

Australian/New Zealand Standard™

AS/NZS 3580.12.1:2015

Methods for sampling and analysis of ambient air

Method 12.1: Determination of light scattering—Integrating nephelometer method

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 3580.12.1:2001, *Methods for sampling and analysis of ambient air*, Method 12.1, *Determination of light scattering—Integrating nephelometer method*.

The objective of this Standard is to provide a method for the measurement of light scattering produced by fine particles.

Most light scattering is derived from particles less than 2.0 µm. These particles affect visibility and are of concern to health. Some common sources of such particles are combustion processes including motor vehicle emissions, incineration, and some industrial processes.

The term ‘informative’ has been used in this Standard to define the application of the appendix to which it applies. An ‘informative’ appendix is only for information and guidance.

FOREWORD

Objects become visible to an observer when light from the object is detected by the observer. A particular object is seen against its surroundings by virtue of the difference in either intensity or wavelength of the radiation emanating from it compared with that emanating from its surroundings.

Light is attenuated through scattering and absorption by both gases and particles in the atmosphere, with the result that objects viewed at a distance become less visible than when viewed close-up. A dark object appears lighter with increasing distance and a light coloured object appears darker. In either case a loss of contrast occurs between the object and its surroundings until at a sufficiently large distance the object merges into the background. It is generally held that an object can be no longer distinguished from its background once the contrast has been reduced to some two percent.

METHOD

1 SCOPE

This Standard sets out a continuous, direct-reading, instrumental method for determining the light-scattering attributable to the presence of particulate matter in a sample of ambient air. The light scattering coefficient as measured by this Standard is an indicator of the perceived visual degradation caused by suspended particles in the air.

2 REFERENCED DOCUMENTS

AS/NZS

3580 Methods for sampling and analysis of ambient air

3580.1.1 Part 1.1: Guide to siting air monitoring equipment

ISO/IEC

Guide 98 Uncertainty of measurement

Guide 98-3 Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)

3 DEFINITIONS

For the purpose of this Standard the definitions below apply.

3.1 Full scale (FS)

The nominated maximum value for which an instrument has been calibrated.

3.2 Range

Nominal minimum and maximum values that an instrument is capable of measuring.

NOTE: The nominal range is specified by the lower and upper range limits in measurement units, e.g. 0 to 2000 Mm^{-1} .

3.3 Rise time

The time interval, after a step increase in input, between initial instrument response and 90% of final instrument response.

3.4 U_{95}

A measurement of uncertainty at a confidence interval of 95% according to ISO/IEC Guide 98-3.

3.5 Zero drift

The change in instrument response to filtered air over a 1 h period of continuous unadjusted operation.

4 PRINCIPLE

Attenuation of light passing through the atmosphere may be represented by the Beer-Lambert law:

$$I = I_o e^{-bx}$$

where

I = intensity of light at the observer

I_o = initial light intensity

x = path length of light (i.e. the object to observer distance)

b = extinction coefficient (due to absorption and scattering)

= $b_{ag} + b_{sg} + b_{ap} + b_{sp}$ where b is the extinction coefficient and the subscripts, a, s, g and p refer to absorption, scattering, gases, and particles respectively

The integrating nephelometer measures the scattering component of light extinction. A sample stream of ambient air is conditioned to maintain the relative humidity at less than 60%, to reduce the light scattering effects of suspended water droplets and absorbed water on particles. The sample is then continuously drawn through an integrating nephelometer where the light scattering coefficient of the sample is measured.

The light-scattering coefficient due to fine particles (the instrument output) is the reciprocal of the distance in metres, over which 63% of initial light intensity is lost by particle scattering. In polluted urban situations, b_{sp} is generally the dominating component of b and hence its importance as an indicator of particulate pollution. This method measures b_{sp} .

The particle light scattering coefficient (b_{sp}) depends on particle concentration, light distribution and wavelength (λ) of the incident light. Scattering is proportional to $\lambda^{-\alpha}$ where α is 4 for gases and typically 0.5 to 2.5 for particles depending on the size distribution, α increases as the mass mean diameter of the fine particles decreases.

In polluted atmospheres, loss of light intensity by scattering is a major proportion of light extinction. Substitution of typical values for b_{sp} and neglecting the other b terms in the equation gives an indication of the effect of scattering on the attenuation of light. For example, a typical reading of 200 Mm^{-1} for a hazy atmosphere, is the inverse of the distance (i.e. 5 km) over which 63% of the initial light intensity is lost. The scattering coefficient may also be interpreted as the proportion of light lost per unit distance. In the above example, 0.02% of the light is lost in one metre.

In urban areas in Australia and New Zealand, levels of b_{sp} have been found to be generally within the range 1.0 to 1000 Mm^{-1} .

5 APPARATUS

5.1 Integrating nephelometer

The integrating nephelometer is a continuous direct-reading instrument that measures the light-scattering coefficient of a sample of air and shall meet or exceed the specifications given in Table 1. The sample is drawn through a light-proof housing where it is illuminated by a diffuse visible light source and the intensity of the scattered light is measured. The response is sensitive to the spectral characteristics of the instrument. Suitable instruments have a spectral response centred at $500 \pm 50 \text{ nm}$. As light scattering is a function of the scattering angle the internal optical geometry of the instrument is arranged so that the response of the detector is proportional to the light scattering integrated over all scattering angles. In practice, physical limitations dictate that the integration angle is from approximately 10° to approximately 170° . The principal features of a nephelometer are shown in Figure 1.

The integrating nephelometer shall include a sample inlet, sample conditioner, relative humidity sensor and temperature sensor. The nephelometer shall be capable of ensuring that the relative humidity of air sampled is not greater than 60% measured at a point representative of the air in the scattering chamber. The temperature of the air sample measured at a point representative of the air in the scattering chamber shall be maintained at not more than 25°C above ambient temperature.

NOTE: The readings obtained using a nephelometer depends on its internal optical geometry, the spectral characteristics of the light source and the spectral response of the light sensor. Hence the readings obtained using different nephelometers are not comparable unless they are of equivalent optical geometry and spectral characteristics.

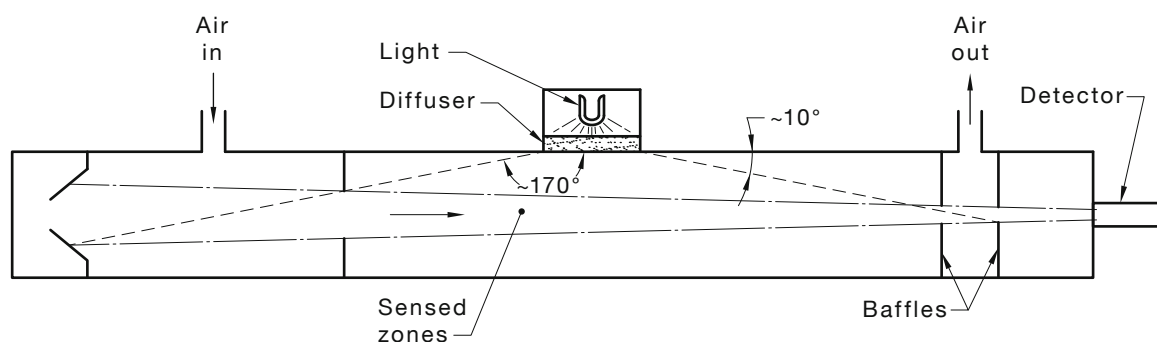


FIGURE 1 SECTIONAL OUTLINE OF A NEPHELOMETER TO INDICATE ITS WORKING PRINCIPLE

TABLE 1
INSTRUMENT PERFORMANCE
SPECIFICATIONS

Parameter	Requirements
Range	0–2000 Mm^{-1}
Wavelength	450–550 nm
Angular integration	10° to 170°
Rise time (90%)	≤60 s
Lower detection limit	≤0.3 Mm^{-1}
Zero drift (1 h)	≤0.5 Mm^{-1}
Operating temperature	10–40°C
Operating humidity	10–90%

5.2 Calibration gas

1,1,1,2,3,3,3-heptafluoropropane (FM-200), greater than 99.9% purity.

5.3 Precision check gas

Carbon dioxide (CO_2), greater than 99.9% purity.

5.4 Zero air

Ambient air filtered to remove particles (see Clause 5.5).

5.5 Particulate filter

A filter shall be used for removing particles from zero air, calibration and precision check gases and shall have a specified collection efficiency of at least 99.9% for particles of 0.3 μm equivalent aerodynamic diameter.

NOTE: A 1.0 μm PTFE filter has been found to be satisfactory. HEPA cartridge filters would also be suitable.

5.6 Reference barometer

A reference (working standard) barometer, traceable to national standards, with an uncertainty of $\pm 0.5 \text{ kPa } U_{95}$, is required for the calibration of any pressure transducers that form part of the measurement system.

5.7 Reference thermometer

A reference (working standard) thermometer, traceable to national standards with an uncertainty of $\pm 0.5^\circ\text{C } U_{95}$, is required for the calibration of any temperature sensors that form part of the measurement system.