

AS/NZS 3580.9.12:2022



Australian/New Zealand Standard™

Methods for sampling and analysis of ambient air

**Method 9.12: Determination of suspended particulate matter — PM_{2.5}
beta attenuation monitors**



AS/NZS 3580.9.12:2022

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Method 9.12: Determination of suspended particulate matter — PM_{2.5} beta attenuation monitors

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Preface

This Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee EV-007, Methods for Examination of Air, to supersede AS/NZS 3580.9.12:2013.

The objective of this document is to provide regulatory and testing bodies with a method for continuously monitoring suspended particulate matter with an equivalent aerodynamic diameter (EAD) of less than 2.5 μm (PM_{2.5}) in ambient air, providing near real-time measurement of mean particle concentration.

The major changes in this edition are as follows:

- (a) Alignment with current technology and to ensure consistency and uniformity across the different methods used in other continuous particulate monitoring Standards.
- (b) Provision of an essential reference to AS 3580.19.

The requirements for instruments specified in this document were derived from those given in the United States Environmental Protection Agency (US EPA), Code of Federal Regulations, Title 40 Protection of Environment, Part 53 Ambient Air Monitoring Reference and Equivalent Methods (40 CFR 53), or instruments that have demonstrated equivalence in accordance with AS/NZS 3580.9.17.

The terms “normative” and “informative” are used in Standards to define the application of the appendices to which they apply. A “normative” appendix is an integral part of a Standard, whereas an “informative” appendix is only for information and guidance.

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Australian/New Zealand Standard

Methods for sampling and analysis of ambient air

Method 9.12: Determination of suspended particulate matter — PM_{2.5} beta attenuation monitors

1 Scope

This document sets out the method for determining suspended particulate matter in ambient air using a beta attenuation monitor (BAM).

NOTE PM_{2.5} has been statistically associated with certain human health end points, including daily mortality, hospital admissions and exacerbation of asthma. PM_{2.5} emission sources include industrial processes, fuel combustion, burning of vegetation, incineration and natural causes such as windblown dust and salt laden air. Combustion processes tend to contribute more PM_{2.5} than non-combustion sources. Important anthropogenic sources include domestic wood heaters and motor vehicles (especially diesel fuelled vehicles).

The method can provide a measure of the time-integrated mean particle concentrations for periods ranging from 10 min to 24 h. Measurements made in accordance with this method, when averaged over a 24 h period, are considered to be equivalent to those determined in accordance with US EPA 40 CFR 50 Appendix L and US EPA 40 CFR 53 Subparts E and F.

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.

NOTE Documents for informative purposes are listed in the Bibliography.

AS 3580.9.10, *Methods for sampling and analysis of ambient air, Method 9.14: Determination of suspended particulate matter—PM_{2.5} low volume sampler—Gravimetric method*

AS 3580.19, *Methods for sampling and analysis of ambient air, Method 19: Ambient air quality data validation and reporting*

AS/NZS 3580.1.1, *Methods for sampling and analysis of ambient air, Part 1.1: Guide to siting air monitoring equipment*

AS/NZS 3580.9.14, *Methods for sampling and analysis of ambient air, Method 9.14: Determination of suspended particulate matter—PM_{2.5} high volume sampler with size selective inlet—Gravimetric method*

AS/NZS 3580.9.17, *Methods for sampling and analysis of ambient air, Method 9.17: Demonstration of equivalence for ambient particulate matter monitoring methods*

AS ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories*

US EPA 40 CFR 50 Appendix L, Code of Federal Regulations, Title 40 Protection of Environment, Part 50 National Primary and Secondary Ambient Air Quality Standards, Appendix L Reference Method for the Determination of Fine Particulate Matter as PM_{2.5} in the Atmosphere

US EPA 40 CFR 53 Subpart D, Code of Federal Regulations, Title 40 Protection of Environment, Part 53 Ambient Air Monitoring Reference and Equivalent Methods, Subpart D Procedures for Testing Performance Characteristics of Methods for PM₁₀

US EPA 40 CFR 53 Subpart E, Code of Federal Regulations, Title 40 Protection of Environment, Part 53 Ambient Air Monitoring Reference and Equivalent Methods, Subpart E Procedures for Testing Physical (Design) and Performance Characteristics of Reference Methods and Class I and Class II Equivalent Methods for PM_{2.5} or PM_{10-2.5}

US EPA 40 CFR 53 Subpart F, Code of Federal Regulations, Title 40 Protection of Environment, Part 53 Ambient Air Monitoring Reference and Equivalent Methods, Subpart F Procedures for Testing Performance Characteristics of Class II Equivalent Methods for PM_{2.5}

3 Terms and definitions

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

3.1

areic

modifier used to denote an attribute divided by area

3.2

beta particle

radiation emitted during the nuclear decay of radioactive elements

Note 1 to entry: Monitors used in accordance with this method typically use an element such as ¹⁴C.

3.3

equivalent aerodynamic diameter

EAD

diameter of a spherical particle of unit density 1 g/cm³ that exhibits the same aerodynamic behaviour as the particle in question

3.4

may

indicates the presence of an option

3.5

PM_{2.5}

suspended particulate matter consisting of particles having an EAD of less than 2.5 µm, which is passed by a size classifier having defined performance characteristics

Note 1 to entry: Performance characteristics are defined in US EPA 40 CFR 50 Appendix L.

3.6

PM₁₀

suspended particulate matter consisting of particles having an EAD of less than 10 µm, which is passed by a size classifier having defined performance characteristics

Note 1 to entry: Performance characteristics are defined in US EPA 40 CFR 53 Subpart D.

3.7

range

nominal minimum and maximum concentrations that a method is capable of measuring

Note 1 to entry: The nominal range is given by lower and upper range limits in concentration units, e.g. 0 to 1 000 µg per cubic metre (µg/m³).

3.8

shall

indicates that a statement is mandatory

3.9

should

indicates a recommendation

3.10

U₉₅

estimate of expanded uncertainty at a confidence interval of 95 %

Note 1 to entry: Refer to ISO/IEC Guide 98-3 for further information.

4 Principle

4.1 Principle of measurement

When the high-energy beta particles emanating from the radioactive decay of a suitable source such as Carbon 14 (¹⁴C) or Krypton 85 (⁸⁵Kr) interact with nearby matter they lose energy and, in some cases, are absorbed by the matter. When matter is placed between the radioactive source and a device designed to detect beta particles, the beta particles are absorbed and/or their energy diminished. This results in a reduction in the number of beta particles detected.

The magnitude of the reduction in detected beta particles is a function of the mass of the absorbing matter between the beta source and the detector. The number of beta particles passing through absorbing matter, such as particulate matter deposited on a filter media, decrease nearly exponentially with the mass through which they pass. [Equation 4.1\(1\)](#) (Empirical Absorption Law or Lenard's Law) shows this relationship:

$$I = I_0 \cdot e^{-km} \quad 4.1(1)$$

where

- I = number of incident beta particles per unit of time (counts per second). (The measured beta particle intensity of the attenuated beta particles — particulate matter laden filter media)
- I_0 = number of incident beta particles per unit of time (counts per second). (The measured beta particle intensity of the unattenuated beta particles — clean filter media)
- k = coefficient of absorption per unit mass (cm²/mg). (The absorption cross-section of the material absorbing the beta particles)
- m = areic mass of matter encountered by the beta particles (mg/cm²). (The mass density of the absorbing matter)

Practically, it is not necessary to determine I_0 and the areic mass of the collected particulate matter is determined as follows:

- (a) Step one — A measurement is made on a blank filter using [Equation 4.1\(2\)](#):

$$I_1 = I_0 \cdot e^{-km_0} \quad 4.1(2)$$

where

- I_1 = number of beta particles transmitted per unit of time (counts per second) measured after the filter
- m_0 = areic mass (mg/cm²) of the blank filter

- (b) Step two — A measurement is made on the same filter loaded with particulate matter using [Equation 4.1\(3\)](#):

$$I_2 = I_0 \cdot e^{-k(m_0 + \Delta m)} \quad 4.1(3)$$

where

I_2 = number of beta particles transmitted per unit of time (counts per second) measured after the filter loaded with particulate matter

Δm = areic mass (mg/cm²) of particulate matter collected on the filter

Combining [Equations 4.1\(2\)](#) and [4.1\(3\)](#), as follows in [Equations 4.1\(4\)](#) and [4.1\(5\)](#):

$$I_1 = I_2 \cdot e^{+k\Delta m} \quad 4.1(4)$$

$$\Delta m = \frac{1}{k} \ln \left[\frac{I_1}{I_2} \right] \quad 4.1(5)$$

NOTE The Empirical Exponential Law [see [Equation 4.1\(1\)](#)] is valid in the practical working range. However, there is an upper limit that is directly proportional to the maximum energy of the emission spectrum of the beta source used.

4.2 Limitations and interferences

Errors in mass determination can be caused by irregularities in the spatial distribution of the stream of beta particles and heterogeneous deposits of particulate matter due to a deterioration of the sampling system.

Changes in atmospheric pressure and temperature cause the density of air between the source and the detector to change. This can affect the determination of the mass of particulate matter deposited on the filter. The error can be minimized by keeping the time between the measurement of I_1 and I_2 as short as possible. It can be corrected by measuring the atmospheric pressure and temperature, or by use of a dual detection system. In the latter case, the result of the second measurement (I_2) has to be recorded continuously as mass accumulates over time.

The elemental and chemical composition of atmospheric particulate matter has a small effect on the value of the coefficient of absorption per unit of mass, k . The k value depends on the maximum energy of the beta particles therefore its value depends on the radioactive isotope used.

The effect of radioactivity in particulate matter is negligible for long-lived radioisotopes. However, in locations where low levels of radon and its daughters are present, the response of BAMs may be affected. Some BAMs have in-built systems to correct for this type of interference. The magnitude of the error depends on the type of equipment used.

In some sampling climates (high humidity and/or temperature), there is the potential for water to condense on the filter media causing artificially high readings. The use of a sample inlet heater can mitigate this problem. However, care needs to be taken to ensure the sample is not excessively heated so as to lose semi-volatile compounds in the particulate matter.

5 Apparatus

5.1 General

[Figure 1](#) shows the main components of a typical BAM.