National Environment Protection
(Ambient Air Quality) Measure

Technical Paper on Monitoring for Particles as $PM_{2.5}$

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1 INTRODUCTION

The National Environment Protection (Ambient Air Quality) Measure was varied in 2003 to introduce particles as $PM_{2.5}$, in the form of advisory reporting standards. The goal of the Variation to the Ambient Air Quality NEPM is not framed in terms of compliance with the standards, rather it is "to gather sufficient data nationally to facilitate the review of the Principal Measure as varied, scheduled to commence in 2005".

It is important that the Variation facilitates consistent data collection and reporting of $PM_{2.5}$ data by jurisdictions. The purpose of this technical paper is to provide consistent advice on $PM_{2.5}$ monitoring using accepted monitoring methods, and to outline how the monitoring data will be used to prepare a consistent national database that will inform the review of the Principle Measure as varied.

This document will be updated from time to time. The need for this flexibility arises from:

- development and publication of additional Australian Standards for $PM_{2.5}$ monitoring. Such standards may supersede the current guidance contained in this document, provided that they are equivalent to the protocol adopted for the NEPM Variation;
- jurisdictional experiences in introducing new monitoring methods into air quality monitoring networks; and
- ongoing assessment and development of preferred analysis methods for the comparison of $PM_{2.5}$ monitoring data collected using the reference method (Section 2) and the candidate method (Section 3).

2 REFERENCE METHOD FOR $PM_{2.5}$ MONITORING

In the absence of a suitable Australian Standard, the USEPA reference method (*US Code of Federal Regulations Title 40 Part 50 Appendix L Reference Method for the Determination of Fine Particulate Matter as $PM_{2.5}$ in the Atmosphere*) has been designated the reference method for monitoring particles as $PM_{2.5}$ in Australia, hereafter referred to as the "reference method".

The USEPA reference method documentation contains design and performance specifications that define the reference method $PM_{2.5}$ sampler. To minimise the number and extent of performance tests to which candidate equivalent methods must be subjected, USEPA designated three classes of equivalent methods.

Class I equivalent methods are based on samplers that have relatively small deviations from the specifications for reference method samplers. Therefore, in addition to the tests and other requirements applicable to reference method samplers, candidate Class I equivalent samplers must be tested to only make sure that the modifications do not significantly compromise sampler performance. The additional tests for most Class I candidate equivalent samplers are a test for possible loss of $PM_{2.5}$ in any new or modified components in the sampler inlet upstream of the sample filter, and the field testing for comparability to reference method samplers.

Class II equivalent methods will generally have one or more substantial deviations from the design or performance specifications of the reference method, such that it cannot qualify as a Class I equivalent method. For example, these samplers may have a different inlet, a different particle size separator or a different volumetric flow rate.

The term "reference method" in the context of this Variation includes Class I and Class II equivalent methods. The specification of Class II equivalent methods will, for example, allow

for the use of very sharp-cut cyclone (VSCC) inlets to reference samplers (Section 2.1), which have significantly reduced maintenance requirements.

With the introduction of monitoring of particles as $PM_{2.5}$ into performance monitoring stations using the reference method, jurisdictions will need to gain experience with new equipment and new quality assurance procedures. It is expected that jurisdictions already monitoring $PM_{2.5}$ with reference method samplers will be a useful source of information for jurisdictions planning to introduce reference methods into their air quality monitoring networks. The experience already gained in some jurisdictions may also be useful in assessing whether deviations from the reference method procedures are justified in order to make methods more suitable to the Australian context.

2.1 REFERENCE SAMPLERS - OPERATIONAL GUIDANCE

It is desirable to operate reference samplers in strict accordance with the USEPA FRM. There are, however, a number of areas where jurisdictions have advised that it will be difficult to meet all aspects of FRM requirements. A summary of the guidance and minimum requirements of this Variation as they relate to the FRM is presented below. In some cases, the minimum requirements represent a relaxation of the FRM specifications, but are considered to be justified in the Australian context. These deviations have been discussed with jurisdictions and broad consensus has been reached.

Guidance / Requirements for Reference Sampler Operation

1. For jurisdictions using Rupprecht and Patashnick (R&P) reference samplers, sampling inlets can be either WINS impactor inlets or R&P very short cut cyclone inlets (which have USEPA equivalency, as per EQPM-2020-143). The very short cut cyclone inlets have significantly reduced maintenance requirements over the WINS impactor inlets.

2. For candidate gravimetric methods (Class II samplers), filter conditioning and weighing procedures should meet the same criteria as for the USEPA FRM.

3. Jurisdictional monitoring representatives provided comment on the practicality of complying with key aspects of the reference method as detailed in the *USEPA Quality Assurance Document 2.12: Monitoring $PM_{2.5}$ in Ambient Air Using Designated Reference or Class I Equivalent Methods* and in Appendix L Part 50 of the FRM. Details of necessary deviations from the reference method are presented in the table below.

4. All other aspects of the method must conform with USEPA FRM. The FRM documentation is available from the USEPA website (www.epa.gov).

PROPOSED VARIATIONS FROM THE USEPA QUALITY ASSURANCE DOCUMENT

Reference	Summary of Criteria	Guidance/Requirement
4.3.4 Transport	Insulated shipping containers capable of maintaining temperature below 25^{o}C required for shipping samples after sampling.	1. For sample collection days when vehicle temperatures are likely to exceed 25oC, filter storage canisters are to be placed in a car fridge with a cold pack. 2. Monitoring of maximum-minimum temperatures is not required. Where possible, sample collection/exchange should be conducted in the morning, with samples stored in a storage magazine inside a metal transport container, and transported in an air conditioned vehicle. 3. Filters requiring transportation from regional centres or to interstate laboratories can be shipped without temperature control, but the most rapid transport method must be used. 4. Field blanks will accompany sample filters (10% of samples).
7.2 Weighing environment	Microbalance environment and filter conditioning environment.	A number of jurisdictions do not have a weighing environment that meets these criteria. Jurisdictions will need to consider investing in such a facility or investigate outsourcing options. Compliance with these specifications is required, whether analysis is conducted in-house or externally.
8.2.4.1 Handling a valid sample	The sample must be removed from the collector within 96 hours (4 days) of the end of the run, with final analysis within 10 days of sample run (30 days <4oC).	Taking account of existing resources and the need for efficient integration of $PM_{2.5}$ monitoring with existing operations, alternate criteria for the purposes of the NEPM Variation are: 1. The sample must be removed from the collector within 14 days of the end of the run. 2. The period between filter collection and final analysis must not exceed 20 days (50 days <4oC). 3. Laboratory analysis must be completed within 7 days from receipt of sample. 4. Records of sample handling must be maintained.
Filter temperature control	The sampler shall provide a means to limit the temperature rise of the sample filter (all sample filters for sequential samplers) from insolation and other sources to no more than 5oC above the temperature of the ambient air surrounding the sampler, during both sampling and post-sampling periods of operation.	Reference samplers are likely to have a ventilation system that is claimed by the manufacturers to maintain the temperature of the sample filter to within 5oC of the outside ambient temperature. These instruments log the filter temperature, ambient temperature and pressure during and after filter exposure. Records are to be monitored and maintained, but no action is required to invalidate samples if exceedences are observed.
10.0 Performance evaluation	This process requires additional collocated samplers and audit samplers.	There is currently no requirement to establish collocated samplers. However, if the existing network of reference samplers is decreased at any stage, trials may be run to investigate $PM_{2.5}$ precision with collocated samplers.
Sensor calibration	Calibration of temperature, pressure, flow and mass sensors.	Compliance with NATA requirements (ISO/IEC 17025 Application Document) for calibration of $PM_{2.5}$ sensors is satisfactory for demonstration of compliance with USEPA Quality Assurance Guidance Document 2.12.

3 ALTERNATIVE METHODS FOR $PM_{2.5}$ MONITORING

Jurisdictions have requested that continuous direct mass methods using a tapered element oscillating microbalance be considered as an alternative method because they:

- are consistent with existing equipment and quality systems are well established;
- enable reporting for daily air quality bulletins;
- are less labour intensive than manual gravimetric methods; and
- provide near real-time continuous monitoring for evaluation of diurnal trends.

Under this Variation, $PM_{2.5}$ data collected using continuous direct mass methods using a tapered element oscillating microbalance may be reported for the purpose of establishing equivalence with the designated reference method. To assess whether these methods are an equivalent method to the USEPA FRM, an equivalence test program has been proposed (section 4).

This approach acknowledges the substantial investment that jurisdictions have made in such equipment, and the fact that continuous methods are an important component of day to day air quality management in jurisdictions.

3.1 CONTINUOUS DIRECT MASS METHODS USING A TAPERED ELEMENT OSCILLATING MICROBALANCE - OPERATIONAL GUIDANCE

The operational requirements for these methods are based on AS 3580.9.8 (*Determination of suspended particulate matter - PM_{10} continuous direct mass method using a tapered element oscillating microbalance analyser*), with reference to $PM_{2.5}$ in place of PM_{10} as appropriate. Minor modifications required to adapt the Standard for the purposes of $PM_{2.5}$ monitoring are:

Section 5 - APPARATUS

Section 5.1 - Analyser

Continuous direct mass methods using a tapered element oscillating microbalance for PM_{10} monitoring are not equivalent samplers for $PM_{2.5}$ monitoring. The internal software is configured to make an empirically established adjustment to the mass concentration to achieve comparable results to the USEPA PM_{10} reference methods. This is done using the formula:

$$Y=A + BX$$

When the monitor is operated as an equivalent PM_{10} monitor, the values of A and B are set to 3.0 and 1.03 respectively. For operation as a $PM_{2.5}$ monitor for the equivalency program the values for A and B must be set to 0 and 1.0 respectively (*R&P Operating Manual TEOM Series 1400a Ambient Particulate (PM10) Monitor (AB serial Numbers) December 1995 Revision B Section 4.7 Setting Other Hardware Parameters*).

Section 5.4 - Size Selective Inlet

Very Sharp Cut Cyclone $PM_{2.5}$ Fractionator (VSCC) - the VSCC is a secondary inlet that fits below a standard PM_{10} inlet. The VSCC meets the specifications of USEPA 40 CFR Part 53, Subpart D, and achieves a sharp particle size separation that closely approximates the performance of a freshly oiled USEPA WINS $PM_{2.5}$ inlet. The preferred $PM_{2.5}$ inlet for the Variation is the VSCC inlet.

Table 2 - Routine Maintenance

The requirement for cleaning the VSCC is the same as for the PM_{10} inlet (after 30 days of continuous sampling). Both the PM_{10} and VSCC inlets require cleaning every 3 months. More frequent attention to maintenance intervals may be required when the $PM_{2.5}$ particle concentrations regularly exceed 25µg / m^3.

Section 10 - Calculation and Expression of Results

Operating monitors according to AS 3580.9.8 records the mass concentration referenced to 0oC and 101.3kPa. For the purposes of this Variation, reporting of $PM_{2.5}$ data must be in units of µg / m^3 at conditions of temperature and pressure as follows:

- 0^oC and 101.3 kPa (as per the Standard) and;
- actual average temperature and pressure conditions, to facilitate comparison with overseas data.

4 EQUIVALENCE PROGRAM

As part of the Variation, an "equivalence" program is proposed, which will enable an assessment of the accuracy and precision of other $PM_{2.5}$ monitoring methods with regard to monitoring data obtained using the reference method.

The program allows existing jurisdictional equipment (ie continuous direct mass methods using a tapered element oscillating microbalance) to be used for monitoring particles as $PM_{2.5}$, but requires collocation with a reference sampler at a limited number of sites across Australia. The collocation sites nominated by jurisdictions are presented in the table below, however it should be noted that the site listing is considered to be provisional at this time.

The collocated data collected at these sites will be used to establish if continuous direct mass methods using a tapered element oscillating microbalance have accuracy and precision comparable with the reference method. If equivalence can be demonstrated, then $PM_{2.5}$ monitoring data collected using the non-reference method can be used for the purpose of comparing monitored levels with the $PM_{2.5}$ standards.

The equivalence program requires collection of data over a three-year period. Noting that the review of the Principal Measure as varied is scheduled to commence in 2005, it is acknowledged that three years data would not be available at the commencement of the review. However, it is expected that these data would not be required until the decision is made regarding any variation of the Principal Measure. If a variation to the Principal Measure is to occur subsequent to the review, it is expected that three years of data would be available at that time. Data from the equivalency program are to be reviewed annually during the three year period which may indicate whether equivalence is likely before the program is completed.

4.1 EQUIVALENCE PROTOCOL

The following protocol will form the basis of data collected at the nominated sites as part of the equivalency program:

- If alternative monitoring methods for particles as $PM_{2.5}$ are used, equivalence between the reference method and the alternative method must be demonstrated by collocation of samplers over a three-year period. If jurisdictional monitoring resources are limited, allowance may be made for shorter monitoring periods if data covering a wide range of $PM_{2.5}$ sources and concentrations can be obtained in less than three years, thus enabling

limited monitoring resources to be used to gather data at other locations. Such arrangements would be considered on a case-by-case basis.

- For jurisdictions undertaking equivalence monitoring, there must be at least one collocation site with a reference sampler run on a minimum 1-in-3 day operation.

- Data availability must exceed 75% and it is recommended that higher data recovery be achieved during seasons with expected elevated particle loadings.

- The sample inlets of the reference sampler and the candidate sampler must sample the same ambient environment:
  - air flow around the sample inlets must be unrestricted;
  - samplers must not interfere with one another; and
  - sample inlets must be at the same height.

- Reporting of $PM_{2.5}$ data must be in units of $\mu g / m^3$ at conditions of temperature and pressure as follows:
  - 0°C and 101.3 kPa (Australian Standard conditions); and
  - actual average temperature and pressure conditions, to facilitate comparison with overseas data.

- Reporting of $PM_{2.5}$ data must also include actual temperature, pressure and humidity on a 24-hour average basis. Additional equipment may be required to be installed at $PM_{2.5}$ monitoring sites to enable this reporting.

4.2 COLLOCATION SITES

Jurisdictions may determine the sites at which equivalence monitoring is undertaken. It is expected that there will be sites in each jurisdiction at which monitoring of $PM_{2.5}$ is desirable, for example, wood smoke impacted areas or areas of high traffic density.

If several sites are suitable for equivalence monitoring, the site likely to produce the highest particle levels should be selected. The measured concentration ranges must be distributed over the broadest range of concentrations possible. A set of data points over a small concentration range will not be considered as demonstrating equivalence. The measurements should be taken at locations typical of prevailing meteorological conditions within the jurisdiction.

The collocation performance monitoring sites around Australia for the equivalence program have been proposed by jurisdictions. The selection of sites is considered to be provisional and is subject to adequate resources being made available. The sites nominated are presented in the table below. These sites are considered to provide a range of particle pollution levels and are representative of diverse Australian conditions. The relationships between sampling methods derived from collocation studies may be applied to regions of Australia where non-reference samplers are used, although this is to be assessed on a case by case basis. This approach will allow the generation of a nationally consistent data set on particles as $PM_{2.5}$ that will be used in the review of the Principal Measure as varied, scheduled to commence in 2005.

Sites Proposed for the Equivalence Program

Jurisdiction	Site	Sampling Frequency (reference sampler)	Sampling Period	Alternative Method	Commencement Date
New South Wales	Earlwood Richmond	1 in 3 days 1 in 3 days	3 years 3 years	$PM_{2.5}$ TEOM	1 January 2004
Victoria	Alphington Mooroolbark	1 in 3 days 1 in 3 days	3 years 3 years	$PM_{2.5}$ TEOM	1 January 2004
Queensland	Springwood Rocklea	1 in 3 days 1 in 3 days	3 years 3 years	$PM_{2.5}$ TEOM	1 January 2004
Western Australia	Duncraig	1 in 3 days	3 years	$PM_{2.5}$ TEOM	1 January 2004
South Australia	Netley	1 in 3 days	3 years	$PM_{2.5}$ TEOM	1 January 2004
Tasmania	Launceston	1 in 3 days	3 years	$PM_{2.5}$ TEOM	1 July 2004

4.3 DATA ANALYSIS

The detailed protocols for data analysis will be developed as the collocated data are collected over the three-year monitoring period. This document will be updated accordingly as these protocols are established, however, an outline of the process is:

1. The mass concentration measurements of particles as $PM_{2.5}$ to be compared must be performed over the same time period. The sampling duration will normally be 24 hours ±1 hour. Relationships established between the reference method and alternative methods will include temperature, pressure and humidity.

2. By performing collocated measurements under ambient conditions characteristic of the wide range of environmental conditions typical of the nominated performance monitoring sites, the relationship between the reference method and alternative methods will be determined. The application of relationships established in one jurisdiction to other jurisdictions without collocation sites is to be assessed on a case by case basis.

3. Data collected over the three-year period will be used for a rigorous validation and correlation assessment. The assessment will be performed by a National Environment Protection Council consultancy or a Working Group convened by the National Environment Protection Council Service Corporation. The method of data analysis would be developed during the three-year equivalence period.

4. For correlation purposes, relationships between monitoring methods will be tested during the three-year equivalence period. Data will be assessed and relationships developed after each year of $PM_{2.5}$ data collection. Relationships will be tested and refined as necessary in the following year(s).

5. Performance criteria for candidate methods will be developed during the equivalence period. Existing information on the relationships between reference and candidate methods, and variability of collocated data collected by identical reference samplers will be used to set performance criteria.

6. Jurisdictions will be required to report on their equivalence programs as part of reporting on the Principle Measure as varied.

4.4 AUDITING REQUIREMENTS

The objective of the auditing process is to assist the collection of comparable data during the collocation exercise. It is envisaged that the auditing process will contain the following elements:

1. The evaluation of detailed monitoring protocols maintained within each state to ensure consistency.

2. Nomination of a 'standard' laboratory that will be responsible for evaluating the comparability of samples collected by the jurisdictions. This laboratory must have a good appreciation of the field work and laboratory procedures associated with the methods.

3. The 'standard' laboratory will provide a series of blank and standard samples. These samples will be handled in accordance with the monitoring protocol to assess any discrepancies in sample handling that may affect the comparability of results. For statistical evaluation, at least three samples per jurisdiction are required per evaluation.

4. Personnel from the 'standard' laboratory would be required to visit the jurisdictions and associated laboratories to evaluate and discuss any problems that may arise.