$

The relative difference between C^* and C_i is called the bias. Knowing the particle-size distribution of the aerosol (index j) characterised by the function $f_{Mj}(D)$ and the measured value of C_i it is possible to correct for the bias Δ_{ij} and to calculate the bias-corrected concentration of the aerosol fraction, C_i^*:

$$C_i^* = \frac{C_i}{1+\Delta_{ij}} \quad (4)$$

Neither C_i nor Δ_{ij} are exactly known. C_i is experimentally obtained from the mass of collected material, the flow rate and the sampling time. Therefore, the value of C_i is affected by random propagating errors, which can be summarised by the variance $\sigma^2(C_i)$. Δ_{ij} can be calculated for any sampler i and for a given aerosol j from equations (2) and (3). The function $E_i(D)$ is generally obtained from least square fitting of discrete sampling efficiency data in the laboratory. The errors of the experimental efficiency data propagate through E_i to Δ_{ij} and thus the variance $\sigma^2(\Delta_{ij})$ can be estimated, as described in EN 13205:2001, Annex F.

According to EN 13205 the relative variance of the concentration C_i^* is $RSD^2(C_i^*)$ (where RSD means Relative Standard Deviation). $RSD^2(C_i^*)$ simply results from the corrected relative variance of the amount of analytically determined sample, $RSD^2(M_i)$, the relative variance of sampling bias, $RSD^2(\Delta_{ij})$, and the relative variance of the determination of sampled volume, $RSD^2(V_i)$:

$$RSD^2\left(C_i^*\right) = RSD^2\left(C_i\right) + RSD^2\left(1+\Delta_{ij}\right) \quad (5)$$

or

$$\left(\frac{\sigma(C_i^*)}{C_i^*}\right)^2 = \left(\frac{\sigma(M_i)}{M_i}\right)^2 + \left(\frac{\sigma(\Delta_{ij})}{(1+\Delta_{ij})}\right)^2 + \left(\frac{\sigma(V_i)}{V_i}\right)^2 \quad (6)$$

The information from the laboratory studies together with the uncertainties on flow rate and collected mass M_i allows the calculation of the 95 % confidence interval I_{95} of the concentration of the health-related fraction C_i^*, based on sample taken with sampler i, $I_{95}(C_i^*)$. This interval is calculated as:

$$I_{95}(C_i^*) = C_i^* \pm 2\sigma(C_i^*) \quad (7)$$