SLOVENSKI STANDARD
kSIST-TS FprCEN/TS 18073:2024

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Zunanji zrak - Določanje koncentracije delcev. ki se lahko usedajo na površino pljuč (LDSA) z uporabo monitorjev aerosolov na podlagi difuzije in naboja

Ambient air - Determination of lung deposited surface area (LDSA) concentration using aerosol monitors based on diffusion charging

Außenluft - Bestimmung der lungendeponierbaren Oberflächenkonzentration (LDSA) mit Aerosolmonitoren auf Basis der Diffusionsaufladung

Air ambiant - Détermination de la concentration en surface spécifique des particules pouvant se déposer dans les poumons (LDSA) à l’aide de moniteurs d’aérosols basés sur la charge par diffusion

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TECHNICAL SPECIFICATION

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English Version

Ambient air - Determination of lung deposited surface area (LDSA) concentration using aerosol monitors based on diffusion charging

Air ambiant - Détermination de la concentration surfacique des particules d'aérosol atmosphérique à l'aide de moniteurs d'aérosols électriques basés sur la charge par diffusion

Außenluft - Bestimmung der lungendeponierbaren Oberflächenkonzentration (LDSA) mit Aerosolmonitoren auf Basis der Diffusionsaufladung

This draft Technical Specification is submitted to CEN members for Vote. It has been drawn up by the Technical Committee CEN/TC 264.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
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European foreword

This document (FprCEN/TS 18073:2024) has been prepared by Technical Committee CEN/TC 264 “Air quality”, the secretariat of which is held by DIN.

This document is currently submitted to the Vote on TS.

Introduction

There is growing recognition of the importance of aerosol particles with diameters D < 1 µm for human health as well as for their effects on climate. While usually the mass concentration of airborne particles is quantified both in the environment and at the workplace, various studies have shown the relevance of the number and surface area concentration to their health effects. Correlations between the incidence of respiratory diseases and the number concentrations of airborne particles are, e.g. given in [1]. It was shown that the effects on health due to inhaled particles correlate better with the particle surface area dose than with the particle mass dose [2] or the particle number dose [3]. To describe the air quality in terms of dust load, it therefore appears advisable to supplement the parameters of mass concentration (for PM_{10} and $PM_{2,5}$, see EN 12341 [4]), particle number concentration and number size distribution (see prEN 16976 [5] and CEN/TS 17434 [6]) with measurements of further metrics, e.g. particle surface area concentration as a health-relevant metric.

For the measuring device required for the implementation of the measuring method described in this document, the designation “electrical aerosol monitor based on diffusion charging” abbreviated to DCAM (Diffusion-Charger-based Aerosol Monitor) is introduced.

1 Scope

This document specifies a process for the electrical diffusion charging of aerosols with subsequent measurement of particle charge. With the aid of this method, it is possible to determine the lung-deposited surface area (LDSA) concentration of particles in ambient air. Depending on the design of the electrical diffusion charger, the LDSA of particles in the size range of approximately 20 nm to approximately 300 nm is measurable.

Furthermore, this document specifies design criteria for LDSA measuring aerosol monitors as well as performance criteria and the associated test procedures. The performance criteria depend on the application and they are more stringent when the instrument is operated in an air quality monitoring station.

In the determination of the LDSA concentration, the share of geometric particle surface area concentration is determined that can be deposited in the alveolar region of the human lung. Typical particle surface area concentrations with alveolar deposition measured in urban areas range from 5 $\mu m^2/cm^3$ to 50 $\mu m^2/cm^3$.

Instruments based on this measurement principle can be designed to be very compact with a low power consumption. This makes them ideally suited for hand-held measurements, other forms of mobile application or to measure personal exposure. On the other hand, they can be easily adapted to serve as a stationary instrument in air quality monitoring stations.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at https://www.electropedia.org/

— ISO Online browsing platform: available at https://www.iso.org/obp

3.1 Aerosol properties

3.1.1
aerosol
multi-phase system of solid and/or liquid particles suspended in a gas, ranging in particle size from 0,001 µm to 100 µm

[SOURCE: prEN 16976:2023] [5]

3.1.2
particle
small piece of matter with defined physical boundary

Note 1 to entry: The phase of a particle can be solid, liquid, or between solid and liquid and a mixture of any of the phases.

[SOURCE: ISO 27891:2015, modified] [7]

3.1.3
number size distribution
frequency distribution of the particle number concentration as a function of particle size

[SOURCE: prEN 16976:2023] [5]

3.2 Particle size metrics

3.2.1
equivalent diameter
diameter of the sphere with defined characteristics which behaves under defined conditions in exactly the same way as the particle being described

[SOURCE: ISO 27891:2015] [7]

3.2.2
aerodynamic diameter
diameter of a sphere of density ρ_0 = 10^3 kg·m^{-3} = 1 g·cm^{-3} with the same terminal velocity due to gravitational force in calm air as the particle, under the prevailing conditions of temperature, pressure and relative humidity within the respiratory tract

[SOURCE: ISO 13138:2012] [8]

3.2.3
Stokes diameter
diameter of a spherical particle which at the same velocity relative to a medium experiences the same drag force as the particle to be described

3.3 Particle concentration metrics

3.3.1
particle number concentration
number of particles related to the unit volume of the carrier gas

[SOURCE: ISO 27891:2015] [7]

3.3.2
particle surface area concentration
total surface area of all dispersed particles per unit of volume of the carrier gas

3.3.3
lung-deposited surface area concentration
LDSA concentration
particle surface area concentration per unit volume of air, weighted by the deposition probability in the lung

[SOURCE: ISO 16000-34:2018] [9]

4 Principle

4.1 Physical principles

This method combines the particle-size-dependent electrical diffusion charging of particles with subsequent measurement of the electrical current caused by the charged particles. In this process, gas ions of a single polarity are attached by diffusion to the aerosol particles. The mean particle charge n_c resulting from this diffusion charging is a function of particle size D_p (Stokes diameter) and can be approximated with Formula (1):

$$n_c(D_p) = k_c \cdot D_p^x \qquad (1)$$

Here, the coefficient k_c and exponent x are empirically determined quantities that are dependent on the particle size range concerned and specific to a charger type. For pure diffusion chargers, various studies have shown that, for particles of diameter < approx. 400 nm, the exponent x ranges from 1,1 to 1,4 (e.g. [10 to 12]).

To convert the charge transport by the particles into a measurable electrical current, the particles can be deposited either directly on a conductive electrode (e.g. by an electric field) or transported in the gas-borne state into a Faraday cup. If the particles are deposited on a filter within the Faraday cup, current flows onto the electrically isolated, metal Faraday cup (electrostatic induction) to compensate for the charge introduced into the cup. Alternatively, the charging process can be switched on and off at a certain frequency. This gives rise to charged “aerosol packets” that generate a pulse of current on entering and leaving the Faraday cup.

In all cases the very small electrical currents (< 1 pA) are converted with electrometer amplifiers into a voltage that represents the method’s output signal and can be further processed by a data acquisition system.

Diffusion charging shows only little dependence on the ambient conditions of temperature and pressure and on particle material [13]. The relative humidity can indirectly affect the charging process if it results in a change in particle size.

4.2 Physiological principles

Only a portion of the inhaled particles is deposited in the lung, the remainder being exhaled. Particles are deposited in the lung principally because of their Brownian motion (diffusional deposition), the blocking effect (interception deposition) and particle inertia (impaction deposition). Particle inertia is not relevant in the considered size range from approx. 20 nm to approx. 300 nm. With increasing particle size, diffusional deposition declines, while interception and impaction deposition increase. Thus, the lung deposition efficiency is the particle-size-dependent ratio of the quantity of particles deposited in the lung to the total quantity of inhaled particles.

Figure 1 shows the deposition efficiency in the alveolar region of the human lung calculated using KDEP [14], an open source implementation of the ICRP (International Commission on Radiological Protection) model [15]. The curve represents an average for male and female individuals with nose breathing and the activity pattern “member of the public”. Spherical particles with a density of 1 500 kg/m^3 were used as model for the atmospheric aerosol. Numerical results of the calculation can be found in Annex B. Owing to the size dependences of the separation mechanisms in the respiratory tract, this yields a characteristic curve with an efficiency maximum at approx. 20 nm and an efficiency minimum at approx. 300 nm. Since impaction deposition predominates above this minimum, the efficiency becomes additionally dependent on particle density. The Figure also illustrates that, in the size range from approx. 20 nm and approx. 300 nm, the alveolar deposition curve shows a slope, which on the double logarithmic scale employed is almost constant and proportional to $D_P^{-0,9}$ (compare the dot-dashed straight line). If the particle surface area dependent on the square of particle diameter is weighted with this ratio, this yields $D_P^2 \cdot D_P^{-0,9} = D_P^{1,1}$. For certain parameters of the charging process, this corresponds to the relationship for the mean particle charge given in 4.1, so an interpretation of the signal as the lung-deposited surface area concentration is possible.

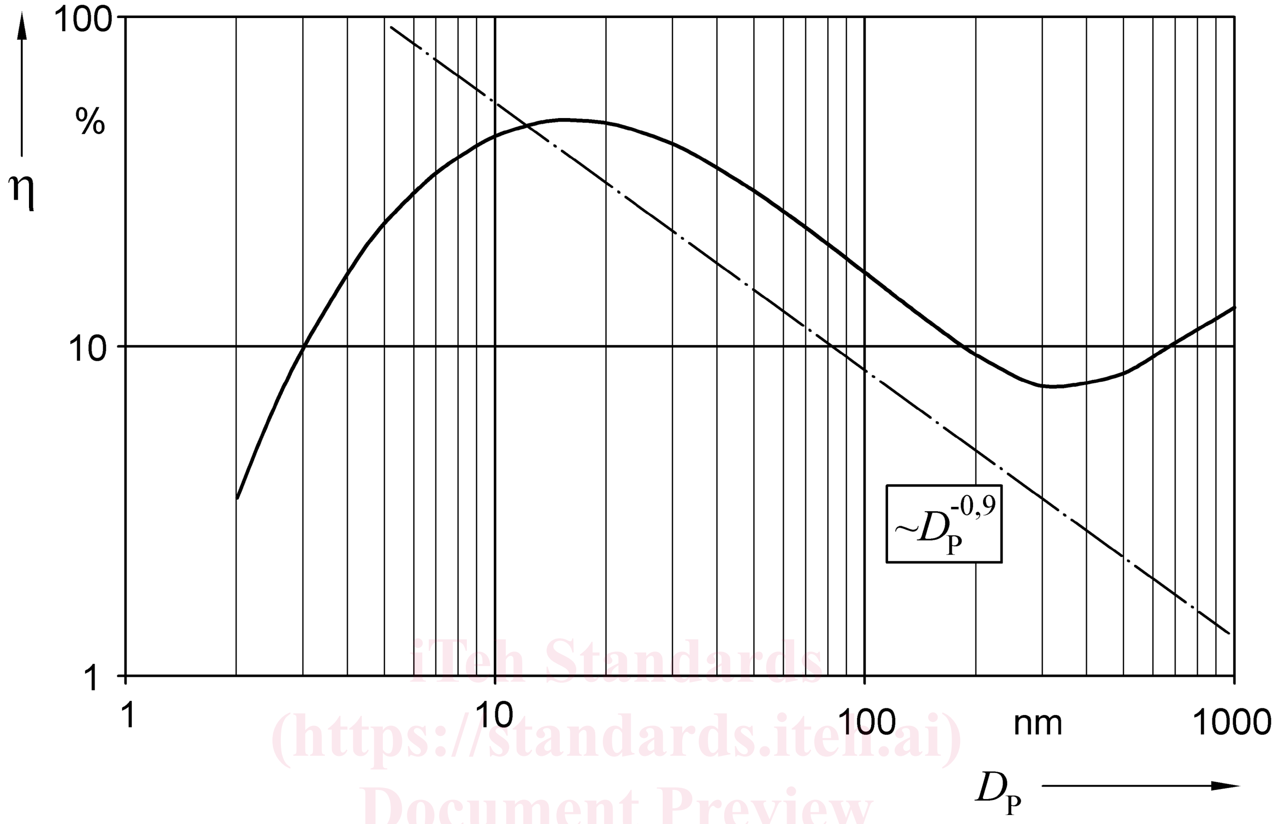

Figure 1 — Efficiency *η* of particle deposition in the alveolar region of the human lung as a function of particle diameter D_P (conforming to [15]; parameters given above)

5 Function

5.1 General

In an electrical aerosol monitor based on diffusion charging (DCAM), particles, after passing through an inertial separator, if necessary, are electrically charged in a diffusion charger. Excess ions are then removed in an ion trap and the particle charges are measured. Depending on the charging characteristics, the measured current is proportional to the particle diameter concentration or to the lung-deposited surface area concentration. Figure 2 shows a general schematic of a DCAM.