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Zrak na delovnem mestu - Navodilo za vzorčenje inhalabilnih, torakalnih in respirabilnih frakcij aerosolov

Workplace atmospheres - Guidance for sampling of inhalable, thoracic and respirable aerosol fractions

Arbeitsplatzatmosphäre - Leitfaden zur Probenahme der einatembaren, thorakalen und alveolengängigen Aerosolfraktion

Atmospheres de lieux de travail - Guide pour l'échantillonnage des fractions d'aérosols inhalables, thoraciques et alvéolaires

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Workplace atmospheres - Guidance for sampling of inhalable, thoracic and respirable aerosol fractions

Atmosphères de lieux de travail - Guide pour l'échantillonnage des fractions d'aérosols inhalables, thoraciques et alvéolaires

Arbeitsplatzatmosphäre - Leitfaden zur Probenahme der einatembaren, thorakalen und alveolengängigen Aerosolfraktion

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Foreword

This Technical Report (CEN/TR 15230:2005) 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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0 Introduction

0.1 Background

A number of materials hazardous to health occur in the workplace in the form of aerosols, i.e. suspensions of solid or liquid particles in air. Dust is generally understood to be an aerosol of solid particles, mechanically produced, with individual particle diameters of 0,1 µm upwards. Dust particles can be compact in shape, or can have extreme shapes, as for example in the case of airborne fibres. Fume is an aerosol of solid particles generated by condensation from the vapour state usually following the evaporation of molten metals. Smoke is an aerosol of solid and or liquid particles generated by condensation or nucleation of vapours after burning of carbonaceous material. In both fumes and smokes the primary particle diameters are typically less than 0,1 µm which form larger aggregated particles. Mists are aerosols formed from liquid droplets. In this document the term ''aerosol' is used to describe any suspension of particles in air, whether the airborne particles constitute a solid dust, airborne fibres or droplets, a fume, a smoke or a mist.

Aerosol sampling at workplaces can be performed for many reasons using different sampling strategies: These include comparison of the measured concentration with the occupational exposure Limit Value (LV), exposure assessment for epidemiological studies and evaluation of control measures. Occupational Exposure Limits have been defined for many types of aerosol. In order to demonstrate that personal exposure is adequately controlled it is usually necessary to determine the concentration of the aerosol by means of personal sampling. In some cases a direct determination of the aerosol concentration is all that is needed. In other cases a subsequent analytical technique is applied for the determination of a particular harmful element or compound present in the aerosol.

0.2 Sampling instruments

Many instruments have been developed over the years for sampling airborne particles for the purpose of assessing exposure or for determining the efficacy of dust control measures (see [6]). In the past, sampling instruments were often inadequately standardised in terms of their collection characteristics. Modern standards for monitoring exposure to airborne particles are performance based, i.e. they require that the instruments used meet agreed performance criteria with respect to target specifications. This document is intended to help those responsible for making measurements to select and use instruments that meet these modern performance standards.

0.3 Inhalable, thoracic and respirable fractions of airborne particles

Most industrial aerosols contain particles of a wide range of sizes. The behaviour, deposition and fate of any particle after entry into the human respiratory system, and the response that it elicits, depends on the nature and size of the particle. For the purposes of occupational hygiene it is important to consider the concentrations of particles present in different size fractions.

Inhalable dust corresponds to the fraction of airborne material that enters the nose and mouth during breathing, and is therefore available for deposition anywhere in the respiratory tract. The target specification for sampling the inhalable fraction is given in EN 481. In reality the inhalable fraction depends on the prevailing air movement around the exposed person (wind speed and direction), and on whether breathing is by nose or mouth. It has, however, been possible to define a target specification for sampling instruments that approximates to the inhalable fraction, for representative values of breathing rate, and for a person exposed equally to all wind directions.

Thoracic dust corresponds to the fraction of airborne material that passes through the nose or mouth of the exposed person, and enters the branching airways of the lungs. The target specification for sampling the thoracic fraction is given in EN 481. In reality the thoracic fraction depends on breathing rate and varies for different individuals, however it has been possible to define a target specification for sampling instruments which approximates to the thoracic fraction for an average person.

Respirable dust corresponds to the fraction of airborne material that penetrates to the gas exchange region of the lung. The target specification for sampling the respirable fraction is given in EN 481. The respirable fraction varies for different individuals, however it has been possible to define a target specification for sampling instruments, which approximates to the respirable fraction for an average person.

NOTE 1 The PM 10 fraction is defined by US Environmental Protection Agency (and adopted in EN 12341). It also corresponds to the fraction of material that passes through the nose or mouth of the exposed person, and passes the larynx. However, it is based on other experimental data than the scientific basis for the thoracic fraction, and is therefore slightly different. The main difference between the PM 10 and thoracic sampling conventions is that at 15 µm the sampling efficiency for a sampler for PM 10 should be zero whereas it for a sampler for the thoracic fraction should be 19 %.

NOTE 2 The PM 2,5 fraction sampler is defined by US Environmental Protection Agency (see also EN 14907). It corresponds to the fraction of material in the accumulation and nuclei modes of the ambient particle size distribution.

1 Scope

This Technical Report describes methods that are suitable for the determination of the health-related fractions of most aerosols in the workplace.

For more complex aerosols such as bioaerosols, fibres, radioactive aerosols and particle-vapour mixtures further considerations are necessary (see e.g. relevant standards).

This Technical Report is not applicable to the monitoring of airborne particle concentrations using direct-reading instruments.

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

EN 482, *Workplace atmospheres – General requirements for the performance of procedures for the measurement of chemical agents*

EN 689, *Workplace atmospheres – Guidance for the assessment of exposure by inhalation to chemical agents for comparison with limit values and measurement strategy*

EN 1232, *Workplace atmospheres – Pumps for personal sampling of chemical agents – Requirements and test methods*

EN 1540, *Workplace atmospheres – 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*

EN 13098, *Workplace atmospheres – Guidelines for measurement of airborne micro-organisms and endotoxin*

EN 13205, *Workplace atmospheres – Assessment of performance of instruments for measurement of airborne particle concentrations*

ISO 15767, *Workplace atmosphere – Controlling and characterizing errors in weighing collected aerosols*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in the standards listed above, if applicable, apply.

4 Sampling strategy

No sampling strategy can provide comprehensive information for all objectives. The sampling strategy should be carefully tailored to meet the required objectives. Before a measurement survey is started in the workplace a number of fundamental questions like these have to be answered:

— why sample?

— how to sample?

— whose exposure should be measured?

— where to sample?

— when to measure?

— how long to sample for?

— how many measurements?

— how often to sample?

The reason being that time, money and sampling technology constraints are such that not every worker's dust exposure can be measured on every single day of his working career. An optimal sampling strategy will have to be designed given the limited budget available. The actual sampling strategy used will be largely determined by the reasons for the measurement survey. Several objectives can be mentioned:

— to provide information on personal exposure to evaluate compliance with limit values;

— to provide information on personal exposure in the framework of an epidemiological study;

— to provide information on the location and intensity of a source;

— to provide information on prevailing concentrations and trends in the general workplace atmosphere;

— to provide information on the effectiveness of control measures;

— to provide samples of airborne particles for subsequent analytical or toxicological investigations.

For the first two objectives personal sampling is well suited to measure or to monitor individual exposure of workers to airborne particles. The aerosol is sampled in the breathing zone of individual workers. The other objectives on the other hand are often met through static sampling. The aim of static sampling is usually to measure and to analyse the workplace atmosphere in terms of aerosol concentration, particle size-distribution and chemical or mineralogical composition. Another purpose of static sampling is monitoring of time-variations in aerosol concentration at fixed locations. There can be special situations which need the application of a static-sampling strategy, for example, when higher air volume flow rates are needed, or when the system of compliance control measurements depends on that approach. All deviations from a personal sampling strategy should be specifically justified.

When checking compliance often so-called "worst-case" sampling is performed, but these measurements are of limited use for assessing exposure epidemiological purposes. Strategies like "worst-case" sampling can be cost-effective for compliance testing. However, special care should be taken when measurement results coming from a "worst-case" strategy have to be used for epidemiological purposes. Nevertheless this is done in many cases.

Studies focusing on temporal and personal patterns of occupational exposure concentrations, have shown that assumptions of homogeneous or similar exposure groups made up of workers performing the same tasks in one location are often not met. Efficient and effective measurement strategies therefore should take into account temporal and personal variations in exposure concentrations.

Guidance for the assessment of exposure to inhalation to chemical agents for comparison with limit values can be found in EN 689. The strategies described in EN 689 assume that homogeneous exposure groups exist. Rappaport *et al.* (see [4]) have described more recently a measurement strategy taking into account between-worker variability in long-term exposure. This strategy uses an observational group approach, but recognises that exposure varies both within and between workers. The strategy proposed by Rappaport *et.al*. is only suitable for situations where we seek to evaluate and control long-term exposures, which can give rise to chronic health effects. It would be inappropriate to employ this approach to evaluate and control short-term exposures or scenarios where acute effects are likely. Additionally, in short-term sampling the limit of quantitation has to be considered.

5 Method performance

5.1 Limit of detection and limit of quantitation

Both the limit of detection and the limit of quantitation of the methods described in this document depend on the volume of air sampled, and on the analytical method used to quantify the dust collected on the sampling substrates used within the sampling instruments described. Further information on the determination of the limits of detection and quantitation for gravimetric analysis of airborne dust samples is given in ISO 15767.

5.2 Sampling bias

Sampling bias arises primarily from two sources:

a) Concentration bias is minimised by carefully siting the sampler within the breathing zone of the worker, close to the nose and mouth (see 8.2). The concentration to which the sampler is exposed is not necessarily the same as the concentration to which the person is exposed. This is a particularly difficult problem for sampling the inhalable fraction, as larger dust particles are very non-uniformly distributed and are typically produced by localised sources in the workplace.

b) The samplers listed in this Technical Report have been demonstrated to match the target specifications over a reasonable range of conditions, as laid down by the test procedures and requirements of EN 13205. There are no sampling instruments in existence that closely match the target specifications given in EN 481 under all possible workplace conditions.

5.3 Sampling precision

The main source of lack of precision in the measurement of workplace dust concentrations is the non-uniformity (in time and space) of the aerosol cloud surrounding the worker. Analytical and sampling precisions are generally better in comparison. Workplace-based studies using pairs of samplers on each worker have been used to determine the real precision in dust sampling results. For sampling of the inhalable aerosol fraction for example, a second contemporaneous sample on a worker was found to lie within a factor of two of the first sample, on 95 % of occasions (see [5]). Precision in the measurement of thoracic or respirable dust is lower than this figure as smaller particles become more uniformly mixed in workplace air.

Lack of precision caused by the sampling instrument itself is limited by the requirements of EN 13205. See 5.5 of this document.

5.4 Analytical bias and precision

Relevant standards, for example ISO 15767 for gravimetric analysis, should be consulted for details of the analytical bias and precision. Compared to the variability of the workplace aerosol itself, analytical bias and lack of precision generally have (with adequate laboratory quality control) minor impact on the error in the measurement of airborne particle concentrations.

5.5 Expanded uncertainty

Sampling instruments meeting the requirements of EN 13205 will have an accuracy better than or equal to 30 %. Note however, for complete measurement procedures for airborne particles, the expanded uncertainty (see EN 482) is a combination of the uncertainty of the sampled volume, the uncertainty of the sampled fraction, the uncertainty of the transportation, storage, sample preparation, etc. and the uncertainty of the analytical method employed.

The measured concentration will be a good approximation of the concentration to which the worker is exposed, only, if the sampler meets the requirements of EN 13205, if it has been correctly sited (see 8.2), if the sampling time corresponds to or is representative of the exposure time and if the transportation, storage and analytical methods used are appropriate. The temporal, spatial and personal variability of the workplace aerosol concentration often far exceeds the variability of sampling and analysis procedures. The sampling strategy used needs to accommodate the large variability of workplace concentrations.

6 Sampling instruments

6.1 Personal and static samplers

Workplace aerosols can be sampled for different purposes, which determine the choice of an appropriate sampler (personal or static).

Static samplers often use high flow rates (> 10 l min^{-1}) in order to collect a high amount of particulate matter, sufficient for further analysis.

A high flow rate pump shall not be allowed to exhaust more than a small fraction of the air flow through a room.

Personal sampling systems are worn by the persons themselves, and for this reason a personal sampler should be small and light and therefore its flow rate is usually also small.

In practice, it is also possible to use personal samplers for static sampling but a personal sampler might not be a validated static sampler. Static samplers are usually not suitable for personal sampling because of their weight, except for special cases, e.g. samplers mounted in a driving cabin for sampling the exposure of the driver.

NOTE Static samplers are sometimes called stationary samplers, area samplers or fixed-point samplers.

Personal and static samplers should meet the same sampling performance criteria as given in EN 13205. See 5.2 b).

6.2 Personal and static samplers for the inhalable aerosol fraction

Samplers for the inhalable aerosol fraction with the potential to meet the requirements of EN 481 and EN 13205 for several environmental conditions are listed in Table B.1. With each sampler name, references are given to reports and papers that demonstrate the performance of the sampler. These references should be consulted for detailed information on the field conditions for which satisfactory performance is obtained.

For samplers of the inhalable aerosol fraction, the instruments listed have most difficulty to meet the requirements in field situations where there are

- high external winds, e.g. in underground mines or out doors;
- large particles generated with high momentum ("projectiles"), e.g. as produced in woodworking or textile manufacture;
- losses during transportation of samples, e.g. when samples are taken remotely from the analytical laboratory and shipped by mail.

In general these problematic situations lead to undersampling of the inhalable aerosol fraction, except for "projectiles".

NOTE The concentration of the inhalable aerosol fraction is usually very localised and therefore static samplers are unlikely to give a valid indication of personal exposure.