National Environment Protection (Ambient Air Quality) Measure

Technical Paper No. 10

Collection and Reporting of TEOM PM_{10} Data

Prepared by the
Peer Review Committee

May 2001

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PREAMBLE

The National Environment Protection Measure (NEPM) for Ambient Air Quality was made in June 1998 with the desired environmental outcome of "ambient air quality that allows for the adequate protection of human health and well-being" across Australia. The NEPM sets national standards against which ambient air quality can be assessed. The NEPM includes a monitoring protocol to determine whether these standards are being met. Each jurisdiction is required to submit to the National Environment Protection Council (NEPC) a monitoring plan consistent with the protocol.

The Peer Review Committee (PRC) was established to assist NEPC in its task of assessing and reporting on the implementation and effectiveness of the NEPM by participating jurisdictions. The PRC includes government experts from all participating jurisdictions, in addition to representatives from industry and community groups. A significant activity of the PRC is the provision of advice to NEPC on the adequacy of jurisdictional monitoring arrangements, to ensure as far as possible that a nationally consistent data set is obtained.

To assure the consistency and transparency of its advisory function, the PRC has developed a set of guidance papers that clarify a number of technical issues in interpretation of the NEPM protocol. These Technical Papers provide the basis for PRC assessment of jurisdictional plans, aimed at assuring the quality and national consistency of NEPM monitoring.

The PRC Technical Papers are advisory for jurisdictions, and they will evolve with time as the science of air quality monitoring and assessment develops and as practical experience with monitoring increases.

M J Manton
Chair
Peer Review Committee

1. PURPOSE

The purpose of this technical paper is to provide guidance and procedures for the uniform recording, handling and reporting of Tapered Element Oscillating Microbalance (TEOM) PM_{10} data to ensure a nationally consistent implementation of the Ambient Air Quality – National Environment Protection Measure (AAQ NEPM) in Australia.

2. INTRODUCTION

The AAQ NEPM requires that uniform criteria be used when measuring and reporting ambient air quality. To satisfy this requirement the AAQ NEPM specifies methods for monitoring and requires quality assurance that will produce data using uniform criteria for the purpose of comparison to the standards.

The standard for particles as PM_{10} is specified in Schedule 2 of the AAQ NEPM as 50 $\mu g/m^3$ for a 1-day average. The ten year goal for maximum allowable exceedences is five days a year.

Clause 18 of the AAQ NEPM on reporting specifies that the annual report must include:

- An analysis of the extent to which the standards are, or are not, met; and
- The description of the circumstances which led to exceedences.

Clause 16 of the AAQ NEPM is about monitoring methods and specifies that

1) Subject to subclauses (2) and (3) the Australian Standard Methods set out in Schedule 3 should be used for monitoring pollutants in the air.
2) Where an Australian Standard Method has not yet been developed for a monitoring method, appropriate internationally recognised methods or standards may be used that provide equivalent information for assessment purposes.

Gravimetric methods of High Volume (with size selective inlet) and Dichotomous samplers are the two methods listed in Schedule 3 as Australian Standard Methods for monitoring particles as PM_{10}.

Schedule 2 of the AAQ NEPM also requires daily samples to be collected and analysed. Because of the labour-intensive nature of operation of High Volume (Hi-Vol) samplers and the reporting and other advantages of obtaining continuous measurements, TEOM samplers have almost universally been adopted by jurisdictions for measuring PM_{10}.

An Australian Standard for the TEOM was established in March 2001.

To increase the information available to the Peer Review Committee (PRC) on the treatment of the TEOM within the AAQ NEPM, Environment Australia commissioned two consultancies. The first consultancy involved a literature review of Australian and overseas comparative studies on TEOM and Hi-Vol sampler data. The second consultancy involved the analysis by CSIRO of existing data from collocated Hi-Vol and TEOM samplers. The results of the analysis are summarised in a report titled "Fine Particle Measurement Calibration Study Data Analysis." On 6 March 2001, Environment Australia sponsored a technical workshop on TEOM PM_{10} data handling to provide a forum for discussion of measurement of PM_{10} under the AAQ NEPM. Twenty-one people representing every State and Territory environmental agency, except NT, attended the workshop in Melbourne. Representation included experts in the field. Workshop participants included members of the PRC some of whom represent community environmental groups and industry. The purpose of this Workshop was to provide advice to the PRC on the use of the TEOM sampler for AAQ NEPM. This advice has been considered in drawing up this technical paper that forms the basis of handling the TEOM data in AAQ NEPM reporting.

For a monitoring method to be used for NEPM purposes, Clause 16 of the AAQ NEPM requires that the method provides equivalent information for assessment purposes. Statistical approaches (linear regression), such as the ones specified by the USEPA or the Australian Standard (AS), can be used to establish formal equivalence. Other criteria, which require the Hi-Vol and TEOM to have consistency in assessments at extreme concentration levels, in the number of exceedence days, and for individual events, could be used to establish formal equivalence between TEOM and Hi-Vol data. However, the PRC believes that for NEPM purposes the focus should be on the derivation of equivalent information from the TEOM. This technical paper therefore aims to establish how TEOMs can be used to generate equivalent information.

General aspects of data and reporting are covered in the National Environment Protection (Ambient Air Quality) Measure Technical Papers No. 5, "Data Collection and Handling" and No. 8, "Annual Reports for AAQ NEPM."

3. PARTICLE MEASUREMENT METHODS

The TEOM is an automated continuous particle monitor. The TEOM draws air through a hollow tapered tube, with the wide end of the tube fixed, while the narrow end oscillates in response to an applied electric field. The filter cartridge is at the narrow end of the tube. The sampled airflow passes from the sampling inlet, through the filter, to a flow controller. As particles are collected on the filter, the mass changes, resulting in a change of the oscillating frequency. Using the rate of mass accumulation on the filter and the flowrate through the sample (main) flow controller, the TEOM's microprocessor calculates the mass concentration. The flowrate through the sample filter is set at a nominal 3.0 litres per minute (L/min). A bypass (auxiliary) flow is used to provide an additional 13.67 L/min for a total flowrate of 16.67 L/min, the design flow of the size selective inlet.

Hi-Vol sampling is a gravimetric method. The Hi-Vol with a size selective inlet draws a large volume of air through a pre-weighed and conditioned sample filter over a day (a 24-hour period). The mass of collected particles is determined gravimetrically. The operating conditions are specified by Australian Standard AS 3580.9.6-1990. Samples are collected at ambient temperature and returned to the laboratory for conditioning to pre-sampling weighing conditions of 20°C and about 50% relative humidity. In Winter, average daily temperatures are often significantly lower than 20°C (around 10°C) and some volatiles are likely to be lost either due to changes in ambient conditions post-sampling or during conditioning in the laboratory prior to final weighing. However, Hi-Vols can produce reliable estimates of daily PM_{10}, providing that proper quality assurance and quality control procedures are implemented. The reproducibility of Hi-Vol data is considered to be good.

To minimise the contribution of liquid water to measured particle mass, the TEOM analyser conditions the incoming sample aerosol to 50°C prior to and during its measurement. This is the main difference between the two methods, as the Hi-Vol samples at ambient temperatures. The heating to an above-ambient inlet and sampling temperature, set at 50°C by the Australian Standard, can cause the loss of some volatile and semi-volatile species. The TEOM therefore has been shown to produce 24-hour average particle concentrations that can be significantly different from those data produced by the Hi-Vol, in particular when the ambient temperature is low during Autumn and Winter. The TEOM appears to provide a good measurement of PM_{10}, consistent with Hi-Vol data, during the warmer Spring and Summer months or when the aerosol is less volatile.

4. QUALITY ASSURANCE

The TEOM method and the operating conditions are described in Australian Standard, AS 3580.9.8-2001 (Method 9.8: Determination of suspended particulate matter – PM_{10} continuous direct mass method using a tapered element oscillating microbalance analyser). AS 3580.9.8, specifies that:

- Measurements should be reported at standard temperature and pressure conditions of 0°C and 101.3 kPa respectively.
- Ambient air is drawn through the inlet at a constant flow rate of 16.7 L/min.
- The main flow is adjustable and should be maintained at 3.0 ± 0.1 L/min. Under some conditions, the main flow rate can be operated at 1.0 ± 0.1 L/min.
- For sampling conditions, the mass transducer temperature, the base-of-air-inlet temperature and the preheated sample temperature should all be 50°C.

The TEOM analyser should be operated according to AS 3580.9.8-2001 and the instrument operating manual. The Australian Standard specifies that the TEOM should be operated with the empirically established adjustments which gained the instrument equivalence to the USEPA reference method. More complete quality assurance and data quality assessment procedures for the TEOM (and the Hi-Vol) can be found in USEPA documents such as Code of Federal Regulations, 40 CFR Part 58, Appendix A. Additional detailed quality assurance procedures and guidance are provided in USEPA's Quality Assurance Handbook for Air Pollution Measurement Systems, Volume II. Daily, weekly, biweekly, semiannual, annual and biennial maintenance checks are detailed in this handbook.

Each agency must develop a quality assurance system to ensure provision of data of adequate quality and to avoid loss of air quality data due to malfunctions. All quality assurance and quality control procedures implemented during the data collection, analysis, and reporting phases must be suitably documented.

Where collocated samplers are used, the two collocated samplers must be within 4 metres of each other, and at least 2 metres apart to preclude airflow interferences. Collocated sampling and comparative studies need to be conducted according to a strict quality control system. Independent auditing should be part of the requirements for data quality assessment. The monitors should be audited several times per year as required in the 40 CFR Part 58.

5. RELATIONSHIP BETWEEN THE TEOM AND HI-VOL

There are uncertainties in both techniques, and the accuracy of each method should be taken into account in assessments.

Operating conditions that affect the measurements of the TEOM and Hi-Vol include:

- Filter type;
- Time delays in Hi-Vol filter analysis (loss of volatiles while filters are left in the sampler for up to six days before collection and then while filters wait in the laboratory for weeks to be analysed);
- Filter handling;
- Cleanliness of the inlet (how frequently the sample inlet is checked and cleaned);
- Flow rate calibration and maintenance checks;
- Humidity control.

Siting and exposure are additional important factors. In particular, the distance between the samplers for comparative studies should be small enough (within 4 metres) to ensure similar exposure for both samplers.

For the TEOM in Australia, the empirical US corrections and in particular the heating of the inlet to 50°C which leads to loss of volatiles are other operational parameters which impact significantly on the measurements.

The relationship between the TEOM and the Hi-Vol measurements is sensitive to operating conditions, environmental conditions (meteorology, wind, temperature, and seasonal effects) and aerosol composition. The aerosol composition is considered to be the main determinant of discrepancies between Hi-Vol and TEOM measurements. The temperature effect is due to the effect of aerosol composition. In winter, on cold days in places where wood fires are used for heating, the TEOM underestimates the PM_{10} level significantly. Where additional data are available on these occasions, they show a high ratio of $PM_{2.5}$ to PM_{10}; contributions from semi-volatiles which are mostly in the $PM_{2.5}$ size range are significant on such occasions.

The contributions to particle mass measurements from wood smoke vary from place to place. The contribution can be as much as 90% in Launceston, but is much less in Melbourne. Assuming wood smoke is the main source of volatiles lost in TEOM measurements, there are difficulties in finding one adjustment factor from the TEOM to the Hi-Vol that would be universally applicable throughout Australia.

It is considered that subject to differences due to volatiles both the TEOM and the Hi-Vol measure the same PM_{10} levels. Dealing with loss of volatiles by the TEOM would enable provision of equivalent information from both instruments. The means of establishing equivalent information is seen as the key issue in using the TEOM within the AAQ NEPM process, rather than establishing formal equivalence of the TEOM and Hi-Vol samplers.

The CSIRO study involved data from seventeen sites across Australia where TEOM and Hi-Vol instruments were operated in parallel for some years. The study found:

- Systematic differences between TEOM data and collocated Hi-Vol data were evident in several of the available data records. The controlling meteorological variable was found to be the ambient temperature.
- For daily mean temperatures below about 15°C the TEOM showed an increasing (essentially linear) tendency to underestimate the PM_{10} level determined by the Australian Standard Hi-Vol method.
- The increasing discrepancy with decreasing ambient temperature could be ascribed to two main factors:
    1. The lower the ambient temperature, the larger the temperature rise required to bring the sample air to the 50°C TEOM measurement temperature, providing a greater driving force for loss of aerosol material by volatilisation; and
    2. The lower the ambient temperature the greater the contribution to ambient particle loading of domestic wood smoke emissions, which are known to contain semi-volatile organic material.
- During the warmer months, the TEOM mostly provided measurements comparable to Hi-Vol, with a tendency for the TEOM to provide slightly higher PM_{10} measurement than the Hi-Vol; this could be due to the empirical US corrections built into the TEOM.

These are all inter-related factors. Overall, temperature was considered to be the best variable for capturing the impact of environmental conditions.

In the TEOM measurement system operational conditions aim at eliminating significant particle measurement bias due to condensed water, in particular humidity reduction is achieved by heating the sample air to an above-ambient temperature, usually 50°C. Dehumidifying is considered to be an alternative as the effect of increasing the temperature on the volatility of semi-volatile organics is significant. A new sample equilibration system which incorporates a Nafion dryer is being tested.

The empirical corrections built into the TEOM, which were established at the time it was granted equivalence in the US are an integral part of the TEOM used in Australia. There are some concerns that the empirical factors developed for the US conditions may not apply to Australian conditions.

In conclusion, the CSIRO study shows that ambient temperature can be used to adjust TEOM data to provide a nationally consistent picture of PM_{10} levels. Using all PM_{10} data from collocated Hi-Vol and TEOM samplers in Australia, a linear temperature adjustment varying from 0 to 40 % was derived (Attachment 1). Such an adjustment could be used in removing bias nationally. The outcome would be a nationally uniform variance with possible underestimation in some regions and overestimation in others.

6. OPTIONS FOR TREATMENT OF TEOM DATA IN AAQ NEPM REPORTING

When TEOM and Hi-Vol measurements are compared, it is generally found that there are differences, and these differences are the basis for concern about the ability to generate equivalent information from TEOM samplers. Although the Hi-Vol is treated as the Standard in such comparisons, there is no reason to assume that the Hi-Vol is inherently a more accurate method than the TEOM. In the context of the results from the CSIRO analysis of the existing Australian collocated monitors, four options for the treatment of the TEOM data were considered by the PRC. Since all of the options have drawbacks, selection of the best option involved careful evaluation of various advantages and disadvantages.

The four options are discussed below, highlighting the positive and negative aspects of each one.

Option 1

Collocate TEOMs with Hi-Vols, develop and apply site-specific adjustments to TEOM PM_{10} *data.*
The operation of collocated TEOM and Hi-Vol samplers should allow a site-specific adjustment to be made to TEOM data to obtain equivalent information for the AAQ NEPM. Collocation is required until a consistent site-specific relationship between Hi-Vol and TEOM data is obtained. It is necessary to operate under a strict quality assurance program and cover all seasons and weather conditions. A statistically robust number of samples (at least 100) is required to develop a site-specific adjustment. The measurements should span at least one year. Where there is known to be large inter-annual variability, several years of data will be necessary. The conditions in which the adjustments are significant should be well represented. In general, the Hi-Vol could be operated on the normal cycle of one day in six. However, more frequent sampling would be desirable to reduce the length of period for collocated operation. The established relationship can be translated to other sites with comparable sources and meteorology.

Perceived advantages:

- This approach deals with the bias directly and should provide the most robust estimate of PM_{10} levels.
- Data credibility and public confidence in the data will be high.
- Use of site-specific adjustment factors could effectively reduce site-to-site variations in bias and reduce errors in trends and compliance assessments
- Collocated monitoring should result in quality-assured comparative data sets.

Perceived disadvantages:

- Collocated operation is expensive, and quantitative determination of site-specific factors is difficult because of the variations observed under different environmental and emission conditions.
- Implementation of site-specific adjustment factors is not straightforward. Each jurisdiction will need to analyse the collocated data to demonstrate to the PRC that
  - the sampling period is sufficiently long to ensure that statistically-robust estimates can be made;
  - the adjustment factor is statistically well-founded;
  - the adjustment factor accounts for the known properties of the local aerosol; and
  - the adjustment factor accounts for the local meteorology.

<u>Option 2</u>

Adjust the TEOM PM_{10} data with a national temperature adjustment
From the analysis results of all available collocated TEOM and Hi-Vol data in Australia, CSIRO derived a single adjustment factor as a first step towards national harmonisation of TEOM and Hi-Vol PM_{10} data (Attachment 1). It appears that a linear temperature adjustment applied to the TEOM PM_{10} data would provide a nationally-consistent means for removing the bias.

Perceived advantages:

- It is important to make an attempt to correct for the known bias even when the site-specific relationship between Hi-Vol and TEOM is not known.
- The application of a national adjustment factor based on the aggregated data results in essentially zero bias across the range of temperatures experienced in Australia.
- This option would be more acceptable to the Community at large than no adjustment in view of the observed underestimation by the TEOM relative to the Hi-Vol.
- This approach should result in more accurate compliance assessments than the use of unadjusted TEOM data.

Perceived disadvantages:

- Since biases are site-dependent, factors developed on a nationwide basis would not be accurate. The impact of a national adjustment factor will vary from site to site, resulting in underestimation in some regions and overestimation in others.
- The adjustment factor is based on bias of the TEOM relative to the Hi-Vol rather than on its absolute error.
- Adjustments to TEOM data might undermine the confidence in the performance of the TEOM sampler.
- If the TEOM sampler bias relative to that of the Hi-Vol is effectively reduced with an appropriate adjustment factor, there could be less incentive for further improvement or redesign of the TEOM sampler to address the problem, which should be the ultimate goal.
- As experience and new data lead to better understanding and more refined adjustment factors, further adjustments or changes may need to be applied.

<u>Option 3</u>
As an interim measure, apply to the TEOM PM_{10} data a factor, such as 1.3 or 1.4, to make TEOM measurements comparable with Hi-Vol measurements, particularly in the critical range of concentrations around the NEPM standard.

This method has been used in UK as an interim measure.

Perceived advantages:

- This is a conservative approach and maximises protection of public health with an adequate margin of safety.
- This approach would be reassuring to the public, as underestimation of exceedences of the standard will be minimised.

Perceived disadvantages:

- A blanket application of such an adjustment is considered inappropriate as the whole distribution of the measurements is distorted, and the TEOM method is unjustifiably undermined with the application of an adjustment that is not justified.
- The method is too simplistic.

Option 4

Report and use TEOM data without any adjustments but clearly distinguished as "TEOM data" and provide an explanation of uncertainty and accuracy of the method.

In this approach, all validated PM_{10} data are used at face value, just as are data for other pollutants. All PM_{10} and other pollutant measurements have uncertainty, and where possible this uncertainty should be quantified. Over the last several years, PM_{10} data have been collected with Hi-Vols and Dichotomous samplers. Significant differences between the measurements from different samplers and from earlier and later versions of the same sampler were identified in field studies. In particular, there was awareness of the loss of volatiles by the Hi-Vol but no adjustments were applied. Instead, various improvements have been incorporated into the design and operation of the monitor resulting in reduced uncertainty.

Perceived advantages:

- It is consistent with the approach to other pollutants and methods. The TEOM method is (since March 2001) an Australian Standard method just like the Hi-Vol method.
- It encourages and anticipates improvements in the method, which should result in further reductions in the bias. For example, pursuing avenues, such as use of nafion dryer or reduced inlet temperature are likely to reduce the uncertainty of the TEOM measurements.
- It supports the view that since the relative differences in the measurements provided by the two instruments cannot be estimated accurately, adjustments should not be applied. Moreover, the Hi-Vol sampler too has a problem of losing volatiles (even though not to the same extent), but Hi-Vol data are never corrected.
- In the absence of a well-established and quantified relationship between the TEOM and Hi-Vol data it is better to avoid complications of simplistic adjustments to the data.
- This approach is simple to implement and requires no change in current practices.

Perceived disadvantages:

- This approach ignores the known relative differences in the measurements provided by the TEOM and the Hi-Vol, and reporting TEOM data without adjustment may not be acceptable to the broad community.
- This approach may be seen as a failure to deal with the known bias problem.
- Where differences exist between the TEOM and Hi-Vol data, replacing one sampler with another at a site may lead to erroneous trend analysis.
- This approach could cause an erroneous compliance assessment.

7. RECOMMENDED OPTIONS

The PRC believes that the disadvantages of options 3 and 4 outweigh the advantages, and so they are considered inappropriate for NEPM purposes. Note, however, that where volatiles form an insignificant proportion of PM_{10}, option 2 becomes the same as option 4.

Options 1 and 2 are seen to provide acceptable courses of action for NEPM purposes. Option 1 is the preferred option, but where it is not feasible, option 2 is to be used.

The recommendations are summarised below:

1. *Wherever possible, TEOM PM_{10} data should be adjusted through the application of a site-specific adjustment based on collocated TEOM and Hi-Vol measurements.*

2. *When a site-specific adjustment is not available and the TEOM site is known to experience a significant contribution from volatiles, TEOM data should be adjusted by the CSIRO temperature adjustment which provides a nationally consistent basis for the removal of bias due to the loss of volatiles. The temperature adjustment computed by CSIRO using the data from WA, Vic and NSW is described in Attachment 1. In applying this adjustment, the TEOM data are multiplied by a factor which varies linearly from 1.4 at daily mean temperatures less than or equal to 5°C, to 1.2 at 10°C and 1 at temperatures equal to or greater than 15°C.*

It is important that the physical basis of the adjustments applied by jurisdictions is understood and, where necessary, justified. Following are some decisions and guidance to assist with the implementation of these recommendations.

- Jurisdictions are to identify the sites with existing collocated PM_{10} data, develop the relationships between the TEOM and Hi-Vol PM_{10} measurements, and submit appropriate adjustment factors to the PRC.
- The PRC is to review and where appropriate approve the adjustments proposed or used by jurisdictions to ensure a consistent approach.
- The PRC, together with jurisdictions, will also determine the sites where site-specific factors can be translated.
- Site-specific relationships would be in terms of environmental conditions and emissions.
- In translating to other sites, similarities in sampling conditions (e.g., meteorology, PM_{10} emissions, and particle size distribution) are to be considered in determining the applicability of an adjustment factor.
- The national temperature adjustment is not required in regions where volatiles do not contribute significantly to the particle measurements. Jurisdictions should justify this course of action on the basis of emissions.

8. DATA HANDLING AND REPORTING

The purpose of establishing equivalence between the TEOM and Hi-Vol measurements was to produce air quality data based on uniform criteria for comparison to the standards for compliance assessment.

General requirements on data validation, data handling and reporting are specified in Technical Papers No. 5, "Data Collection and Handling" and No. 8, "Annual Reports for AAQ NEPM," and in the documents given under "Quality Assurance." Additional requirements and comments specific to the TEOM are included here.
Technical Paper No. 5 recommends that, as a minimum requirement, daily PM_{10} data should form the basis of the NEPM data set. Provision of hourly TEOM PM_{10} data is an optional addition. The following points were considered in deciding on the treatment of TEOM data in the NEPM data set.

- Adjustment factors derived from analysis of daily data may not be valid for hourly averages;
- The AAQ NEPM standard is for daily, not hourly, PM_{10};
- Hourly data are reported in real time; particularly on pollution days, accurate description and consistency with the actual data in the database, are desirable;
- The diurnal pattern could be suppressed if adjustments are applied to daily, rather than hourly data.

Recommendations:

- As a minimum requirement, for NEPM reporting, adjustments should be applied to validated daily (24-hour) averages. The AAQ NEPM data set should consist of adjusted daily averages.
- In addition to daily averages, it is optional for jurisdictions, to apply adjustments to validated hourly data, and make available the validated adjusted hourly averages. For consistency, the adjustment computed for the 24-hour average based on the daily average temperature should be applied to the individual hourly data for that day. It should be emphasised that the adjustment factor has been derived using daily averages of PM_{10} concentrations and temperatures and the validity of this approach has not yet been established.
- Where adjustments are applied, it should be clearly stated that TEOM data are the "adjusted TEOM data," and the raw data set (unadjusted TEOM data) should also be archived and available.

These recommendations are consistent with the Australian Standard which specifies that "…if the application of derived empirical factors to TEOM data is to be employed, it shall be made post-sampling and shall be clearly identified as derived data."

9. SUMMARY AND CONCLUSIONS

After careful consideration of various options, the PRC decided that for NEPM purposes, validated TEOM PM_{10} data need to be adjusted in an attempt to reduce or eliminate the observed tendency of the TEOM to underestimate the PM_{10} levels relative to those derived by Hi-Vol when a significant fraction of particles are volatile. Adjustment factors have to be established based on comparative data. Use of site-specific adjustment factors would be more effective in dealing with the differences, but in the absence of site-specific adjustment factors, use of a national adjustment factor is recommended in regions where a significant fraction of particles are volatile.

This technical paper will need to be reviewed in the light of future developments. The process of establishing equivalence and adjustment factors is ongoing and evolving. Experience and additional data may lead to changes or refinements to the adjustment factors. In addition, improvements to the TEOM method which will reduce uncertainty, are likely. In the interim, the recommendations of this technical paper should provide more accurate compliance assessments for NEPM reporting.

ATTACHMENT 1

(EXTRACT FROM (EDITED APPENDIX OF) THE CSIRO ATMOSPHERIC RESEARCH, G.P. AYERS, M. EDWARDS AND J.L. GRAS REPORT TO ENVIRONMENT AUSTRALIA "FINE PARTICLE MEASUREMENT CALIBRATION STUDY DATA ANALYSIS," APRIL 2001)

The analysis presented in the body of the report suggests that a first step towards national harmonisation of TEOM PM10 data and Hi-Vol PM10 data could be made by defining a single, temperature-dependent TEOM adjustment factor to be applied to all 24-hour averaged TEOM data at temperatures below 15ºC. In principle such an adjustment procedure should be tailored to the specific aerosol composition encountered in different climatic and geographic regions, as suggested in the Phase A report. However as noted earlier in this report, the currently available collocated TEOM and Hi-Vol datasets are too few in number and contain "noise" at levels that do not justify such a detailed approach at this time. In the future, as additional collocated records from new locations across the country become available, a breakdown into regionally-specific adjustment factors may be possible.

At this stage we employ the available WA, Vic and combined-NSW datasets (Figures 11, 12 and 25) to deduce a single adjustment factor. Each dataset is given equal weight by fitting a linear adjustment factor separately, with the results averaged to give a single, overall value. The fitting procedure involved minimising for each dataset the sum of the absolute differences of Hi-Vol minus corrected TEOM values for each pair of measurements made at a daily mean temperature below 15ºC. The minimisation involved adjusting the TEOM adjustment constant K, with the multiplicative TEOM adjustment factor defined as 1 + K(15-T), where T is daily mean surface temperature in ºC. Daily mean temperature is computed from 24 hourly mean temperatures. Fitted values of K were 0.054, 0.040, 0.031 respectively for the WA, Vic and combined-NSW datasets, yielding an average value of 0.042, which we round off to 0.04. Thus the multiplicative TEOM adjustment factor varies linearly from 1.4 at 5ºC, to 1.2 at 10ºC and 1 at ≥15ºC.

The adjustment factor can be described as:

Adjustment	Temperature range
1	$T \geq 15°C$
$1 + 0.04(15 - T)$	$5°C < T < 15°C$
1.4	$T \leq 5°C$

Adjustments in the range 0 – 40% are consistent with results from relevant comparative studies carried out overseas.

Figure A1 illustrates the effect of this first-order adjustment on the individual data points in the Vic record, while Figure A2 shows the effect on the mean temperature-dependencies of the three available datasets.

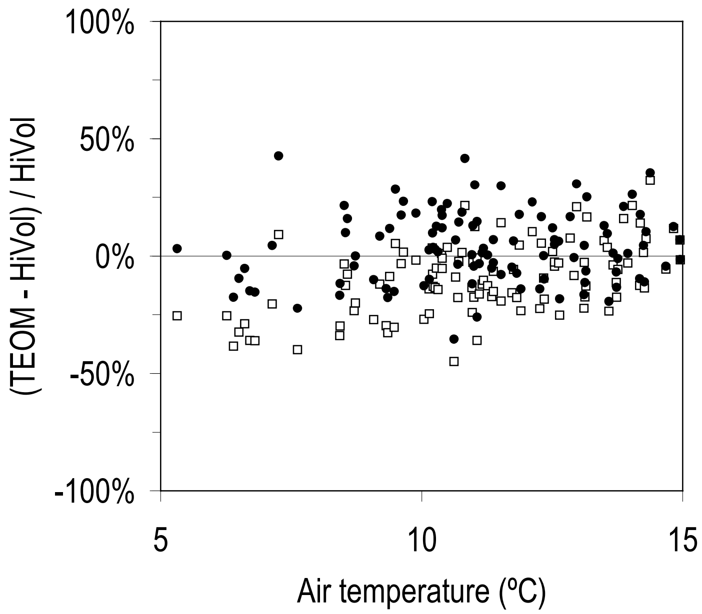
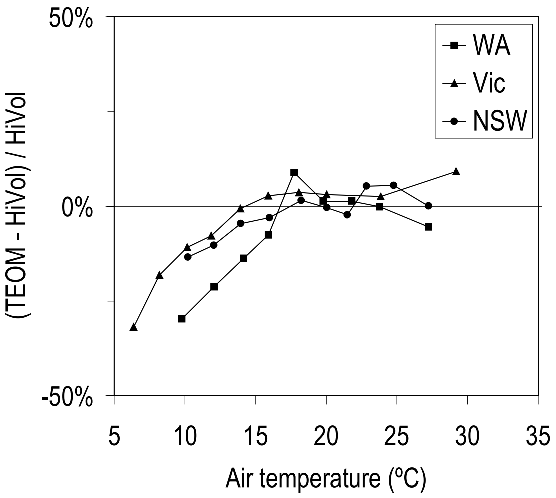


Figure A1. Temperature dependence of unadjusted and adjusted Hi-Vol – TEOM differences, Vic dataset; unadjusted data - open squares; adjusted data - closed circles.



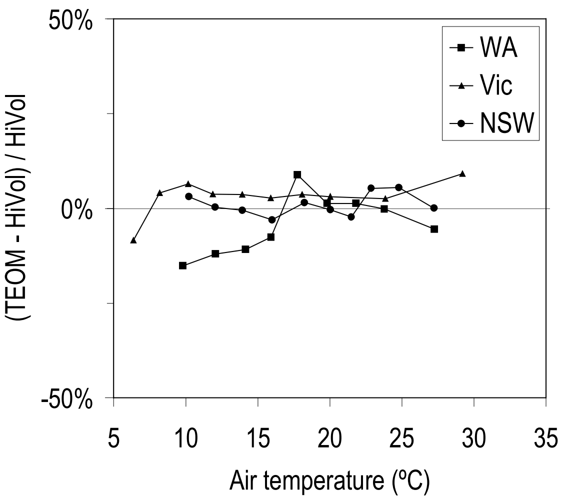


Figure A2. Mean temperature dependence of unadjusted (top) and adjusted (bottom) Hi-Vol – TEOM differences (note expanded vertical scale).