National Environmental Monitoring Standards

Air Quality: Continuous Particulate Monitoring

Measurement of PM_{10} and $PM_{2.5}$ for Environmental Monitoring Purposes

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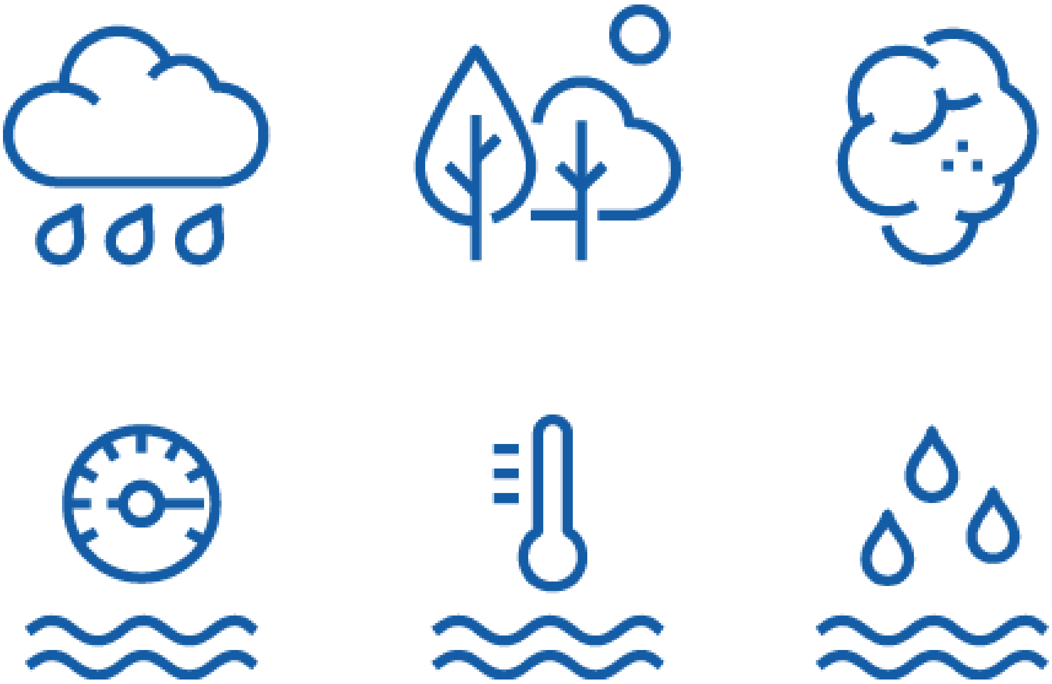

Change Register

Version Number	Date	Section	Significant Change
1.0.0	November 2022		Initial release

The National Environmental Monitoring Standards

The current suite of National Environmental Monitoring Standards (NEMS) documents, Best Practice Guidelines, Glossary and Quality Code Schema can be found at www.nems.org.nz.

Implementation

When implementing the Standards, current legislation relating to health and safety in New Zealand and subsequent amendments, and the NEMS Safe Collection of Environmental Data guidelines shall be complied with.

Limitations

It is assumed that as a minimum the reader of these documents has undertaken industry-based training and has a basic understanding of environmental monitoring techniques. Instructions for manufacturer-specific instrumentation and methodologies are not included in this document.

The information contained in these NEMS documents relies upon material and data derived from a number of third-party sources.

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Development

The National Environmental Monitoring Standards (NEMS) Steering Group has prepared a series of environmental monitoring standards on authority from the Regional Chief Executive Officers and the Ministry for the Environment (MfE).

The strategy that led to the development of these Standards was established by Jeff Watson (Chairman) and Rob Christie (Project Director) in 2014. Implementation of the strategy has been overseen by a Steering Group that currently comprises Jeff Watson, Phillip Downes, Michael Ede, Glenn Ellery, Jon Marks, Charles Pearson, Jochen Schmidt, Rachel Herbert, Sonja Miller, Dan Elder, Abi Loughnan and Raelene Mercer (Project Manager).

The development of this particular standard involved consultation with regional and unitary councils across New Zealand, the National Institute for Water and Atmospheric Research Ltd (NIWA), the Cawthron Institute and several analytical laboratory industry representatives.

The lead writer of this document was Sally Gray (NIWA), with working group members Stephen Sing (Watercare Services), Lauren Hunter (Otago Regional Council), Rhys Evans (Greater Wellington Regional Council), Nathan Cross (Environment Canterbury Regional Council), and NEMS Steering Group members Glenn Ellery (Bay of Plenty Regional Council) and Jeff Watson. The input of these members into the development of this document is gratefully acknowledged, in particular the review undertaken by the NEMS Steering Group.

Funding

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Other financial and in-kind support to the overall NEMS project has been provided by the following organisations:

- National Institute of Water and Atmospheric Research Ltd (NIWA)
- Ministry of Business, Innovation and Employment – Science and Innovation Group
- GNS Science
- Genesis Energy
- StatisticsNZ
- Contact Energy
- Meridian Energy
- Mercury New Zealand Limited

Review

This document will be assessed for review by the NEMS Steering Group within one year of its release and thereafter will be assessed for review approximately once every two years. Further details on the review process can be found at www.nems.org.nz.

Table of Contents

Terms, Definitions and Symbols

Relevant definitions and descriptions of symbols used in this Standard will be contained within the NEMS *Glossary* available at www.nems.org.nz. *(Under development at the time of publication of this Standard).*

Normative References

This Standard should be read in conjunction with the following references:

- NEMS *Glossary*
- NEMS *Safe Collection of Environmental Data*
- NEMS *National Quality Code Schema*
- *Resource Management (National Environmental Standards for Air Quality) Regulations 2004* (amended in 2011)
- AS/NZS 3580.1.1 *Methods for sampling and analysis of ambient air. Method 1.1: Guide to siting air monitoring equipment*
- AS 3580.9.8. *Methods for sampling and analysis of ambient air. Method 9.8: Determination of suspended particulate matter – PM_{10} continuous direct mass method using a tapered element oscillating microbalance analyser*
- AS/NZS 3580.9.11. *Methods for sampling and analysis of ambient air. Method 9.11: Determination of suspended particulate matter – PM_{10} beta attenuation monitors*
- AS/NZS 3580.9.16. *Methods for sampling and analysis of ambient air. Method 9.16: Determination of suspended particulate matter – PM_{10} continuous direct mass method using a tapered element oscillating microbalance monitor incorporating a filter dynamic measurement system (FDMS) unit*
- AS/NZS 3580.9.12. *Methods for sampling and analysis of ambient air. Method 9.11: Determination of suspended particulate matter – $PM_{2.5}$ beta attenuation monitors*
- AS/NZS 3580.9.13. *Methods for sampling and analysis of ambient air. Method 9.13: Determination of suspended particulate matter – $PM_{2.5}$ continuous direct mass method using a tapered element oscillating microbalance analyser*
- 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 3580.19. *Methods for sampling and analysis of ambient air. Method 19: Ambient air quality data validation and reporting*

About this Standard

Introduction

This document provides requirements, information and methodologies to enable the consistent collection, processing and archiving of long-term PM_{10} and $PM_{2.5}$ data. The key to planning, maintaining and recording particulate matter (PM) measurement is the understanding of, and catering for, stationarity of record and analyser exposure.

The requirements for operating a site for the monitoring of $PM_{2.5}$ are the same as those required for the monitoring of PM_{10}.

Particulate matter monitoring is undertaken by many agencies for a broad range of purposes including long-term monitoring to meet State of the Environment (SOE) and Resource Management (National Environmental Standards for Air Quality) Regulations National Environmental Standards for Air Quality (henceforth NES-AQ) requirements, research, assessing potential and actual public health impacts, and specific investigations into sources. While sampling for purposes other than SOE and NES-AQ is not specifically addressed in this document, much of the guidance around equipment installation, monitoring and data management is applicable to these purposes.

Historically within New Zealand, PM_{10} was measured using filters, which were weighed, exposed to the ambient air over a specific time interval, removed and reweighed, with the concentration of PM_{10} calculated from the difference in weights and the volume of air sampled. As technology has improved, analysers that monitor PM_{10} continuously have become available and used more frequently. $PM_{2.5}$ is being monitored more often now, as a consequence of the greater health impacts of the finer-sized particles.

The equipment used for measuring PM_{10} and $PM_{2.5}$ can range from USEPA or EU certified reference samplers (filter-based) or equivalent monitors (continuous measurement), through to non-certified optical equipment. Monitoring PM_{10} for NES-AQ requires the use of instruments that are listed in Schedule 2 of the Resource Management (National Environmental Standards for Air Quality) Regulations. It is also recommended that all continuous instruments undergo equivalency testing in New Zealand, in accordance with AS/NZS 3580.9.17.

The underlying theory of operation for each type of analyser is different, resulting in different concentrations of particulate matter measured by different analysers, even when the analysers are located at the same place. Hence, local equivalency testing is required. Equivalency testing (as described elsewhere in this document) is required if QC 600 data is to be achieved.

Each methodology has situations where it is more applicable than others, and this should be considered during instrument selection.

Scope

The scope of this NEMS document is for long-term monitoring of PM_{10} and $PM_{2.5}$ to meet SOE and NES-AQ requirements, using continuous instrumentation.

This Standard requires the use of continuous instruments; therefore, filter-based methods cannot be used except for the purpose of performing a demonstration of equivalence test.

This Standard covers all processes associated with:

- site selection
- types of continuous instruments
- deployment and maintenance of field equipment
- calibration
- equivalency testing and co-location of instruments
- data collection
- data processing
- quality assurance (QA), and
- quality coding.

Data Quality

This Standard requires all collected data to be assigned a quality code.

Data that are collected, processed and archived in a verifiable and consistent manner according to this Standard can meet the highest quality code (QC 600). Data that do not meet QC 600 shall be coded appropriately.

Note: Enduring use – It is important to note that data that are coded QC 500 or QC 400 may be restricted in their use for a wide range of (yet unknown) purposes in the future.

The Standard – Continuous Particulate Matter (PM_{10} and $PM_{2.5}$) Monitoring

As a means of achieving good quality particulate matter data under this Standard the following requirements shall apply:

Instrumentation	Monitoring method and associated instrument types *Section 2.2.1*	The monitoring method used is specified in Schedule 2 of the Resource Management (National Environmental Standards for Air Quality) Regulations.
	Instrument operation *Section 3.1*	The monitoring instrument is operated in accordance with the applicable AS/NZS Standard. If there is no existing Standard, it is operated in accordance with AS/NZS 3580.9.17.
	Equivalency testing *Section 4.1*	Equivalency test to New Zealand conditions has been carried out in accordance with AS/NZS 3580.9.17 within the last ten years and resulting correlation factor is applied to the data.
	Change in instrument type *Section 4.2*	The old and new monitoring instruments are operated for an overlapping period of at least 12 months to derive a site-specific correlation factor.
Site Criteria	Stationarity of record *Section 1.1*	If the site is moved more than 10m it shall be considered to be a new site unless the old and the new site are operated concurrently for a period of not less than 12 months to enable a relationship between observations at the two sites to be established
	Distance to nearest point source *Section 1.3.8*	The site is at least 50 m away from the nearest particulate matter point source [Neighbourhood/Regional/National-scale site] OR The nearest roadway (closest kerbside) is within 2–5 m [Peak site].
	Position of the sampling inlet *Section 1.3.9*	The sampling inlet is between 1.5 and 5 m (± 100 mm) above ground level.
		The sampling inlet is at least 1 m (± 100 mm) away from any supporting structures, such as a wall or building roof.
	Air flow around sampling inlet	There is an unrestricted air flow of at least 270° around the sampling inlet

	Section 1.3.10	[Neighbourhood/Regional/National-scale site] OR There is an unrestricted air flow of at least 180° around sampling inlet and no obstructions between the major source and the sampling inlet [Peak site].
	Obstructions above sampling inlet *Section 1.3.10*	There is a clear sky angle of 120° above the sampling inlet [Neighbourhood/Regional/National-scale site only].
	Obstructions below sampling inlet *Section 1.3.10*	The sampling inlet is at least 10 m from the nearest building or tree that is higher than 2 m below the height of the sampling inlet.
	Changes in obstructions *Section 1.3.11*	The impact of obstructions on site exposure is checked and documented (including photographs) at least once every 12 months.
Data Criteria	Recording interval *Section 2.6*	The recording interval shall be no greater than 1 hour.
	Time resolution *Section 2.6*	The data logger shall have a time resolution of not more than 1 second.
	Time zone *Section 2.6*	All data are recorded in New Zealand Standard Time (NZST).
	Time drift *Section 2.6*	The drift in time on the logging device is no more than 90 seconds per month.
	Particulate matter data resolution *Section 2.5*	All particulate matter concentration data shall be recorded to a resolution of 0.1 μg/m^3.
	Data correction *Section 2.5*	All particulate matter concentration data are corrected to standard temperature and pressure conditions, which for New Zealand are 0°C (273.15 K) and 1 atmosphere (1013.25 hPa), respectively.
	Data uncertainty *Section 5.7.3*	Uncertainty of the data is calculated.
	Data processing and metadata *Sections 5.6, 5.8 and 5.9*	The following data are archived and retained indefinitely: • final checked and verified data • original raw data, • processed records,

		• associated metadata, including all recording installation inspection, verification, validation and calibration records, and; • supplementary measurements including any associated meteorological data and instrument status codes
	Quality coding *Section 6.2*	All data are quality coded as per the Quality Codes flowchart and associated matrix.
Auditing *Section 5.10*		*Quality assurance requirements are under development.*
Equipment servicing and Housing Criteria	Routine servicing tasks *Section 3.2*	All routine servicing tasks are completed on schedule and within specifications as per the relevant AS/NZS Standard (or manufacturer's manual for optical instruments).
	Annual servicing tasks *Section 3.3*	All annual servicing tasks are completed on schedule and within specifications as per the relevant AS/NZS Standard (or manufacturer's manual for optical instruments).
	Maintenance equipment calibration *Section 3.4*	Any equipment used for maintenance and calibration is within its calibration period.
	Housing internal temperature *Section 3.1*	Internal temperature of the housing is logged and maintained within specifications for the instrument(s) being used.

1 Site Selection and Deployment

This section contains a set of requirements and guidelines that need to be implemented in order to ensure that particulate matter (PM) instruments provide reliable data.

The main reference document for selecting sites is AS/NZS 3580.1.1 *Methods for sampling and analysis of ambient air Part 1.1: Guide to siting air monitoring equipment*. Ensure you are using the latest version of this standard.

1.1 Stationarity of record

Stationarity of a record is maintained when variability of the PM measurement is only caused by the natural processes associated with the particles.

The usefulness of a PM record is dependent upon it having been collected at the same location (position and height), with similar exposure, and using similar recording standards over the entire period of record. Stationarity of record ceases when variability is caused or affected by other processes, e.g. moving the station, changes in the type of instrument or the height of the sampling inlet.

Over time, a range of instrumentation will have been utilised at most PM recording sites, and changes in instrument types will undoubtedly continue into the future. It is very important to ensure any changes are documented in the metadata.

If the instrument methodology needs to be changed, there should be a period of duplicate measurements using both the old and new technology. Parallel measurements for a period of time (at least 12 months, to cover seasonal variation) are required to provide sufficient data to enable correlation factors to be derived (see Section 4.2). When the instrument is replaced with the same model duplication is not necessary.

Stationarity can also be affected by the competence of the staff undertaking all stages of the monitoring and data processing, so it is necessary to ensure ongoing staff training is undertaken. A written set of procedures to follow shall be developed to maintain consistent operations over time.

One aspect that can potentially affect stationarity that cannot be controlled by the monitoring agency is changes in property and land use in the neighbourhood of the air quality site. An example is where a property had a single house using a wood burner and it is changed into a block of apartments with heat pumps. It is important to record any changes in the metadata and, when necessary, consider whether relocation of the site is appropriate.

Relocation is needed when the current site no longer meets its original purpose. When PM monitoring is for SOE or NES-AQ purposes, the aim is for regional representation (e.g. suburb/town/city scale) and not point-source monitoring. Thus, a large part of the area would need to experience land use change before a site needs relocating. At the same time, the development or expansion of an industrial area with additional particle emission sources in a previously residential area would necessitate a site relocation.

To assist in ensuring stationarity, a site inspection to check for any changes (e.g. in obstructions) must be undertaken at least annually (see Section 1.3.11).

Where a site has to be moved more than a few meters for whatever reason this shall be considered to be a new site. Ideally the new site and the old site should be run concurrently for a minimum of twelve months in order to enable a relationship between the two monitoring locations to be established and thus enable (with the necessary adjustments) an ongoing stationary record to be created.

1.2 Where to monitor

1.2.1 Requirements for locating PM_{10} monitoring under NES-AQ

Sections 3.5 and 4.6 of the *2011 Users' Guide to the revised National Environmental Standards for Air Quality updated 2014* (Ministry for the Environment, 2011) discuss where PM_{10} monitoring shall be undertaken. Section 4.6 states that PM_{10} monitoring must:

- be undertaken in an airshed (whether gazetted or not) if it is likely the ambient PM_{10} standard will be breached
- be undertaken in an airshed until such time as air quality is unlikely to breach the ambient PM_{10} standard
- occur in the airshed where people are likely to be exposed
- be undertaken where the ambient standards are most likely to be breached by the greatest margin or with the most frequency, whichever is more likely, and
- be undertaken in accordance with the PM_{10} monitoring methods specified in Schedule 2 of the NES-AQ regulations.

1.2.2 Site classifications

The purpose of a site classification system is to distinguish between different types of monitoring sites and to allow data sets to be compared nationally and internationally (Ministry for the Environment, 2009). All PM monitoring sites should be classified according to the Ministry for the Environment (2009) New Zealand site classification. This classification is also consistent with the LAWA database.

Table 2 in the AS/NZS 3580.1.1 includes information on siting PM_{10} and $PM_{2.5}$ monitoring sites based on Australian siting categories of 'peak', 'neighbourhood' and 'background'. These are not the same as the New Zealand site categories outlined by Ministry for the Environment (2009).

The New Zealand categories (Table 1) are 'Traffic', 'Industrial', 'Residential' and 'Special', to which one or more of four site scales (peak, neighbourhood, regional and national) are assigned. The site scales are:

- peak – metres to tens of metres
- neighbourhood – tens of metres to 0.5 km for industrial and 0.5 km to tens of kilometres for residential
- regional – tens to hundreds of kilometres
- national – greater than hundreds of kilometres to support global networks.

Table 1: PM monitoring site classification for New Zealand (from Ministry for the Environment, 2009)

Site category	Site scale	Typical area
Traffic	**Peak** (metres to tens of metres)	Typically very close to high traffic use roads and intersections. Site should be between 2 m and 5 m from the roadside.
Industrial	**Peak** (metres to tens of metres)	Close to one large point source or fugitive emissions. Typically used for compliance monitoring.
	Neighbourhood (tens of metres to 0.5 km)	With large and varied point source industry emissions and high population density. Such areas may contain heavy commercial and processing industries.
Residential	**Peak** (metres to tens of metres)	A monitoring site located somewhere not truly representative (so it is not neighbourhood scale) but does not exactly fit the 'traffic' or 'industrial' peak site descriptions.
	Neighbourhood (0.5 to tens of kilometres)	Suburban areas in larger cities with a relatively high population density, but not in the immediate vicinity of congested roads or industry. This category also includes residential areas in smaller towns in rural areas.
Special (site description)	**Regional** (tens to hundreds of kilometres)	Airsheds that are distinct in their geographical, meteorological and emissions characteristics. Included are the effects of any point sources or urban plumes on the regional air quality. Could include places where natural emissions are significant (e.g. Rotorua)

		in which case the category would be *Special (Geothermal)*
	National	National background sites that contribute to the global network: e.g. *Special (National)*

A background site (Special (national) in the New Zealand classification) is commonly included in many air quality monitoring programmes to assist in showing the difference between polluted and clean locations. 'Background' is classified (according to AS/NZS 3580.1.1) as an area of homogeneous land use and geography, that can be useful for assessing transportation of pollutants into a region. In the New Zealand context, it is understood to represent open, natural land, away from point sources of pollution (for example, a rural location with grass or trees nearby, to avoid the impact of rural dust).

Most sampling sites in New Zealand for SOE and NES-AQ fall into the Residential (neighbourhood), Residential (peak) or Special (national) classifications.

1.3 Practical Considerations

1.3.1 Site access – property owner

Site access should be secure and safe for the full period of deployment, although this can be difficult to determine at the start of a monitoring programme when the length of operation may be unknown.

A long-term access agreement is recommended with any landowner(s) whose land must be crossed to gain access to the site, or on whose property the site is located.

Even though most site visits occur from Monday to Friday during standard work hours, remember that 24/7 access may be required, and this should be discussed with the landowner(s).

The potential for vandalism needs to be considered when deciding where to locate the site. Options to reduce the likelihood of vandalism include the equipment being inside a security fence or having an alarm on the building. Neighbours are often very helpful in reporting damage or concerning behaviour so ensure a good working relationship is developed and maintained with them.

1.3.2 Site access – operational

The operation of a site will normally involve the installation of some form of housing (a walk-in shelter is common) and a power supply, so access for trucks needs to be taken into consideration. Ensure the housing is well attached to the ground, especially in areas that are subject to strong winds. This may involve putting in a concrete pad. Ensure there is a secure attachment point on the roof and the ground for portable ladders.

Consider where your vehicle(s) can be parked:

- is there an all-weather driveway to use?
- is your vehicle going to emit particulates into the intakes?
- do you walk in from the road?
- are you going to block neighbour's access?

Walking in from a roadway may be suitable but consideration should be given to times when heavy equipment needs to be replaced.

1.3.3 Power

Most of the instruments used for continuous monitoring require a mains power supply. Ensure the supply (both the instruments and the housing) is checked for electrical safety on a regular basis by a certified electrical worker. All portable equipment (e.g. instruments, laptop and battery charger, electric drills) shall be electrically tested to AS/NZS 2760, which is the standard that oversees the test and tag industry in New Zealand.

It is important to ensure the power supply can handle both the instrument and any air conditioner at the same time. In some situations, it may be preferable to have a separate phase for the air conditioner and any other equipment that draws a lot of power.

It is recommended that instruments and any associated racking system is earthed.

1.3.4 Communications

Data collected at the site need to be transmitted back to a central location to allow for ongoing data checking. This is commonly done using the cellular network, so ensure the site location has suitable connectivity. The same would apply to other communication methods such as radio telemetry.

1.3.5 Concerns for neighbours

Some instruments used for monitoring PM are noisy. Noise can also come from the air conditioning units. When selecting a suitable location for the monitoring site, it is important to consider how far the noise will travel, especially at night in residential areas when background noise is lower. Ensure the site noise level meets the requirements of any council noise plans.

Reflections off outdoor installations can be a nuisance to some people. This could be addressed by changing the housing colour or removing (or not installing) solar panels.

Consider where vehicles can be parked while staff are working at the site, especially when staff need to be on site for a long period.

It is important to have a minimal impact on neighbours, as they can assist in keeping the site safe and reporting any damage.

1.3.6 Things to consider when installing a site

When deploying instruments, carefully consider how to mitigate the effects of obstructions, such as trees and buildings, on the exposure of the sampling. A site with poor exposure will result in the collection of lower quality data.

Selecting a suitable site, and even the position of the sampling intake, should consider the local meteorological conditions, especially wind direction. There should be minimal impediments to air approaching from the predominant directions.

The source(s) of pollution in the area should also be considered when determining the site location.

The important considerations when selecting the site are:

- distance to a roadway or pollution source areas
- height of the intake, and
- height of and distance to other buildings and trees.

The top of the sample intake is taken as the position from which obstructions should be measured for both height and distance.

1.3.7 Sources of pollution

The potential sources of particulate matter should be reviewed when determining the location of a monitoring site. If the purpose of the monitoring is to get a background concentration, the site should be located in an area with minimal PM sources; likewise, if the purpose is to obtain residential data then the site should be in a predominantly residential area.

With residential monitoring, it is the general pollution in the area (for example, suburb, town, city) that is to be measured so it is important to look for any nearby point sources that may significantly bias the sample. Some examples of point sources are solid fuel heaters (coal or wood), roadways and bare earth parks. The impact of solid fuel heaters is related not only to the number of them but also how they are operated, which can be difficult to determine. A winter evening visit to the area, to observe what chimneys are in use and the amount of visible smoke, is a good indicator.

Vehicle traffic is another source of particulate matter and this comes via two pathways: direct emissions from the exhaust pipe and indirectly from tyre and brake pad wear on the road surface.

Natural sources of particulate, such as sea salt and dust, should be considered when planning the location. A site close to the sea will result in higher concentrations of particulate matter (especially PM_{10}) when the wind is blowing from that direction; likewise, dust has a similar response. The impact is less obvious for $PM_{2.5}$ as dust and salt particles are usually in the larger size fraction.

1.3.8 Proximity to roadways

The distance to the roadway needs to be considered to ensure that vehicle-generated emissions, including particulates, do not over-influence the sampling, unless these emissions are the purpose of the monitoring (e.g. traffic monitoring).

The AS/NZS 3580.1.1 Standard, *Guide to siting air monitoring equipment*, includes information on minimum distance from roadways. For particulate monitoring, the recommendation for a neighbourhood or background station is a minimum of 50 m away from roads with average traffic volumes less than 10,000 vehicles per day, up to 100 m for average volumes less than 40,000 vehicles per day. These figures are based on United States research.

A significant amount of the particulate monitoring in New Zealand is undertaken in a residential environment and finding a suitable location that is more than 50 m from any road will be quite difficult to achieve. However, in order to achieve the best quality data, the monitoring site is required to be located more than 50m from the nearest road in order to minimise the impact of traffic on the observed data

For peak traffic sites in New Zealand, the distance to roadway requirement is 2–5 m away from the kerb, with no traffic volume specification.

The distance and traffic volume (where available) of the nearest road(s) shall be recorded in the metadata record.

Note: The Waka Kotahi NZTA website is a good source of traffic count data for a number of state highway locations. Some regional and local councils also hold traffic count information.

1.3.9 Position of the sampling intake

The height of the intake is dependent on the instrumentation, but it shall be between 1.5 and 5 m (± 100 mm) above ground level.

When there is more than one inlet, the separation distance between the monitoring intakes needs to take account of the flow of each instrument. For instruments with a 16.67 L/m flow rate, the minimum distance is 1 m. Where two or more instruments are being used to determine PM_{10} and $PM_{2.5}$, the inlets should be as close to the same height as possible.

The sampling inlet shall be at least 1 m (±100 mm) away from any supporting structures such as a wall or roof of a building. A safety fence on top of the instrument housing is not regarded as an obstruction if it is an open style and the inlet is above the top of it.

Record information on distances in the metadata record.

When deciding where to locate the intakes, it is very important to check for other sources of particulates, including the extraction units for air conditioning systems and vents from other analysers, to ensure the sampling intake is not sucking in dirty air.

1.3.10 Proximity to obstructions

For a neighbourhood-, regional- or national-scale site (neighbourhood or background under the Australian site classification), the minimum requirements for positioning the sample inlet are:

- clear sky angle of 120°
- unrestricted air flow of 270° around the sample inlet, and
- 10 m from the nearest building or tree that is higher than 2 m below the height of the sampling inlet.

For a peak-scale site, the minimum requirements for positioning the sample inlet are:

- unrestricted air flow of 180° around the sample inlet with no obstructions between the major source and the sample inlet, and
- 10 m from the nearest building or tree that is higher than 2 m below the height of the sampling inlet.

Measurement of the distance to a potential obstruction, from the sampling location, is to the side of a building or the dripline of a tree that is nearest to the sampling intake.

To achieve a 120° clear sky angle, the ratio of distance to height needs to be greater than 2:1. In practice, this can be generalised to the inlet being at least 10 m distant and at least two times the height away from any obstruction. If using a clinometer to measure elevations, then obstructions are more than 30° above the intake level. For quality coding purposes, it is necessary to determine the percentage of (1) the 120° angle above the inlet and (2) the area of 10 m radius within 2 m below the inlet that is obstructed, i.e. obstructions that are inside the 'obstruction plane' as shown in Figure 1.

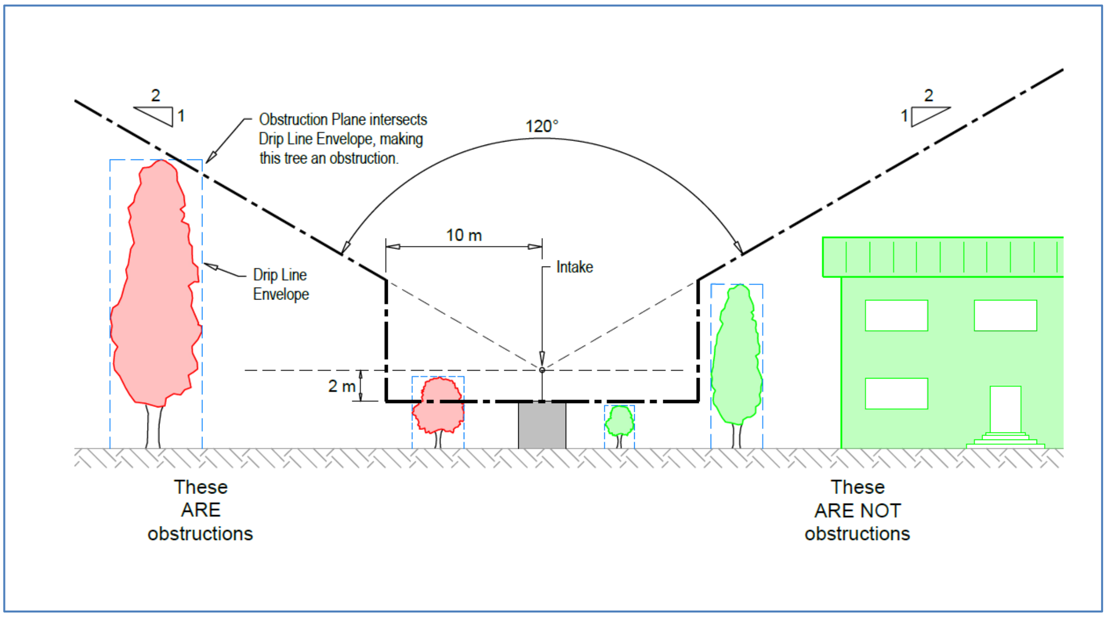


Figure 1: Proximity to obstructions. Red features are considered obstructions and green features are not.

1.3.11 Impact of obstructions around the site

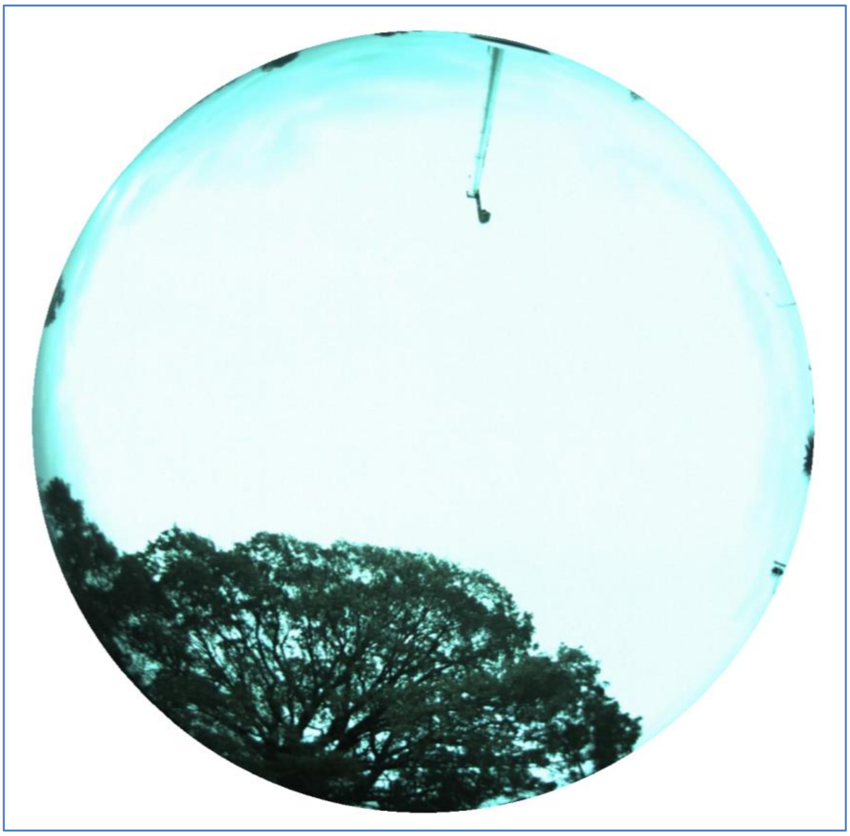
The impact of obstructions around the monitoring site needs to be documented in the metadata and reviewed at least every 12 months to ensure that any changes in exposure are detected.

The method of documentation shall include photographs of the surrounding environment to show the obstructions. These photographs shall be taken at the same height and as close as possible to the sample intake. It is preferable to take the photo when vegetation is in full leaf as this can show the largest impact of obstructions. Ground level photos are useful to watch that low level obstructions do not increase significantly and influence the data being collected at the site.

Other evidence of obstructions can include:

- elevation profiles
- hemispherical images using fisheye cameras
- drone imagery
- LIDaR, and
- site diagrams.

The software provided with some fisheye cameras allows the amount of obstructed horizon to be determined and elevation profiles created. The example below is taken from the inlet of a particulate instrument, where there was a large tree to the south of the site. The high peak in the centre is the meteorological mast attached to the site housing.



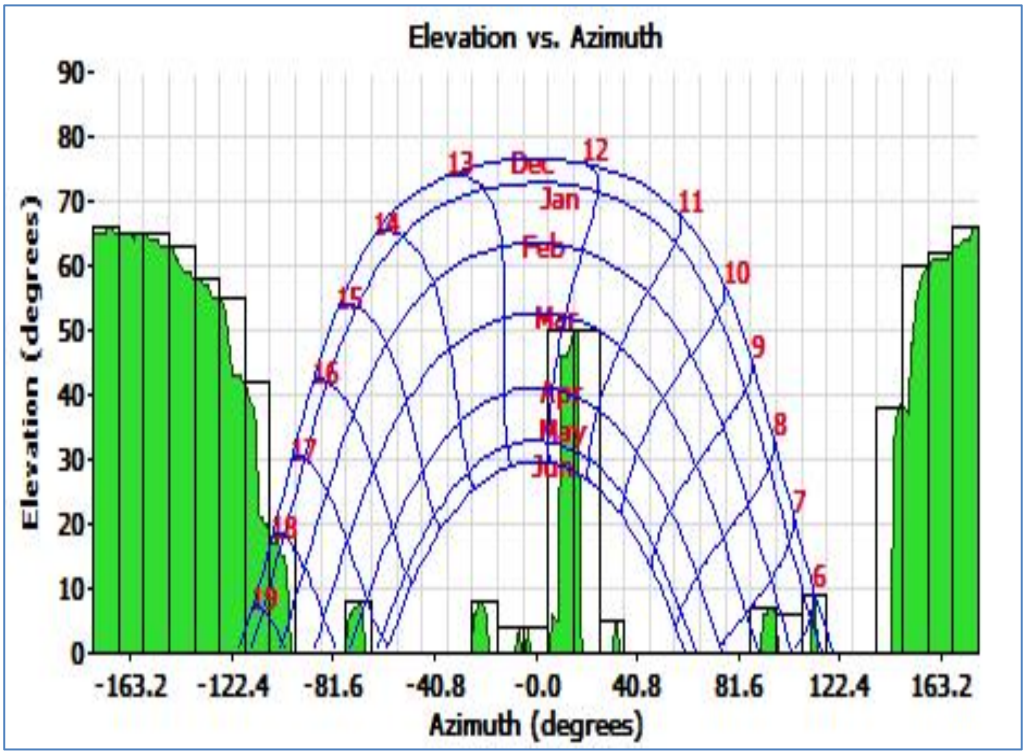


Figure 2: Hemispheric image and associated elevation profile

2 Equipment Selection and Specifications

This section focuses on what type of instrumentation is available for monitoring particulate matter and some of the considerations for selecting instrumentation.

2.1 Purpose of the monitoring

When considering which type of equipment to use, the purpose of the monitoring should inform the decision.

Where chemical analysis is needed, e.g. source apportionment, then an additional filter-based sampler will be needed. It is worth considering what other uses could be made of a filter as new technology becomes available, such as analysing filters for black carbon.

2.2 Instrumentation

2.2.1 NES-AQ requirements

For NES-AQ compliance monitoring, the instrument types that shall be used are specified in Schedule 2 of the NES-AQ. It is very important to check this list when selecting instruments.

As this schedule is updated on an irregular basis, the quality coding matrix for this Standard (Section 0) allows the use of EU- or USEPA-approved instruments not on the Schedule 2 list. If a demonstrated equivalence test is undertaken and the results applied to the data, there is only a small increase in points for using an instrument not on the schedule.

Note: At the time of writing this document (December 2021), Ministry for the Environment are reviewing the methods included in Schedule 2.

2.2.2 Definition of specification terms

Note: Annex B includes some definitions of terms that are referenced in the instrument specifications of AS and AS/NZS standards and in manufacturers' manuals.

2.2.3 Types of instruments

The three primary types of continuous PM_{10} monitoring methods specified in Schedule 2 of NES-AQ are:

- TEOM / FDMS
- beta attenuation, and
- optical.

Some basic information about how these different types of instruments measure particles is provided below.

2.2.3.1 TEOM and TEOM/FDMS

A tapered element oscillating microbalance (TEOM) is an instrument with a microbalance sensor and a sample filter. It collects the PM particles on the filter which is attached to a vibrating transducer and as the mass of the filter increases, the frequency of the vibrations of the transducer decreases. This results in a mass concentration per volume of air sampled.

Later models include a filter dynamic measurement system (FDMS) unit which independently measures the volatile component of the incoming air sample. Once the sample has come through a size-selective inlet, it goes through a dryer before it is alternately switched every six minutes between the TEOM microbalance sensor unit and a purge filter system held at 4°C. The purge filter system effectively removes particles from the sample stream before it passes into the sensor unit. The system then adjusts the final mass concentration by reference to any mass change (typically a reduction) that occurred during the purge cycle.

2.2.3.2 Beta attenuation

Beta attenuation instruments measure the changes in intensity of the beta particles passing through a PM laden filter. The reduction in intensity is due to absorption of the beta particles by the collected material. The relationship between radiation absorbed and mass of particulate collected closely follows an exponential relationship that is reasonably independent of the chemical composition of the atmosphere. The heating of the inlet to reduce relative humidity in the sample (and thus the water content) may lead to a loss of semi-volatile material.

These instruments include a radiation source, which is typically carbon-14, krypton-85 or promethium-147. At the level of radiation used in a single instrument there is no significant health hazard. Where a large number of radiating instruments are used together, total radiation emitted should be calculated to ensure staff are operating in a safe working environment.

2.2.3.3 Optical

Optical instruments are based on the theory of particles scattering a beam of light. A light beam is shone through a known path length and then the air sample is injected into the same path and the difference in light intensity is proportional to the concentration of particles. These instruments can measure PM concentration directly or by using particle counts and making assumptions about the nature of the sampled particles. There is currently no AS/NZS document for the operation of optical instruments.

2.2.3.4 Lower-cost sensors

There are a variety of lower-cost sensors available that can monitor particulate matter. They are usually based on optical properties. These sensors are currently not suitable for SoE or NES-AQ monitoring under this Standard.

However, such sensors do have their uses, for example when trying to observe the spatial pattern of pollution, to undertake spot checks following complaints or enquiries, or before selecting a permanent site location.

When using this type of equipment, a comparison to an approved PM instrument should be undertaken. When multiple lower cost sensors are used, all the units should give similar concentrations when they are positioned at one location.

The results from lower cost sensors should not be compared to any ambient standard or guideline, unless it includes a validation/accuracy statement in the report and in the metadata.

2.2.4 New technology

Technology is changing all the time. As new instruments gain USEPA or EU approval, they could potentially be used for PM_{10} or $PM_{2.5}$ monitoring. Demonstrated equivalence testing to New Zealand conditions shall be undertaken as part of their deployment.

This Standard will have regular updates (usually after the first year and then every two years), and between these updates, monitoring agencies will need to review how any new technology will be incorporated into their monitoring programme and how they will ensure the new technology meets the requirements and intent of this Standard. In addition, monitoring agencies will need to ensure that any new technology is aligned with Schedule 2 of the NES-AQ and any subsequent amendments to it.

2.3 Advantages and disadvantages of instruments

2.3.1 Other costs of monitoring

When considering which instrument to use, always consider the installation and ongoing costs. For continuous instruments these include:

- the need and costs associated with an instrument housing
- monitoring of the housing internal temperature
- routine maintenance costs of the instrument
- air conditioning costs
- telemetry systems, and
- access to power.

2.3.2 Volatility of particulate matter

The volatility of particle matter is dependent on the effect of relative humidity, sublimation, evaporation and secondary particulates.

Due to the hygroscopic nature of some particulate matter, changes in atmospheric relative humidity (RH), can cause the particulate to change, either increasing or decreasing the mass of the particles already on the sample media. This normally results in negative concentrations and less frequently positive concentrations.

All regulatory-grade instruments have a mechanism to minimise this effect, but some RH changes will impact readings while the instrument adjusts its compensation mechanism.

Particles can reduce in mass if they contain components that can volatilise, sublime (solid to gas) or evaporate (liquid to gas) and pass through the sample media. This is more of an issue in colder environments where there is a significant difference between the ambient conditions and those inside the instrument.

Secondary particles form when substances in the gas phase adhere to each other or to particulate already on the sample media, increasing the mass of those particles.

Knowledge of the types of particulate likely to be in the air allows the operator to determine whether rapid changes in concentrations recorded in the data are genuine, a result of the method being used (e.g. sample media mass change) or a fault with the instrument.

2.3.3 Summary of some known advantages and disadvantages

Tables 2 and 3 summarise the main types of instruments and their advantages and disadvantages.

Table 2 – Summary of PM instrument methods and costs

Instrument type	Susceptibility to particle volatility	Cost of operation	Purchase cost	Principle of measurement
TEOM	Very high	Medium	Medium	Frequency change as mass changes on TEOM filter
TEOM/ FDMS	Low	Very high	High	Frequency change as mass changes on TEOM filter, but accounts for volatile loss
Beta attenuation	High	Medium	Medium	Beta radiation absorption as mass increases on filter tape

Optical	Low	Low	High	Counting and sizing of particles based on light scatter

Table 3 – Advantages and disadvantages of the main PM instrument types

Instrument type	Advantages	Disadvantages
TEOM	Very good for monitoring in environments with low volatility of particulates (e.g. quarries)	Filters require semi-frequent changing. If filters are permitted to become significantly loaded, then unstable readings will be generated. Sensitive to vibrations Will read low in volatile environments
TEOM/FDMS	Very good at monitoring in highly volatile environments, e.g. cold environments with wood smoke	Expensive to maintain FDMS dryers Troublesome switching mechanism – prone to failures Sensitive to vibrations Stops working reliably when shelter temperature exceeds 30°C Only outputs hourly running average, updated every 6 minutes
BAM	Simple to operate with automated filter change tape Normally very reliable	Can read low in volatile environments Negative readings during low concentrations and when moisture changes rapidly are common
Optical	Should be reliable	No AS/NZS Standard exists for the operation of these instruments; will require completion of AS/NZS 3580.9.17 equivalency testing

	Little maintenance required	Concentrations are reported based on an algorithm No direct relationship of method to gravimetric mass
	Very quick response to changes in concentrations Can get particle counts, which can be useful Cannot report negative values	Newer technology – less experience and knowledge on performance and reliability in New Zealand

2.4 Instruments for comparison of PM_{10} and $PM_{2.5}$

When the purpose of the monitoring includes the collection of both PM_{10} and $PM_{2.5}$ data for comparison to each other, it is important to ensure the same model of instrument is used. This helps reduce the results being influenced by instrument type.

Ensure that both instruments are configured the same, such as when filter changes are scheduled to occur, relative humidity settings, output settings etc. Also ensure routine maintenance, such as cleaning inlets, is done at the same time.

Measuring $PM_{2.5}$ with a beta attenuation instrument requires changing the filter every 8 hours, so a co-located PM_{10} BAM will also need to have its filter changed every 8 hours for a true comparison.

By ensuring these aspects are adhered to there is less likelihood that the recorded $PM_{2.5}$ data are higher than PM_{10} at the same site. Should $PM_{2.5}$ exceed PM_{10} then endeavour to find out why this happened and include a comment in the metadata and in any reporting.

2.5 Measurement resolution

All particulate matter data shall be recorded to a resolution of 0.1 $\mu g/m^3$ and corrected to standard temperature and pressure conditions (STP), which for New Zealand are 0°C (273.15 K) and 1 atmosphere (1013.25 hPa), respectively.

The logging device/data logger associated with the instrument (monitoring method) shall be able to achieve time resolution of one second and it shall drift by no more than 90 seconds in a month.

Be aware that some instruments automatically report to STP conditions whereas others report to actual conditions. Ensure that you check what the instrument measures and make compensation for this in the data logging system or during data processing.

Some instruments retain a file of diagnostic data, such as temperatures, pressures and flows, and these should be automatically downloaded where possible or manually downloaded when on site.

2.6 Data logger and recording specifications

A data logger is an essential piece of equipment at an air quality recording site. Data loggers allow agencies to store PM data on site at the required resolution, and if telemetered, provide a raw backup of the recorded data.

There are many types of data logger available. Important features of a data logger are the time resolution, accuracy and recording intervals. The data logger clock must have a resolution of 1 second and log time in New Zealand Standard Time (NZST). The time stability of the data logger must be routinely checked (Section 3.2); the maximum drift in recorded time is no more than 90 seconds per month.

All data shall be recorded in New Zealand Standard Time (NZST) and at the end of the averaging period, e.g. a 10-minute average ending at time *y*. Ensure you check how the logging and processing systems handle midnight (does it record 24:00 on day '*x*' or 00:00 on day '*x*+1'?) and note the format in the metadata.

When logging the data from a continuous instrument into a data logger, the scanning and logging interval (averaging interval) shall be no greater than 1 hour.

Where there is an option, the digital output (not the analogue output) should be used.

3 Instrument Operation and Maintenance

This section focuses on the operation, calibration and maintenance of PM monitoring instruments in general terms. The term 'calibration' is taken to mean an adjustment is done to the instrument, whereas 'validation' (or verification) does not include an adjustment.

The applicable AS or AS/NZS document includes sections on routine calibration, verification and maintenance that must be undertaken to meet the standard, along with the acceptable tolerances for these tasks. The specific method for each task is dependent on the make of the instrument and the manufacturer's manual needs to be consulted.

Routine maintenance shall be at the frequency stated in the applicable standard but should also take into account the risk and impacts of losing data, and also any manufacturer's recommendations.

If the inlet is getting dirty, or the instrument is deviating more than is acceptable from the reference checks, then maintenance shall be performed more often.

Maintenance may also be required immediately after an event, for example, a power cut or pollution event. The instrument's performance should be checked to ensure no faults were caused and the collected data are valid.

3.1 Instrument operation

The PM monitoring instrument must be operated in accordance with the applicable AS/NZS Standard. As listed in the Normative References section, the current standards are AS 3580.9.8, AS/NZS 3580.9.11, AS/NZS 3580.9.12, AS/NZS 3580.9.13 and AS/NZS 3580.9.16.

If there is no existing Standard, the instrument shall be operated in accordance with AS/NZS 3580.9.17.

Note: There is currently no AS/NZ for optical instruments.

The internal temperature of the instrument housing has an impact on the operation of many particulate instruments. It needs to remain stable and for this reason air conditioning is usually needed. The internal temperature shall be logged and maintained within the acceptable temperature range for the instrument type.

Note: The acceptable ranges are found in the applicable AS or AS/NZS standard or the manufacturer's manual for optical instruments.

3.2 Routine tasks

Under this Standard, all routine calibration, validation and maintenance tasks must be completed on schedule, as specified in the relevant AS or AS/NZS standards. Table 4 contains a summary of the routine tasks from the AS and AS/NZS standards. There is no difference between the requirements for PM_{10}

and $PM_{2.5}$ for most tasks. The allowable tolerances are in the applicable standard.

Note: Table 4 covers tasks with a frequency of less than 12 months. Tasks with a frequency requirement of approximately 12 months or longer are outlined in Section 3.3.

Table 4 – Routine servicing schedule for PM monitoring instrumentation

Task	Frequency
Clean PM2.5 dust pot	≤ 1 month
Clock check	≤ 1 month
Particle mass check	≤ 3 months
Flow rate / flow controller check	≤ 3 months
Leak check	≤ 3 months
Clean PM10 and PM2.5 size-selective inlet	≤ 3 months
Mass transducer filter (TEOM and TEOM/FDMS)	≤ 3 months or < 90% loading
Temperature and pressure sensor checks	≤ 3 months
Relative humidity sensor check (TEOM/FDMS)	≤ 3 months
Inline filters check (TEOM and TEOM/FDMS)	≤ 6 months

As there are currently no AS or AS/NZS documents for optical equipment, the manufacturer's recommended maintenance shall be followed. The following table shows the routine tasks that need undertaking for a Fidas 200 and the Teledyne T640X (optical) instruments.

Table 5 – Routine servicing schedule for Fidas and Teledyne T640X optical instruments

Task	Frequency
Check operational parameters (T640X)	≤ 1 month
Check pump performance (T640X)	≤ 1 month
Clean sampling head	≤ 3 months
Check air flow (T640X)	≤ 3 months
Leak check (Fidas)	≤ 3 months
Zero check	≤ 3 months
Aerosol sensor offset adjustment (Fidas)	≤ 3 months

Temperature and pressure sensor – checks/calibrations	≤ 3 months
Flows – check/calibration	≤ 3 months
Particle velocity check (Fidas)	≤ 3 months
Particle size calibration (Fidas)	≤ 3 months
Replace sample filter (if installed) (Fidas)	≤ 3 months
Check/adjust photomultiplier tube (PMT) (T640X)	≤ 3 months
Inspect/clean optical chamber (T640X)	≤ 6 months
Inspect/clean relative humidity and temperature sensor (T640X)	≤ 6 months
Change DFU (T640X)	≤ 6 months

3.2.1 Flows

Flow data are used in all instruments when calculating the amount of air that has been sampled in relation to the amount of particulate matter in order to determine a concentration. Thus, it is the most important parameter to be maintained. It requires the use of a calibrated flow meter and a comparison to the measured flow to be undertaken.

For those instruments that measure through a size-selective inlet, the flow is volumetric.

3.2.2 Mass

The particle mass in an instrument that uses the beta attenuation method needs to be checked to ensure the instrument is not changing outside the acceptable range. There are normally at least two foils (zero and span) that need to be installed and allowed to run until a stable value is recorded and verified.

TEOM/FDMS instruments also undergo a mass transducer check, where a filter of known weight is installed where the sample filter is normally positioned and the output is checked.

3.2.3 Leak checks

Leak checks need to be done regularly to ensure there are no leaks in the system. Follow the manufacturer's instructions for how to carry out these checks, as they are instrument dependent.

3.3 Annual servicing

Under this Standard, all annual calibration, validation and maintenance tasks must be completed on schedule and within specifications contained in the relevant AS or AS/NZS standards. Table 6 is a summary of the annual tasks from the AS/NZS standards for instrument annual servicing. Unless stated the frequency is ≤ 12 months and the allowable tolerances are in the applicable document. There is no difference between the requirements for PM_{10} and $PM_{2.5}$ for most tasks.

Some information has been supplied for the Fidas and Teledyne T640X optic instruments, and as more experience with this technology is gained this table will be updated.

Table 6 – Annual servicing requirements for PM monitoring instruments.

Note: BAM is the beta attenuation method.

Task	Instrument	Frequency
Particle mass calibration	BAM	
Volumetric flow rate calibration	BAM	
Flow controller calibration	TEOM, TEOM/FDMS	
Mass transducer constant check	TEOM, TEOM/FDMS	
FDMS cooler and switching valve	TEOM/FDMS	
FDMS dryer replacement	TEOM/FDMS	
Pressure transducer check/calibration	BAM, TEOM	
Temperature sensor check/calibration	BAM, TEOM	
Zero noise check	All	
Analogue calibration	TEOM, TEOM/FDMS	
Clean air inlet system/tubing	All	
Vacuum pump	All (except Fidas)	≤ 24 months
Measurement chamber	BAM	As per manufacturer specification
Replace Filters	Fidas	
Clean aerosol optics	Fidas	As per manufacturer specification

3.5 Calibration of equipment used for instrument servicing

Along with the calibration and maintenance of the PM monitoring instrument according to the frequency in the standards, it is essential that the equipment used to do these tasks (e.g. flow meter; foils; multi-meter; temperature, relative humidity and barometric pressure sensors) are also routinely calibrated to ensure they give the correct output.

Documentation on the results of these calibrations shall be retained indefinitely (Section 5.10).

Table 7 lists the calibration frequency for these pieces of equipment.

Table 7 – Servicing frequency for calibration and maintenance equipment

Maintenance equipment	Frequency of calibration
Flow meter	≤ 12 months
Multi-meter	≤ 24 months
Reference digital temperature sensor – full calibration	≤ 12 months
Reference liquid in glass or resistance thermometers – full calibration	≤ 5 years
Reference temperature sensor – single point check	≤ 6 months
Relative humidity sensor	≤ 12 months
Relative humidity sensor – working point check	≤ 6 months
Fortin or Kew barometer	≤ 5 years
Aneroid or digital barometric pressure sensor	≤ 12 months
Barometer sensor – working point check	≤ 6 months
Clock	≤ 12 months
Mono dispersed dust	≤24 months
Foils	≤ 24 months

4 Equivalency Testing and Co-locations

A major issue with particulate matter monitoring is that the underlying theory of operation for each model of instrument is different, resulting in the recorded concentration not being identical, even when the instruments are located at the same place.

The purpose of equivalency testing is to determine the correlation factor for a continuous particulate instrument model, to make the data equivalent to the reference method under the ambient conditions in New Zealand.

Equivalency testing will be undertaken for different combinations of source types and the results will be valid for similar regions.

The continuous instrument must already conform to either EN15267 or have a USEPA Federal Equivalent Method (FEM) status.

It is expected that each model of instrument from a specific manufacturer will undergo this testing (e.g. a Thermo FH62C14 or a MetOne 1020 BAM), not each individual instrument.

These tests shall be shared with other uses to help create a national 'library' of comparison results.

A site-specific co-location is needed when the type of instrumentation at the site is being changed.

4.1 Equivalency testing

The procedure for undertaking these tests is that of 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*).

4.1.1 Summary of the AS/NZS 3580.9.17 requirements

For a single equivalency test:

- Two continuous instruments of the same model and two reference methods of the same model should be used
- The laboratory doing the filter weighing should meet ISO 17025 requirements
- The selected site needs:
  - a mix of very high and low particulate concentrations
  - a known source matrix
  - a mix of high and low relative humidity and temperature conditions, and
  - high and low wind speeds
- Measurements are at regular, uninterrupted intervals to cover each season
- Forty valid pairs (reference and continuous instrument) of 24-hour average data with a minimum data capture of 95% are needed for the calculations

- A range of concentrations must be measured to cover at least 80% of expected concentrations, and
- The expanded measurement uncertainty shall be determined.

4.1.2 Sampling locations – climate zones

It has been decided that in New Zealand the source of particulate matter is more important than the climate of the region. For this reason, the requirement in AS/NZS 3580.9.17 to carry out equivalency in each climate zone will **NOT** apply. This will be reviewed when more tests have been reported.

It is recommended that a statement about this variation to AS/NZD 3580.9.17 is retained with the results of the equivalency test, so that any future users of the test results are aware of this non-conformance to the AS/NZS standard.

4.1.3 Sampling locations – particulate source

It is expected that equivalency testing will be undertaken for different source type combinations and the results will be valid for similar regional sources. This is currently taken to mean a predominantly smoke source, a sea salt source, a dust source, a road traffic source and an industrial source.

4.1.4 Sampling locations – site selection

Equivalency testing will be undertaken for different combinations of pollution sources and concentrations, with the results being valid for regions with similar combinations.

Where there is one region with multiple monitoring sites, and the pollution source mix and concentrations are similar, only one site needs to be tested and the calculated correlation can be applied to all sites.

4.1.5 Frequency

The equivalency test shall be repeated every 10 years. This time frame will be reviewed when more of these equivalency tests have been undertaken in New Zealand.

4.1.6 Proposed use of equivalency test results

It is intended that the results from equivalency tests will be shared with all users to help create a 'library' of comparison results. These results will establish a relationship between the candidate instrument and a reference instrument based on the source type. The library will be stored on the NEMS website, under the 'tools and resources' tab. This will be developed as the data become available.

The user will determine which source is most applicable to their monitoring location, and the instrument they propose to use. This will give them a relationship (correlation factor) that can be applied to the data.

If the user determines that their site is not covered by an already existing equivalency test, then a new equivalency test would need to be done at that specific site and the result added into the library.

The correlation factors should be applied to data and not programmed into the original instrument for auditing purposes.

4.2 Site-specific co-locations

A site-specific co-location will be needed when the type of instrumentation at the site is being changed. This is to help understand the relationship between the old and new instruments at the specific site. It enables a correlation factor to be derived and then applied to the data to enable a stationary data series to be established, by adjusting either the past or future records.

In this situation, the two instruments shall be operated concurrently for a period of at least 12 months. There is no requirement to have a reference instrument on site, but if it can be done then that is an added benefit, as it can become an equivalency test at the same time.

The correlation factor should be applied to data and not programmed into the original instrument, for auditing purposes.

4.3 Comparability assessments from the United States

There have been a large number of comparability assessments undertaken in the United States for both PM_{10} and $PM_{2.5}$ instruments co-located with a Federal Reference Method sampler. These can be used as guidance for the level of differences seen between reference and continuous instrumentation and show why equivalence testing is needed.

These comparability assessments are available on the USEPA website – links as at 23/11/2021 are:

- https://www.epa.gov/outdoor-air-quality-data/pm10-continuous-monitor-comparability-assessments
- https://www.epa.gov/outdoor-air-quality-data/pm25-continuous-monitor-comparability-assessments

An example of a PM_{10} comparison between a Partisol 2025 and a Teledyne T640X is shown in Figure 3, which clearly shows the T640X reading higher than the Partisol 2025. There is an associated technical note document available on the website that gives details explaining each section of the report.

Dataset	N	FRM	Cont	Ratio (Cont/FRM)
AllData	**286**	**20.3**	**30.3**	**1.49**
Winter	79	9.4	14.8	1.58
Spring	86	17.0	24.3	1.43
Summer	63	26.0	37.9	1.46
Fall	58	34.1	52.0	1.53
2019	116	20.8	29.7	1.43
2020	113	21.5	33.4	1.55
2021	57	17.1	25.3	1.48

Dataset	N (all observations)	Bias (all observations)	N (only >= 3 ug/m^3)	Bias (only >= 3 ug/m^3)
AllData	**286**	**56.1**	**274**	**54.7**
Winter	79	71.1	68	68.3
Spring	86	50.8	85	50.6
Summer	63	42.5	63	42.5
Fall	58	58.0	58	58.0
2019	116	53.2	107	50.9
2020	113	56.5	112	56.3
2021	57	61.1	55	58.7

Figure 3 – USEPA example of an instrument comparison

(https://www.epa.gov/outdoor-air-quality-data/pm10-continuous-monitor-comparability-assessments)

4.4 Reference sampler equipment

The equipment used for the equivalency test will include reference samplers. Annex D contains information on balance room conditions for the sample analysis and filter handling.

It is recommended that the reference and sample instruments should have a similar flow rate where possible, for example using 16.7 L/min reference sampler when comparing it to a beta attenuation instrument.

5 Data Collection, Processing and Archiving

A NEMS for data processing and archiving of time series data is being developed and this will have an annex on air quality data. Once it is developed this section will be removed from this document. The development of the annex will be commenced following the release of this Standard. In the interim, this section contains information on the handling of data from the field, in its original form, and processing into a final archive-ready format.

All new and revised AS and AS/NZS documents since mid-2020 are now mandating the use of AS 3580.19, which is the standard for ambient air quality data validation and processing, and information in that standard needs to be followed.

Essential information that needs to be collected comprises 'metadata' (information about where and when the measurements were made), as well as the actual measured data.

Multiple datasets will be required. This ensures that data can be tracked back to the original values.

5.1 Documentation

Each monitoring or archiving agency shall prepare a data processing document that expands on the principles in this section and relates to the specific processing and storage systems and software they use.

The only specific requirements are:

- all data shall be supplied and corrected to STP, which for New Zealand is 0°C and 1 atmosphere (1013.25 hPa)
- all data shall be recorded in New Zealand Standard Time (NZST)
- final averaged PM concentration data shall be at a resolution of 0.1 $\mu g/m^3$.

5.2 Meaningful data

Regulation 16C of the NES-AQ (2011 amendments) specifies what meaningful PM_{10} data is (reproduced below):

16C Meaningful PM_{10} data for airshed

(1) This regulation specifies what is required for a an airshed to have meaningful PM_{10} data under regulation 16B(2), 16D(2) or 17(4)(a)(i).

(2) An airshed has meaningful PM_{10} data for a 12-month period if,---

(a) When the concentration of PM_{10} in the airshed was measured during that period, it was measured in a way that allowed 24-hour mean concentrations to be calculated under Schedule 1; and

(b) *The measurements captured data for at least 95% of the 12-month period, after deducting from the duration of the 12-month period any periods of time that were not covered by measurements because of maintenance or calibration; and*

(c) *At least 75% data captured was valid data.*

Note: This requirement is only for PM_{10} data and not for other pollutants in the NES-AQ, but the Good Practice Guide (Ministry for the Environment, 2009) recommends all parameters achieve 75% valid data and 95% for data capture.

Note: At the time of writing this document (December 2021), the NES-AQ regulations are under review and the details above may change.

Some confusion exists regarding the difference between the terms 95% data capture and the 75% valid data. The difference is that 'data capture' excludes down time for routine calibrations and maintenance and 'valid data' includes this time. The formulas for calculating these two statistics are in section 8.7 of the *Good Practice Guide* and will be included in the NEMS *Data Processing*.

Note: There is a recommendation from the document working group to change the above to 90% valid data and remove the data capture statistic to eliminate this confusion. The problem with this recommendation, is that MfE and Stats NZ have stated they are going to use 75% valid data for their environmental domain reporting. This potential change to this document will be reconsidered when this document is next reviewed.

5.3 Data processing steps

Data processing includes:

- collection of the original data
- checking of the data on a routine basis
- data editing, to cater for step-changes or data deviations as a result of sensor recalibration, baseline drift or sensor maintenance
- assignment of quality codes, and
- calculating averages.

5.4 Field data collection

Data shall be stored in a recognised time series manager, with associated metadata also stored with it where possible. Alternatively, ensure the data processing documentation includes how to relate data with the corresponding metadata file.

This especially applies to the raw data, which shall never be deleted. Retaining the data in its original form allows it to be retrieved should something happen to the processed data.

5.5 Data checking

5.5.1 Telemetered systems

Regular checks of data received through telemetered systems allows for early detection of sensor drift, malfunction or failure. Where possible this should be daily. These checks can be used to manage the frequency of site visits.

Some suggested checks of incoming data are:

- reviewing the flow rates
- comparing concentration data from nearby sites
- looking at the baseline of the data – is it stable? Is it the same as yesterday?
- checking whether high concentrations correspond to potential high pollution conditions and whether results observed seem consistent with the meteorological conditions
- checking any status data downloaded from instruments
- checking if the data are within the normal range for the site and the time of the year
- confirming the data are coming in on time
- comparing PM with data collected for other pollutants, and
- checking for exceedances of the standards and guidelines.

These checks can be automated, but visually checking the data is also recommended.

5.5.2 Non-telemetered data

If the data is not telemetered, then once downloaded on site it needs to be loaded into the database and the same checks as described above should be undertaken.

Any status or diagnostic data should also be downloaded and added into the database. This needs to be reviewed and any appropriate action taken.

5.6 Data files

There are usually two or three versions of data:

- raw or original dataset
- edited dataset, and
- final dataset.

5.6.1 Raw or original dataset

As mentioned in Section 5.4, the original data record shall be retained indefinitely.

5.6.2 Edited dataset

The edited dataset is a copy of the raw data file with any adjustments applied that may be needed, for example, to apply the results of the equivalency testing.

Some data processing systems may work on the original file and retain information on changes made. This is an acceptable method so long as it enables the original data to be recreated if necessary.

5.6.3 Final dataset

The final dataset is the quality assured dataset, including quality coding. This is the dataset to supply to Ministry for the Environment and other clients, and to be used for publications, whether on the web or in reports. This dataset shall be retained indefinitely.

5.7 Data editing

This section discusses some of the common types of editing that can be done to PM data to create the final dataset.

When validating data, the underlying assumption shall be that all data are considered valid unless evidence or sound scientific principles are given to support its invalidation.

5.7.1 Corrections that can be applied

Corrections to PM data can include:

- removing any spurious data
- removing any negative data from an optical instrument; negative readings suggest an instrument fault and the cause should be investigated
- removing or commenting on any maintenance or calibration related data, (depending on how your data processing system operates). It is important that this data is not included in any averaging, and.
- Adjustments for spikes that relate to volatile moisture changes – sometimes negative values only and sometimes high positive followed by negative values. These should be removed. Where both positive and negative spikes are together in the data, they both should be retained.

Acceptable tolerances for small negative values caused by moisture can be in the range of 0 to -5 µg/m^3 when the true mass concentration is very low (0–5 μg/m³) for both PM_{10} and $PM_{2.5}$ (based on information in the AS and AS/NZS documents). The AS3580.19 data processing standard states that hourly average concentrations should not be routinely lower than -10 μg/m³ and concentrations less than this should be invalidated. These values may differ from those that are contained in some instrument manuals.

5.7.2 Co-location and equivalency test data

Co-location and equivalency testing (Section 4) will output a single 24-hour correlation factor, which shall be applied to the highest resolution data and be recorded in the metadata.

5.7.3 Uncertainty

Data uncertainty shall be calculated.

If the co-location/equivalence data are within the uncertainty of the instrument and data collection system, then no adjustment should be made to the data.

AS and AS/NZS documents reference using the ISO/IEC 98-3 *Uncertainty of Measurement* document for determining uncertainty.

Note: A number of organisations have not calculated the uncertainty associated with their sites. As agencies do not have a good understanding of the uncertainty associated with their measurements it is proposed that an Envirolink funding proposal is prepared to help agencies determine the uncertainty associated with their data. It is proposed that a template will be developed, that each organisation can input their parameters to, instead of each agency creating something individually. This would ensure standardisation of methodology.

Guidance will be sought from Measurement Standards Laboratory. .

5.7.4 Data averaging

Instantaneous data should be used to calculate hourly averages, when possible, and hourly data shall be used to create 24-hour averages.

Note: The use of hourly averages to calculate 24-hour averages is in agreement with the domain reporting methodology utilised by the by Ministry for the Environment and StatsNZ.

5.8 Metadata and comments

Metadata describe the type of data, where it has been measured, length of record and other information relevant to the dataset.

Comments are very useful to explain unusual features or events in the record that users of the data should be aware of. In addition, routine comments are required for key information.

Comments should be in time-stamped text format and include, but not be limited to:

- information about the site, station and characteristics of the data
- alerts and supporting information intended for end users of the data, and
- aspects not easily quality coded or otherwise quantified in point detail.

Note: Current software packages provide several ways to build a database of comments. Comments can be entered into an unstructured file of text. If the comments are entered into an ODBC (Open Database Connectivity) database, they can be accessed by any ODBC compliant software. Therefore, this is the preferred method to use.

5.8.1 Metadata – site details

Adequate mechanisms shall be put in place to store all relevant site-related metadata with the actual data records including, but not limited to:

- site name and past and present aliases
- site location which may be provided by GPS coordinates, Spatial Reference System (SRS), or triangulation information
- altitude
- site purpose and classification
- site exposure and surrounding land use
- distance to nearest pollution sources and structures / potential obstructions
- intake positioning, including heights
- photographs of the site and surroundings
- start and end date and time of site and record utilising New Zealand Standard Time (NZST)
- recording agency/agencies
- related sites and records, and
- reference to the NEMS Standard and version used.

5.8.2 Metadata – other details

Adequate mechanisms shall be put in place to store all non-site-related metadata, preferably with the actual data record. The metadata should include, but not be limited to:

- equipment details (preferably through an agency instrument/asset management system)
- original data format details for example, chart or digitised format details
- logger and telemetry details
- firmware versions
- calibration records and calibration instrument records

- any relevant comments in document vocabularies that future users will understand (for example, terms shall be defined and instrument types referred to, not brands), and
- information about:
  - legal requirements
  - confidentiality agreements
  - intellectual property, and
  - any other restrictions related to data access.

5.9 Data archiving

The archiving procedures, policies and systems of the monitoring agency shall consider:

- future data-format changes
- off-site duplication of records, and
- disaster recovery.

The following data shall be archived and retained indefinitely:

- final checked and verified data
- original raw data, and
- associated metadata.

Note: The original raw data may be required at a later date should the final data:

- *be found to be in error;*
- *become corrupted; or*
- *be lost.*

5.10 Data auditing

All monitoring agencies should implement a standard methodology for data audit and review. This is to ensure standardisation of datasets that enable meaningful analyses and comparison of data within regions, across regions and nationally.

5.10.1 Audit cycle

Quality assurance processes shall include an audit of the data:

- at a frequency appropriate to the organisation's and users' needs, or
- as defined by the organisation's quality management systems documentation or documented procedures.

This work shall be undertaken by a suitably qualified and experienced practitioner.

Unaudited data that are released for use shall be identified as being unaudited.

Note: Sites other than those under review may be included in the audit to help with comparisons. Where available, reliable records from sites operated by other agencies may be used.

5.10.2 Minimum audit report requirements

As a minimum, analyses and information required for an audit report for each site should cover:

- site and deployment metadata details
- comments and quality coding attached to the records
- data tabulations
- data plots, and
- comparison plots to nearby sites.

6 Quality Coding

This section provides further information on quality coding of the data, especially those specific to PM data.

6.1 General information

6.1.1 Performance

All data shall be quality coded in accordance with the *National Quality Code Schema*, using the flow chart and matrix (Section 6.2). The use of supplementary (child) codes is recommended and is discussed in more detail in Section 6.2.1.

Note: The National Quality Code Schema permits valid comparisons within a data series and across multiple data series.

6.1.2 Considerations

The following points shall be considered when quality coding data:

- whether the recording deployment as a whole meets one or both of the following criteria:
  - – operational standards, and/or
  - – best practice at the time of data acquisition
- the instrument calibration status at the time of data acquisition
- the editing of data, and
- the processing standards at the time of archiving.

6.1.3 Data that do not meet the Standard

Any data that are collected from equipment that do not meet this Standard shall be assigned a quality value from QC 100 to QC 500.

Note: A quality value of QC 600 shall only be assigned where this Standard and associated best practice is achieved.

6.2 Flow chart and matrix for quality coding

In order to assign a quality code to PM_{10} data, the user shall work through the matrix (Table 8) and determine the number of points assigned to the data. The points are then used to determine a quality code using the flow chart (Figure 4).

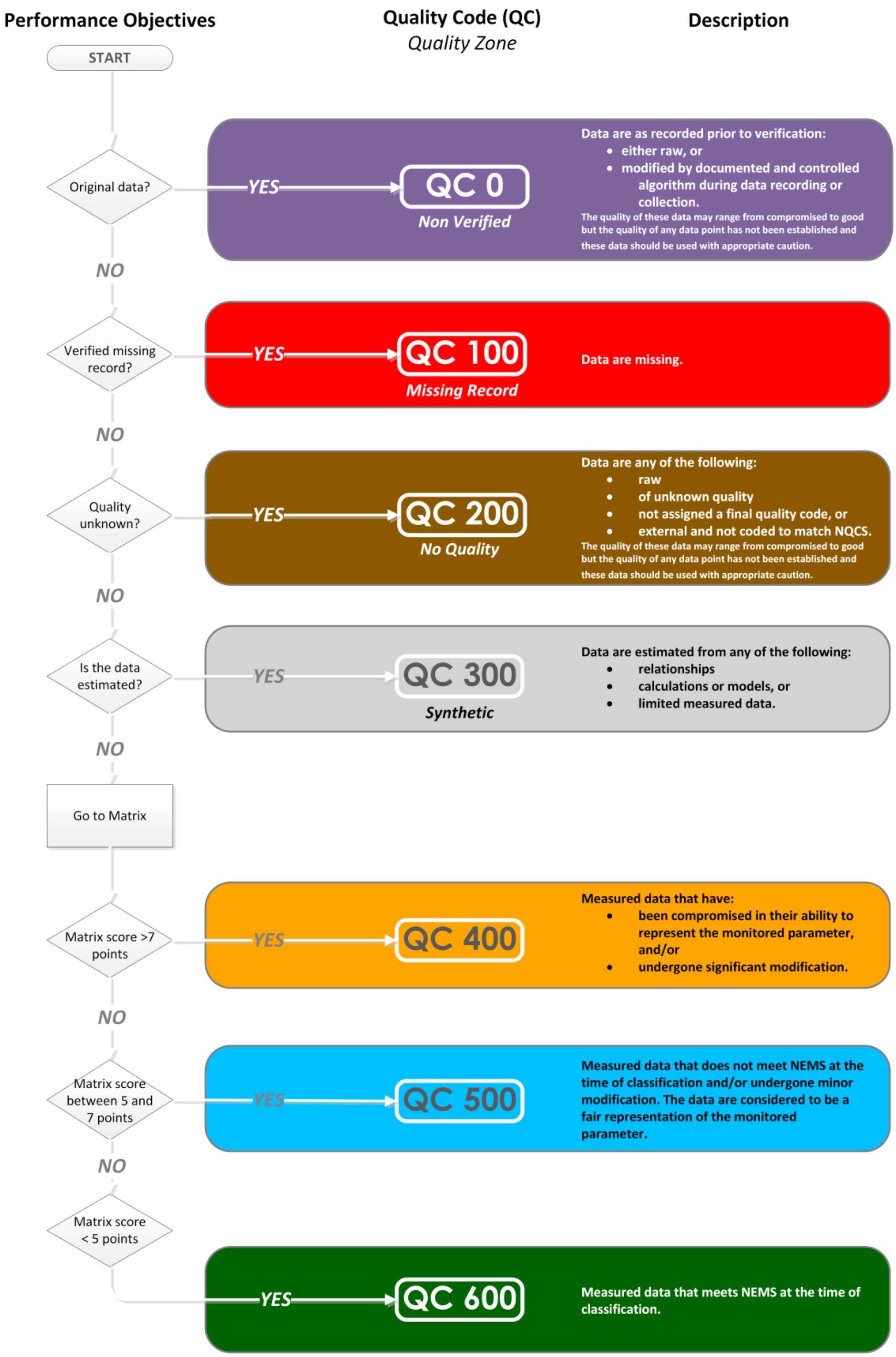


Figure 4 – Flow chart for assigning quality codes to PM data, using points as calculated in Table 8

Table 8 – Matrix for determining points for assigning quality codes to PM data

Criteria	**4 points**	**1 point**	**0 points**
Instrumentation			
Monitoring method *Section 2.2.1*	The method used is not specified in the NES-AQ (Schedule 2) nor has EU or USEPA approval.	The method used is not specified in the NES-AQ (Schedule 2) but has EU or USEPA approval.	The method used is specified in the NES-AQ (Schedule 2).
Instrument operation *Section 3.1*	The monitoring instrument is not operated in accordance with the applicable AS/NZS Standard or, if there is no existing Standard, it is not operated in accordance with AS/NZS 3580.9.17.		The monitoring instrument is operated in accordance with the applicable AS/NZS Standard or, if there is no existing Standard, it is operated in accordance with AS/NZS 3580.9.17.
Equivalency testing *Section 4.1*	An equivalency test has not been carried out within the last ten years, and/or the correlation factor has not been applied to the data.	The monitoring instrument is not on the EU – or - USEPA approved instrument list but a regional equivalency test to New Zealand conditions has been carried out and adjustments applied.	A site specific equivalency test to New Zealand conditions has been carried out in accordance with AS/NZS 3580.9.17 within the last ten years and resulting correlation factor is applied to the data.
Change in instrument type (instrument co-location) *Section 4.2*	The old and new monitoring instruments are operated for an overlapping period less than 9 months (or no co-location of instruments was carried out).	The old and new monitoring instruments are operated for an overlapping period of less than 12 months but more than 9 months to derive a site-specific correlation factor.	The old and new monitoring instruments are operated for an overlapping period of at least 12 months to derive a site-specific correlation factor. (N/A if

			instrument type is not being changed)
Site criteria			
Distance to nearest point source *Section 1.3.8*	The site is less than 40 m away from the nearest particulate matter point source [Neighbourhood/Regional/National-scale site / 'Background' site]. OR The nearest roadway (closest kerbside) is not within 2–5 m [Peak site].	The site is > 40 m but < 50 m away from the nearest particulate matter point source [Neighbourhood/Regional/National-scale site / 'Background' site].	The site is at least 50 m away from the nearest particulate matter point source [Neighbourhood/Regional/National-scale site / 'Background' site] OR The nearest roadway (closest kerbside) is within 2–5 m [Peak site].
Position of the sampling inlet *Section 1.3.9*	The sampling inlet is not between 1.5 and 5 m (± 100 mm) above ground level.		The sampling inlet is between 1.5 and 5 m (± 100 mm) above ground level.
Position of the sampling inlet *Section 1.3.9*	The sampling inlet is less than 1 m (± 100 mm) away from any supporting structures, such as a wall or building roof.		The sampling inlet is at least 1 m (± 100 mm) away from any supporting structures, such as a wall or building roof.
Air flow around sampling inlet *Section 1.3.10*	The air flow around the sampling inlet is restricted so it is less than 270° [Neighbourhood/Regional/National-scale site / 'Background' site]		There is an unrestricted air flow of at least 270° around the sampling inlet [Neighbourhood/Regional/National-scale site / 'Background' site]

	OR The air flow around the sampling inlet is restricted so it is less than 180° and/or there are obstructions between the major source and the sampling inlet [Peak site].		OR There is an unrestricted air flow of at least 180° around sampling inlet and no obstructions between the major source and the sampling inlet [Peak site].
Obstructions above sampling inlet *Section 1.3.10*	The required 120° clear sky angle above the sampling inlet is obstructed by more than 15% (equivalent to > 54° of the 360° horizon). [Neighbourhood/Regional/National-scale site only] Note: To obstruct the 120° clear sky angle, an object/feature will have a horizontal distance from the inlet that is less than two times its height above the inlet.	The required 120° clear sky angle above the sampling inlet is obstructed by 10–15% (equivalent to 36–54° of the 360° horizon). [Neighbourhood/Regional/National-scale site only] Note: To obstruct the 120° clear sky angle, an object/feature will have a horizontal distance from the inlet that is less than two times its height above the inlet.	The required 120° clear sky angle above the sampling inlet is obstructed by less than 10% (equivalent to < 36° of the 360° horizon). [Neighbourhood/Regional/National-scale site only] Note: To obstruct the 120° clear sky angle, an object/feature will have a horizontal distance from the inlet that is less than two times its height above the inlet.
Obstructions of sampling inlet *Section 1.3.10*	The circular area with a radius spanning 10 m from the sampling inlet is obstructed by more than 20% (where an obstruction is an object, building or tree than is higher than 2 m below the height of the sampling inlet).	The circular area with a radius spanning 10 m from the sampling inlet is obstructed by 10–20% (where an obstruction is an object, building or tree than is higher than 2 m below the height of the sampling inlet).	The circular area with a radius spanning 10 m from the sampling inlet is obstructed by less than 10% (where an obstruction is an object, building or tree than is higher than 2 m below the height of the sampling inlet).

Changes in obstructions *Section 1.3.11*	The annual check for the impact of obstructions on site exposure is more than 3 months overdue.	The annual check for the impact of obstructions on site exposure is ≤ 3 months overdue.	The impact of obstructions on site exposure has been checked and documented (including photographs) within the last 12 months.
Data criteria			
Recording interval *Section 2.6*	The data recording interval is greater than 1 hour.		The data recording interval is less than or equal to 1 hour.
Time resolution of data logger *Section 2.6*	The data logger has a time resolution of greater than 1 second.		The data logger has a time resolution of 1 second or less.
Time zone of data *Section 2.6*	Data are not recorded in New Zealand Standard Time (NZST).		Data are recorded in New Zealand Standard Time (NZST).
Allowable time drift *Section 2.6*	The drift in time on the logging device is more than 90 seconds per month.		The drift in time on the logging device is no more than 90 seconds per month.
Data resolution *Section 2.5*	Particulate matter concentration data are recorded to a resolution of greater than 0.1 µg/m^3.		All particulate matter concentration data are recorded to a resolution of 0.1 µg/m^3.

Data uncertainty *Section 5.7.3*		Uncertainty of the particulate matter data has not been calculated.	Uncertainty of the particulate matter data has been calculated.
Data correction *Section 2.5*	Particulate matter data are not corrected to standard temperature and pressure conditions.		All particulate matter concentration data are corrected to standard temperature and pressure conditions, which for New Zealand are 0°C (273.15 K) and 1 atmosphere (1013.25 hPa), respectively.
Metadata	Metadata partially or not documented.	All metadata documented but not checked/updated annually.	All metadata documented in accordance with the Standard and checked/updated annually.
Equipment and housing criteria			
Routine servicing tasks *Section 3.2*	Some or all routine servicing tasks are not completed on schedule and/or are not within specifications as per the relevant AS/NZS Standard (or manufacturer's manual for optical instruments).		All routine servicing tasks are completed on schedule and within specifications as per the relevant AS/NZS Standard (or manufacturer's manual for optical instruments).
Annual servicing tasks *Section 3.3*	Some or all annual servicing tasks are not completed on schedule (> 13 months) and/or are not within specifications as per the relevant	Some or all annual servicing tasks are not completed on schedule (but between 12–13 months) but are within specifications as per the relevant AS/NZS Standard (or	All annual servicing tasks are completed on schedule (≤ 12 months) and within specifications as per the relevant AS/NZS Standard

	AS/NZS Standard (or manufacturer's manual for optical instruments).	manufacturer's manual for optical instruments).	(or manufacturer's manual for optical instruments).
Maintenance equipment calibration *Section 3.4*	Equipment used for maintenance and calibration is not within its calibration period.		All equipment used for maintenance and calibration is within its calibration period.
Housing internal temperature *Section 3.1*	Internal temperature of the housing is not logged. [N/A if not required for the instrument model being used]	Internal temperature of the housing is logged but is not maintained within specifications for the instrument(s) being used. [N/A if not required for the instrument model being used]	Internal temperature of the housing is logged and maintained within specifications for the instrument(s) being used. [N/A if not required for the instrument model being used]

6.2.1 Use of child codes

The basic parent codes of QC 100, 200, 300, 400, 500 and 600 can be expanded to provide more detail on data quality. This will be especially useful in the field of PM monitoring, where there are significant periods of missing record due to scheduled maintenance, as well as a method to assist in identifying the classification of the station (see Section 1.3.2).

For the missing record code (QC 100), it is recommended that the monitoring agency decide and document what child codes are being used. This could range from just planned versus unplanned maintenance through to more detailed coding systems such as using the status codes determined by the instrument. How much detail will depend on what value is placed on individual reasons for missing record in the data set.

It is important to document the basis for the selected codes in the metadata for the site, especially where code x60 (multiple sources) is used.

For the measured data quality codes (QC 400, 500 and 600), the same child code suffixes and summary shall be used. The child codes suffixes to use are listed in Table 9.

Table 9 – Child code suffixes for PM data of QC 400 to 600

Child Code	Child Summary
410, 510 or 610	Traffic
420, 520 or 620	Industrial
430, 530 or 630	Residential
440, 540 or 640	Special
450, 550 or 650	Special - regional
460, 560 or 660	Special - national

Annex A – List of Referenced Documents

Ministry for the Environment. 2011. 2011 Users' Guide to the revised National Environmental Standards for Air Quality: Updated 2014. Wellington: Ministry for the Environment.

Ministry for the Environment. 2009. Good Practice Guide for Air Quality Monitoring and Data Management 2009. Wellington: Ministry for the Environment.

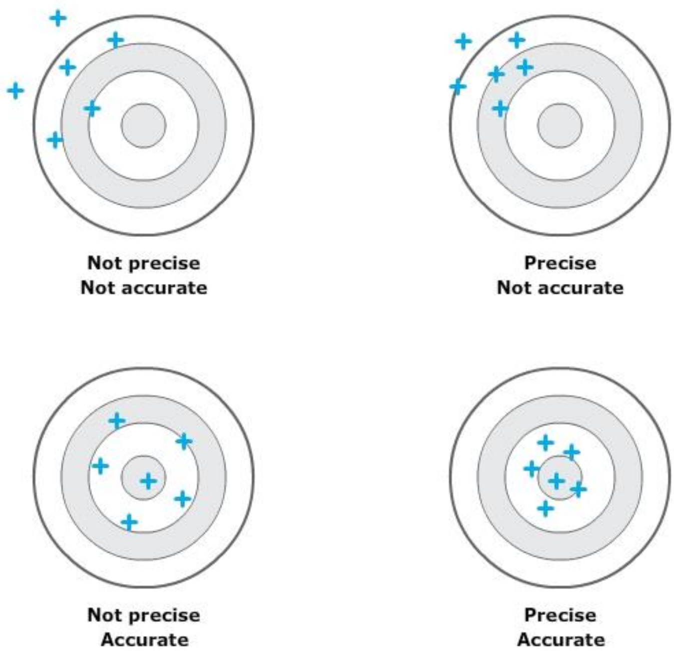
Annex B – Instrument specification terms

Accuracy and Precision

When taking scientific measurements, the goals are to measure accurately and with precision.

- Accuracy indicates the closeness of the measurements to the true or accepted value.
- Precision is the closeness of the results to others obtained in exactly the same way.

In this image, the bull's eye represents the accepted true value. Each cross represents a repeated measurement of the same quantity.



Sources of Error

There are two main sources of error in data. These are systematic measurement error and random measurement error:

Systematic measurement error is the error that in replicate measurements remains constant or varies in a predictable manner.

- Random measurement error is the component of measurement error that in replicate measurements varies in an unpredictable manner.

Measurement bias is an estimate of the systematic measurement error.

Uncertainty

Uncertainty is a variable associated with the result of a measurement that characterises the dispersion of the values that could be reasonably attributed to the variable (quantity intended to be measured). This variable may be a standard deviation or half width or similar, having a stated level of confidence, which is usually 95%.

The AS/NZS standards include a section on measurement uncertainty which requires the user to calculate their own uncertainty based on ISO/TEC Guide 98-3.

The uncertainty value will vary depending on the specific equipment used including the type of instrument, calibration equipment and data logging system.

Resolution

This is the smallest change in a quantity being measured that causes a perceptible change in the corresponding indication.

The resolution for time and for concentration are both important factors to consider. The resolution for concentration is sometimes called the minimum level of detection.

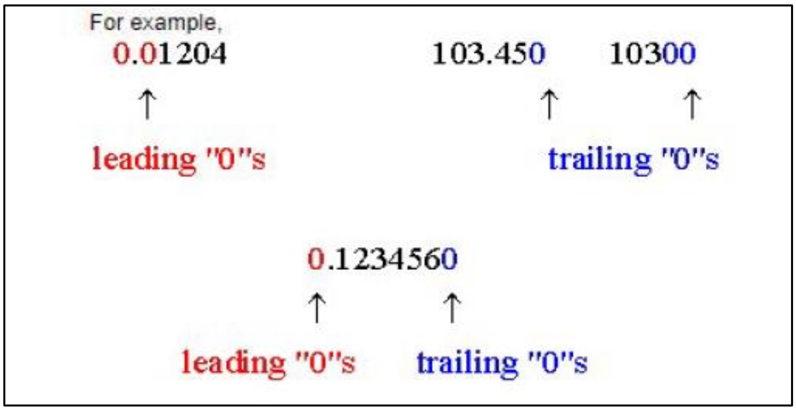
Annex C – Significant figures and decimal points in stored data

When collecting and storing the data, there is no specific requirement about the number of decimal places that should be used. However, for reporting the data to Ministry for the Environment, the public or clients the averaged data needs to be at a resolution of 0.1 ug/m^3.

Here is some background on significant figures and averaging.

All numbers have a value for the number of significant figures. This is the number of digits that are known with some degree of reliability; for example 13.2 has three significant figures and 13.20 has four.

The position of a zero makes a difference. If a decimal number starts with a string of zeros these are called leading zeros and if it ends with a string of zeros they are trailing ones.



There are five main rules in deciding how many significant figures a number has:

- all non-zero digits are significant
- zeros between non-zero numbers are significant (e.g. 103 has 3 significant figures)
- leading zeros **after** the decimal point are not significant (only indicate position of decimal point, e.g. 0.012 has 3 significant figures),
- trailing zeros **before** the decimal point are not significant (e.g. 120 has 2 significant figures), and
- trailing **zeros** after the decimal point are significant (13.20 has 4 significant figures).

When performing calculations, the general rule is that the least accurate measurement gives the number of significant figures:

- in addition and subtraction, the result is rounded to have the same number of significant figures as the measurement having the fewest; e.g. 100 + 23.6 = 124

- in multiplication and division, the result is rounded to the same number of significant figures as the one with least number of significant figures; e.g. 3.0 * 12.60 = 37.8000 rounded to 37.8, and
- when averaging, the final number will have the same number of decimal places that are in their sum; e.g. 130 + 42 + 15 = 187, divided by 3 = 62.333 which would be rounded to 62.

When performing the calculations, carry as many digits as possible through the entire set of calculations and then only round the final result; e.g. (5.00/1.235) + 3.0 = 7.04858… rounded to 7.0.

It is important to determine what resolution a particular instrument can measure data to, by looking at the specifications. Some instruments currently deployed have a resolution of 1 $\mu g/m^3$ and others have a resolution of $0.1 \mu g/m^3$. In the case of those that cannot record decimal places, then the average must also be a whole number.

Annex D – Gravimetric sampling – filter requirements

Balance room

The balance room needs to be a controlled atmosphere with respect to temperature and relative humidity.

Temperature and relative humidity data shall be recorded during the weighing sessions at intervals not exceeding 15 minutes. These data shall be kept with the filter results.

There are different requirements depending on whether the filters are being weighed for PM_{10} or $PM_{2.5}$.

Parameter	**PM10 filters**	**PM2.5 filters**
Temperature	15–30°C ± 3°C	20–25°C ± 2°C
Relative humidity	20–50% ± 5%	30–40% ± 5%
Balance resolution	< 1 µg (low volume sampler filters) < 0.1 mg (high volume sampler filters)	< 0.1 mg for all filters
Resolution for filter weighing	0.1 mg (high volume sampler filters) 3 consecutive readings within ± 5 µg (low volume filters)	0.1 mg (high volume sampler filters) 3 consecutive readings within ± 5 µg (low volume filters)

Filters need to equilibrate to the balance room conditions for at least 24 hours before weighing.

The temperature and relative humidity sensors used in the balance room shall be checked every 6 months against a reference sensor.

The balance shall be checked on a regular basis as specified in the appropriate AS/NZS document. This includes:

- a single point check each month
- a repeatability check every six months, and
- calibration every three years.

Filters

When undertaking filter-based sampling for equivalency testing or co-location tests, PTFE filters shall be used, wherever possible, as they have been shown to give better results for particulate concentration data. Some high-volume samplers use glass fibre filters, and in this situation, it is acceptable to use these instead of PTFE.

The filters need to be checked for pinholes (using a light source) and other defects before use.

Sampling

As a control, field and laboratory blank filters shall be used to determine if there is any variation in the results due to the handling of a filter. These are filters either kept in the laboratory ('lab blank') or taken out to the field, put in the sampler and then removed and brought back to the office for storage ('field blank'). The ratio of field and lab blanks to sample filters is 1 (field or lab) to 20 sample filters.

Post-sampling weighing shall be completed within 20 days of the sample being collected, or 30 days if the sample filters are maintained below 4°C and data are available to show this temperature level is maintained during the period. The temperature probe used for this verification must also be calibrated.

Storage of filters

Pre-weighed filters have been shown to deteriorate over time, so it is recommended that the time between pre-weighing and use is kept to a minimum. High volume sampler filters, being glass fibre, are more susceptible to issues than PTFE filters.

Storing large quantities of pre-weighed filters could cause an issue if the balance used for the pre- and post-weighing is changed or has servicing carried out on it. After a service, it is recommended to check some of the pre-weighed filters to determine if the servicing has changed the weights recorded.

The new filters should be stored out of direct sunlight but normal room temperature is acceptable.

Annex E - Using the quality coding matrix – worked examples

The full matrix should be worked through on installation of a new site or instrument. After that, the sampling programme and data criteria are unlikely to change, with changes more likely in the site and equipment criteria. The matrix shall be reviewed on an annual basis. If changes are made or noticed at the site or in the data processing, then the matrix shall be updated as soon as possible after this occurs.

Here are some examples in the use of the matrix and the resulting quality code.

These examples use the Auckland Council site located near Pukekohe, as shown in the photographs. There are some assumptions made in the site and equipment to help explain the matrix better.

Pukekohe site looking north – note hedge/trees go along north, east and southern boundaries

Looking to the west where most of the glasshouses are

Example 1

The following assumptions have been made:

- it is a 'background' site
- a Thermo FH62C14 BAM is being used, in line with Schedule 2
- there has been no equivalency/co-location or data uncertainty calculation performed, and
- This instrument is still working well so the annual service was delayed.

For the siting criteria:

- there is a 10 m meteorological mast near the site, but this is not going to obstruct the inlet as the diameter is only 40 mm
- the meteorological instrument shed (small one beside the air quality shed) is more than 2 m below the intake so that is not an obstruction, and
- the closest glasshouse to the north is 9 m away, and the boundary trees are 25–65 m away and are usually trimmed to 6–8 m high.

Criteria	4 points	1 point	0 points
Instrumentation			
Monitoring method *Section 2.2.1*	The method used is not specified in the NES-AQ (Schedule 2) nor has EU or USEPA approval.	The method used is not specified in the NES-AQ (Schedule 2) but has EU or USEPA approval.	The method used is specified in the NES-AQ (Schedule 2).
Instrument operation *Section 3.1*	The monitoring instrument is not operated in accordance with the applicable AS/NZS Standard or, if there is no existing Standard, it is not operated in accordance with AS/NZS 3580.9.17.		The monitoring instrument is operated in accordance with the applicable AS/NZS Standard or, if there is no existing Standard, it is operated in accordance with AS/NZS 3580.9.17.
Equivalency testing *Section 4.1*	An equivalency test has not been carried out within the last ten years, and/or the correlation factor has not been applied to the data.		An equivalency test to New Zealand conditions has been carried out in accordance with AS/NZS 3580.9.17 within the last ten years and resulting correlation factor is applied to the data.
Change in instrument type (instrument co-location) *Section 4.2*	The old and new monitoring instruments are operated for an overlapping period less than 9 months (or no co-location of instruments was carried out).	The old and new monitoring instruments are operated for an overlapping period of less than 12 months but more than 9 months to derive a site-specific correlation factor.	The old and new monitoring instruments are operated for an overlapping period of at least 12 months to derive a site-specific correlation factor. (N/A if instrument type is not being changed)

Site criteria			
Distance to nearest point source *Section 1.3.8*	The site is less than 40 m away from the nearest particulate matter point source [Neighbourhood/Regional/National-scale site / 'Background' site]. OR The nearest roadway (closest kerbside) is not within 2–5 m [Peak site].	The site is > 40 m but < 50 m away from the nearest particulate matter point source [Neighbourhood/Regional/National-scale site / 'Background' site].	The site is at least 50 m away from the nearest particulate matter point source [Neighbourhood/Regional/National-scale site / 'Background' site] OR The nearest roadway (closest kerbside) is within 2–5 m [Peak site].
Position of the sampling inlet *Section 1.3.9*	The sampling inlet is not between 1.5 and 5 m (± 100 mm) above ground level.		The sampling inlet is between 1.5 and 5 m (± 100 mm) above ground level.
Position of the sampling inlet *Section 1.3.9*	The sampling inlet is less than 1 m (± 100 mm) away from any supporting structures, such as a wall or building roof.		The sampling inlet is at least 1 m (± 100 mm) away from any supporting structures, such as a wall or building roof.
Air flow around sampling inlet *Section 1.3.10*	The air flow around the sampling inlet is restricted so it is less than 270° [Neighbourhood/Regional/National-scale site / 'Background' site] OR		There is an unrestricted air flow of at least 270° around the sampling inlet [Neighbourhood/Regional/National-scale site / 'Background' site] OR

	The air flow around the sampling inlet is restricted so it is less than 180° and/or there are obstructions between the major source and the sampling inlet [Peak site].		There is an unrestricted air flow of at least 180° around sampling inlet and no obstructions between the major source and the sampling inlet [Peak site].
Obstructions above sampling inlet *Section 1.3.10*	The required 120° clear sky angle above the sampling inlet is obstructed by more than 15% (equivalent to > 54° of the 360° horizon). [Neighbourhood/Regional/National-scale site only] Note: To obstruct the 120° clear sky angle, an object/feature will have a horizontal distance from the inlet that is less than two times its height above the inlet.	The required 120° clear sky angle above the sampling inlet is obstructed by 10–15% (equivalent to 36–54° of the 360° horizon). [Neighbourhood/Regional/National-scale site only] Note: To obstruct the 120° clear sky angle, an object/feature will have a horizontal distance from the inlet that is less than two times its height above the inlet.	The required 120° clear sky angle above the sampling inlet is obstructed by less than 10% (equivalent to < 36° of the 360° horizon). [Neighbourhood/Regional/National-scale site only] Note: To obstruct the 120° clear sky angle, an object/feature will have a horizontal distance from the inlet that is less than two times its height above the inlet.
Obstructions below sampling inlet *Section 1.3.10*	The circular area with a radius spanning 10 m from the sampling inlet is obstructed by more than 20% (where an obstruction is an object, building or tree than is higher than 2 m below the height of the sampling inlet).	The circular area with a radius spanning 10 m from the sampling inlet is obstructed by 10–20% (where an obstruction is an object, building or tree than is higher than 2 m below the height of the sampling inlet).	The circular area with a radius spanning 10 m from the sampling inlet is obstructed by less than 10% (where an obstruction is an object, building or tree than is higher than 2 m below the height of the sampling inlet).

Changes in obstructions *Section 1.3.11*	The annual check for the impact of obstructions on site exposure is more than 3 months overdue.	The annual check for the impact of obstructions on site exposure is ≤ 3 months overdue.	The impact of obstructions on site exposure has been checked and documented (including photographs) within the last 12 months.
Data criteria			
Recording interval *Section 2.6*	The data recording interval is greater than 1 hour.		The data recording interval is less than or equal to 1 hour.
Time resolution of data logger *Section 2.6*	The data logger has a time resolution of greater than 1 second.		The data logger has a time resolution of 1 second or less.
Time zone of data *Section 2.6*	Data are not recorded in New Zealand Standard Time (NZST).		Data are recorded in New Zealand Standard Time (NZST).
Allowable time drift *Section 2.6*	The drift in time on the logging device is more than 90 seconds per month.		The drift in time on the logging device is no more than 90 seconds per month.
Data resolution *Section 2.5*	Particulate matter concentration data are recorded to a resolution of greater than 0.1 μg/m^3.		All particulate matter concentration data are recorded to a resolution of 0.1 μg/m^3.
Data uncertainty *Section 5.7.3*		Uncertainty of the particulate matter data has not been calculated.	Uncertainty of the particulate matter data has been calculated.

Data correction *Section 2.5*	Particulate matter data are not corrected to standard temperature and pressure conditions.		All particulate matter concentration data are corrected to standard temperature and pressure conditions, which for New Zealand are 0°C (273.15 K) and 1 atmosphere (1013.25 hPa), respectively.
Metadata	Metadata partially or not documented.	All metadata documented but not checked/updated annually.	All metadata documented in accordance with the Standard and checked/updated annually.
Equipment and housing criteria			
Routine servicing tasks *Section 3.2*	Some or all routine servicing tasks are not completed on schedule and/or are not within specifications as per the relevant AS/NZS Standard (or manufacturer's manual for optical instruments).		All routine servicing tasks are completed on schedule and within specifications as per the relevant AS/NZS Standard (or manufacturer's manual for optical instruments).
Annual servicing tasks *Section 3.3*	Some or all annual servicing tasks are not completed on schedule (> 13 months) and/or are not within specifications as per the relevant AS/NZS Standard (or manufacturer's manual for optical instruments).	Some or all annual servicing tasks are not completed on schedule (but between 12–13 months) but are within specifications as per the relevant AS/NZS Standard (or manufacturer's manual for optical instruments).	All annual servicing tasks are completed on schedule (≤ 12 months) and within specifications as per the relevant AS/NZS Standard (or manufacturer's manual for optical instruments).

Maintenance equipment calibration *Section 3.4*	Equipment used for maintenance and calibration is not within its calibration period.		All equipment used for maintenance and calibration is within its calibration period.
Housing internal temperature *Section 3.1*	Internal temperature of the housing is not logged. [N/A if not required for the instrument model being used]	Internal temperature of the housing is logged but is not maintained within specifications for the instrument(s) being used. [N/A if not required for the instrument model being used]	Internal temperature of the housing is logged and maintained within specifications for the instrument(s) being used. [N/A if not required for the instrument model being used]

Total points = 9

The data for this period should be coded **QC 400.**

Example 2

As above, but the annual service has been completed on schedule.

Total = 5 points. The data for this period should be coded **QC 500**.

If an equivalency test is conducted and correlation factor applied to the data, then the total comes down to **1 point** and the data are now at **QC 600.**

Example 3

Data are coded QC 600 as in example 2. However, a new glasshouse has been installed adjacent to the monitoring station. It is 5 m away, is 10 m long and the top of it is 3 m above the inlet level.

Calculation of "% of obstructions above the inlet" gives a result of 20% (4 points). Thus, the total is now 5 points, equating to **QC 500**.

If the date of the new obstruction is known (in this case, construction of the glasshouse) the quality code change can be applied from that date onwards.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