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Zunanji zrak - Določevanje spektra velikosti delcev atmosferskih aerosolov s spektrometrom na osnovi mobilnosti (MPSS)

Ambient air - Determination of the particle size spectra of atmospheric aerosol using a Mobility Particle Size Spectrometer (MPSS)

Außenluft - Bestimmung des Partikelgrößenspektrums des atmosphärischen Aerosols mit einem Partikelgrößenmobilitätsspektrometer (MPSS)

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Air ambiant - Détermination de la distribution granulométrique de particules d'un aérosol atmosphérique à l'aide d'un spectromètre de granulométrie à mobilité électrique (MPSS)

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Ambient air - Determination of the particle number size distribution of atmospheric aerosol using a Mobility Particle Size Spectrometer (MPSS)

Air ambiant - Détermination de la distribution granulométrique de particules d'un aérosol atmosphérique à l'aide d'un spectromètre de granulométrie à mobilité électrique (MPSS)

Außenluft - Bestimmung der Partikelanzahlgrößenverteilung des atmosphärischen Aerosols mit einem Mobilitäts-Partikelgrößenspektrometer (MPSS)

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European foreword

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Introduction

There is a growing awareness of the significance of aerosol particles with diameters of D < 1 µm for human health as well as for their climatic impact. To assess air quality, it appears necessary to supplement gravimetrically determined mass concentrations such as PM_{10} or $PM_{2.5}$ with a measurement of the particle number concentration. Since ultrafine particles with diameters of D < 0,1 µm make an almost insignificant contribution to the mass concentration of atmospheric aerosol particles, they can best be detected with counting measuring methods of sufficient sensitivity.

As particle measurement instrumentation allows determining either the particle number concentration or the particle number size distribution two Technical Specifications have been established:

— one dealing with the determination of the single parameter number concentration (a measure of "total" number concentration (CEN/TS 16976)),

— one dealing with the determination of number concentrations within a limited number of size ranges (this document).

Clauses 5 and 6 contain general information about the method and the expected properties of the aerosol particles to be measured.

Clause 7 sets out the performance criteria for MPSSs. Specifically, these are the relevant performance characteristics of MPSS instruments (without any sampling system), the respective criteria that shall be met, and a description of how the tests shall be carried out. In general these tests are expected to be carried out by test houses or MPSS manufacturers rather than users, and could form the basis for type approval of MPSSs in future.

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Clause 8 sets out the performance criteria and test procedures for the sampling and conditioning system. These may be applied by manufacturers of sampling systems, test houses or users (network operators).

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Clause 9 sets out requirements for the installation, initial checks and calibrations, and operation of an MPSS and sampling system at a monitoring site, including routine maintenance, data processing (including use of QA/QC data) and reporting. In general these will be the responsibility of users (network operators), though calibrations requiring test aerosols shall only be carried out by suitably qualified laboratories.

Clause 10 sets out Quality Assurance and Quality Control procedures, i.e. the ongoing checks and calibrations that are required on the MPSS and sampling system during operation at a monitoring site. It is expected that these will be the responsibility of users (network operators). The main sources of measurement uncertainty are described, but it is not possible in this document to quantify the overall measurement uncertainty for data reported following the method.

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1 Scope

This document describes a standard method for determining particle number size distributions in ambient air in the size range from 10 nm to 800 nm at total concentrations up to approximately 10^5 cm^{-3} with a time resolution of a few minutes. The standard method is based on a Mobility Particle Size Spectrometer (MPSS) used with a bipolar diffusion charger and a Condensation Particle Counter (CPC) as the detector. The document describes the performance characteristics and minimum requirements of the instruments and equipment to be used, and describes sampling, operation, data processing and QA/QC procedures, including calibration.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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.

CEN/TS 16976:2016, *Ambient air — Determination of the particle number concentration of atmospheric aerosol*

ISO 15900, *Determination of particle size distribution — Differential electrical mobility analysis for aerosol particles*

ISO 27891:2015, *Aerosol particle number concentration — Calibration of condensation particle counters*

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3 Terms and definitions

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

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

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

3.1
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: CEN/TS 16976:2016]

3.2
detection efficiency
ratio of the particle number concentration determined by the measuring instrument to the reference particle number concentration of the aerosol at the instrument's inlet

[SOURCE: CEN/TS 16976:2016, modified]

3.3
number size distribution
frequency distribution of the particle number concentration represented as a function of the logarithm of particle size, such that the area under the distribution between two sizes is the number concentration of that size range

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3.4
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]

3.5
particle number concentration
number of particles related to the unit volume of the carrier gas

Note 1 to entry: For the exact particle number concentration indication, information on the gaseous condition (temperature and pressure) or the reference to a standard volume indication is necessary.

Note 2 to entry: The usual unit is cm^{-3}.

[SOURCE: ISO 27891:2015, modified]

4 Symbols and abbreviations

CPC	Condensation Particle Counter
DMA	Differential Mobility Analyser
HEPA	High Efficiency Particulate Air
MPSS	Mobility Particle Size Spectrometer
PSL	Polystyrene Latex
QA/QC	Quality Assurance / Quality Control

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5 Atmospheric aerosol

Atmospheric aerosols are strongly dependent on their local and regional sources. Especially, the size distributions in number and mass, as well as the size-resolved chemical composition are highly variable. Aerosol particles are either emitted directly (primary aerosols) or formed by nucleation and condensation from pre-cursor gases (secondary aerosol). Combustion processes lead to both primary and secondary aerosols [1].

Due to these different formation processes the size distribution of the atmospheric aerosol shows three to four different modes which schematically are sketched in Figure 1.

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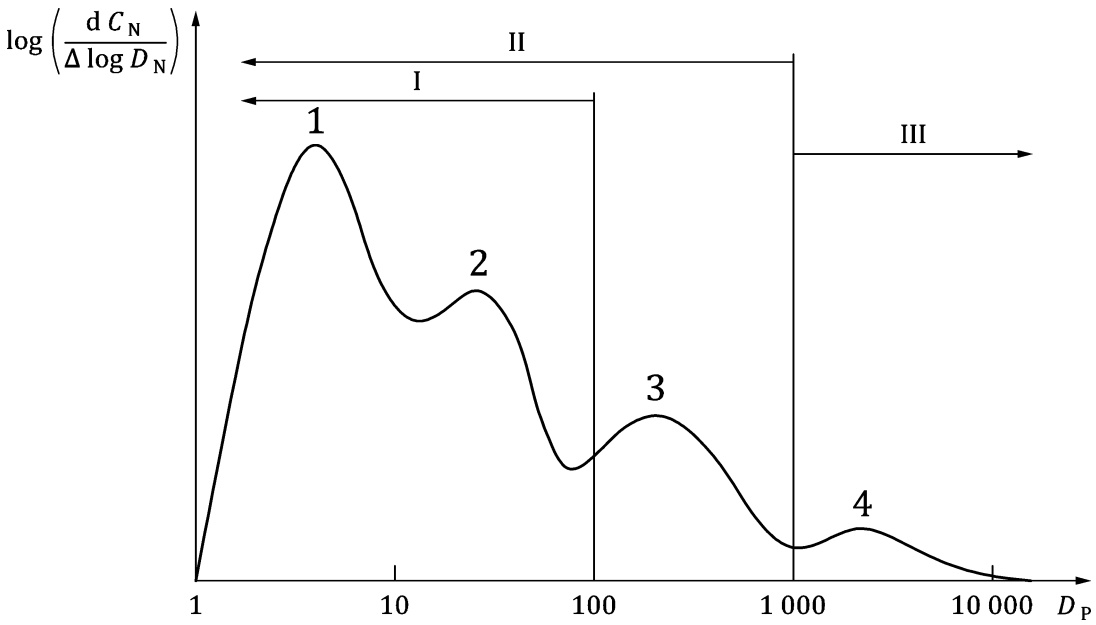

Key

1	Nucleation mode	I	Ultrafine particles
2	Aitken mode	II	Fine particles
3	Accumulation mode	III	Coarse particles
4	Coarse mode		

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Figure 1 — Schematic representation of the different modes of the size distribution of atmospheric aerosols (mode height not to scale)

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Particles in the nucleation mode are mainly produced by photochemical reactions and by mixing processes from gaseous precursors. If supply of gaseous precursors persists, they grow rapidly by condensation so that their size is shifted into the Aitken mode. Combustion processes contribute particles directly to the Aitken mode. The size of the particles in the Aitken mode increases mainly by cloud processing, condensation and coagulation, so that they are shifted into the accumulation mode. Particles in the coarse mode are mainly produced by mechanical processes like the abrasion and resuspension of mineral dust, dispersion of sea salt as particles and emission of pollen and other biological material. Both the accumulation and the coarse mode particles are often not clearly recognizable in the number distribution but contribute substantially to the mass distribution.

Besides these definitions used in the field of atmospheric physics there are the health and regulatory definitions of fine, ultrafine and coarse particles. The size ranges associated with these terms are also given in Figure 1.

Mass-wise, the global direct emission of aerosol particles is dominated by sea salt, biological material as well as by desert and volcanic dust. These particles are generally larger than 1 µm (coarse mode). Anthropogenic emissions in this size range play a minor role on a global scale. Submicrometer natural aerosols consist mainly of marine sulphate, biogenic organics, and wildfire carbonaceous particles. Submicrometer anthropogenic aerosols are complex mixtures of primary and secondary particles, consisting mainly of sulphate, nitrate, organics and elemental carbon.

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Particle number concentrations of atmospheric aerosols cover several orders of magnitude. While remote marine or free tropospheric aerosols have number concentrations as low as tens or a few hundred per cubic centimetre, continental or urban aerosols can contain a few thousand up to one million particles per cubic centimetre. The number concentration of the anthropogenic aerosols over land, especially in urban areas is dominated by particles in the size range smaller than 0,1 µm. Major sources for high particle number concentrations in this size range are regional new particle formation due to homogeneous nucleation and local combustion processes. Average background concentrations in an urban area are several tens of thousands of particles per cubic centimetre.

For details see Annex H.

6 Description of the method

6.1 Sampling and conditioning

6.1.1 Sampling

The measurement of atmospheric aerosols will always necessitate sampling and the transport of the sample to the measuring instrument. Moreover, in certain cases the sample shall be processed in terms of temperature, relative humidity and particle concentration in order to adapt the aerosol to the measuring instrument's permissible operating conditions.

The information given on this issue in this document refers to stationary ambient monitoring sites. For mobile applications (e.g. measurements from aircraft), additional considerations shall be taken into account.

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The measuring instruments shall be accommodated in a protected environment in controlled conditions (temperature 20 °C to 30 °C).

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The sampling location depends on the measurement task. If the undisturbed atmospheric aerosol is to be measured, air intake should take place 5 m to 10 m above the ground level. Buildings, vegetation or the topography of the terrain may make an even higher sampling point necessary. By contrast, the measurement of aerosols affecting the exposure of humans (e.g. traffic) calls for much lower sampling heights (1,5 m to 4 m above the ground, see Directive 2008/50/EC [2]).

The design of the aerosol inlet should permit representative sampling regardless of the direction of the wind for a broad range of wind velocities. However, this is not a critical condition for the small particles measured by the MPSS. Steps shall be taken to avoid soiling of the sampling lines by particles larger than 10 µm. PM10 or PM2.5 inlets can be used for this purpose (see Figure 2).

The sample should ideally be fed via a vertical primary sampling tube without bends to the measuring instruments. Since gas measuring methods have fundamentally different requirements regarding sampling, gas and aerosol sampling should be conducted independently of each other.

To reduce particle losses due to diffusion to walls, it is necessary to sample the aerosol with the aid of a pump at a primary flow rate (Q_{tot}) much higher than the secondary flow rate (Q_{MPSS}). The instrument should sample isoaxially in the central area from this volumetric flow via a secondary sampling tube that is as short as possible. The flow in the primary sampling tube should be laminar in order to prevent additional particle loss due to turbulence. Ideally, a Reynolds number of about Re = 2000 shall be aimed for (see 8.2) to minimize losses due to diffusion.

The particle losses due to diffusion in the sampling system shall be determined and corrected (see Annex C).

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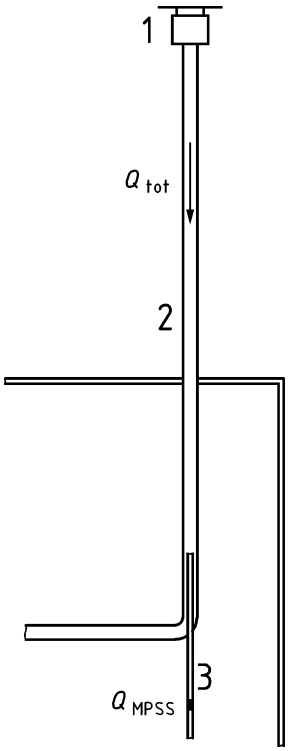

Key

1 PM sampling inlet
2 Primary sampling tube
3 Secondary sampling tube

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Figure 2 — Basic design of the aerosol intake port

The aerosol inlet and the sampling lines shall be made of a conductive, corrosion-resistant material with a low surface roughness (e.g. stainless steel) and electrically earthed. This prevents chemical changes to the aerosol and particle losses due to electrostatic effects. Flexible tubing of electrically conductive material may also be used for small connections or short distances. The length of flexible tubing should be below 50 cm.

The inlet and the flow-splitter of the sampling system shall be checked regularly to detect obstructions, e.g. by insects, and cleaned, if necessary.

6.1.2 Aerosol Drying

Aerosols with a high relative humidity (mist in extreme cases) should be dried, as the size of hydrophilic particles (particles containing salts or water-soluble organic material) is strongly dependent on the relative humidity due to hygroscopic growth. Ambient air may increase its relative humidity considerably when cooled down in an air-conditioned environment. The requirement is to keep the relative humidity of the sample flow at the MPSS inlet lower than 40 % [3]. The relative humidity at the inlet of the MPSS shall be monitored.

With respect to the temperature conditions three cases are to be distinguished:

— In case the room temperature is higher than 22 °C no aerosol dryer is needed if the ambient dew point temperature never exceeds 10 °C.

— If the dew point temperature is between 10 °C and the room temperature, the secondary flow shall be dried.

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— In case that the dew point temperature is above the room temperature, the primary flow shall be dried before entering the room. Additional drying of the secondary flow may be necessary.

There are three recommended methods to dry the aerosol:

— Aerosol diffusion dryer based on silica;

— Membrane dryer (e.g. Nafion™ dryer);

— Dilution with dry particle-free air. In this case, the exact dilution ratio shall be known in order to calculate the correct concentrations. The minimum requirement with respect to accuracy of the dilution factor is given in 8.2, the operation principle of a suitable dilution system is presented in Annex G.

Heating is not recommended as this may change the aerosol (significant evaporation of semi-volatile compounds above 40 °C).

6.2 Determination of particle number size distribution with an MPSS

6.2.1 Physical principle

Mobility particle size spectrometers consist of a sequential setup of a bipolar diffusion charger, a Differential Mobility Analyser (DMA), and a Condensation Particle Counter (CPC). By setting different voltages in the DMA, particles of different electrical mobility are selected and their particle number concentration can be measured. Ramping or stepping the voltage yields an electrical particle mobility distribution, which can later be inverted into a particle number size distribution (ISO 15900).

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NOTE In ISO standardization the terms DMAS (Differential Mobility Analysing System) and DEMC (Differential Electrical Mobility Classifier) are used for MPSS and DMA, respectively. A bipolar diffusion charger is termed charge conditioner in ISO standardization.

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6.2.2 Particle charging

Before the aerosol particles enter the DMA, they are brought to a bipolar charge equilibrium using a bipolar diffusion charger. This bipolar charge equilibrium can be described theoretically [4] (for data on particle charging probabilities as a function of particle size as well as for simplified methods to calculate these data see Annex A). Positive and negative ions are produced continuously in this bipolar diffusion charger, for instance by a radioactive or a soft X-ray source. The radioactive sources used in field observation include e.g. ^{85}Kr, ^{63}Ni (beta emitters), ^{241}Am and ^{210}Po (alpha emitters).

To achieve a bipolar charge equilibrium, the particle number concentration should be significantly lower than the equilibrium ion pair concentration, which is estimated to be approximately 10^7 cm^{-3}. As more charges are attached to large particles than small ones, the upper concentration limit depends on the particle number size distribution of the aerosol, so that no definitive value for the maximum concentration can be given. The recommended upper limit for the total particle number concentration entering the MPSS is 10^5 cm^{-3}.

6.2.3 Mobility analysis

A DMA is usually built in the shape of a cylindrical capacitor (see Figure 3). The charged polydisperse aerosol is injected at a flow rate Q_A through an annular slit close to the outer electrode into the DMA and then merged with the particle-free sheath air flow Q_S.

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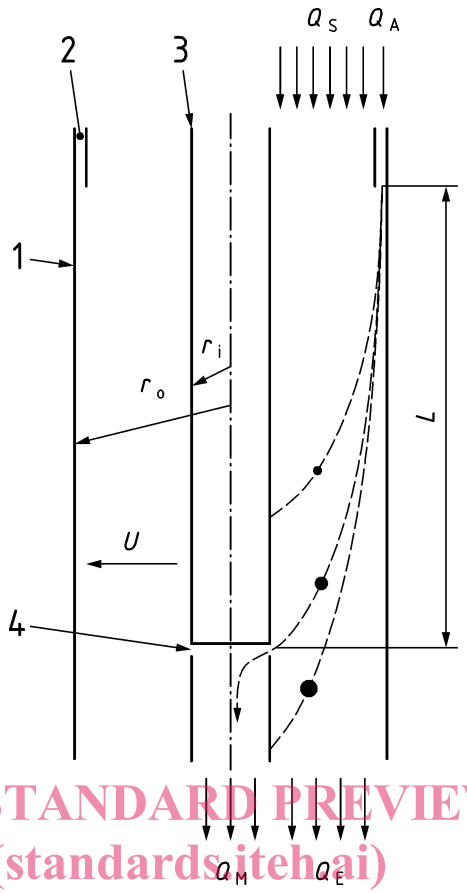

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Key

1	Outer electrode; radius r_o	Q_A	Polydisperse aerosol flow rate
2	Annular inlet slit	Q_S	Sheath air flow rate
3	Inner electrode; radius r_i	Q_M	Mobility-selected aerosol flow rate
4	Annular exit slit	Q_E	Excess air flow rate
U	Voltage	L	Effective length

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Figure 3 — Principle of a DMA