PM2.5 Average Exposure Index

A critical review of the calculation of the index and comparison with the national exposure reduction target.

Report for Defra and the Devolved Administrations

AEAT/ENV/R/3241
ED57002030
Issue Number 1
Date 01/12/2011

Customer:

Department for Environment, Food and Rural Affairs, Scottish Government, Welsh Assembly Government and the DoE in Northern Ireland

Customer reference:

RMP 4961

Confidentiality, copyright & reproduction:

AEA reference:

ID: AEAT/ENV/R/3241

Ref: ED57002030- Issue Number 1

Contact:

Brian Stacey
AEA Technology plc
Gemini Building, Harwell, Didcot, OX11 0QR
t: 0870 190 6571
e: brian.stacey@aeat.co.uk
AEA is a business name of AEA Technology plc
AEA is certificated to ISO9001 and ISO14001

Author:

Brian Stacey

Approved By:

Rachel Yardley

Date:

01 December 2011

Signed:

R E Yardley

Executive summary

The EC Directive 2008/50/EC on ambient air quality and cleaner air for Europe places a requirement on Member States to assess and reduce population exposure to concentrations of $PM_{2.5}$ by 2020. The magnitude of the required reduction depends on national average concentrations between 2009 and 2011.

For the UK, from the 47 $PM_{2.5}$ stations used in this assessment, it is likely that average $PM_{2.5}$ concentrations for 2009-2011 will be between 13-14 µg/m^3. This would require the UK to comply with a 15% reduction target for 2020, equating to a required reduction in average concentrations of around 2.0 µg/m^3.

AEA has undertaken an assessment of the factors that are likely to make a contribution to the uncertainty of measurement of $PM_{2.5}$, both now and in 2020.

Measurement of the AEI for the period 2009-2011 is likely to yield a result with an uncertainty in the order of ±0.2 µg/m^3.

Measurement of the AEI for the period 2018-2020 would normally carry a similar level of uncertainty, but the comparability of this measurement to the value for 2010 will be affected by a number of uncontrollable factors: meteorology, new analysers, service and maintenance, variability in analyser performance and changes to the Reference Method[1] could all play a significant part in compromising the robustness of any comparisons between 2010 and 2020 AEI values.

AEA has estimated that, depending on changes in conditions between now and 2020, the scale of this uncertainty could be between ±2.5 and 8.6µg/m^3. Neither of these results would produce data with a low enough uncertainty to robustly assess a required reduction of 2.0 µg/m^3 in $PM_{2.5}$ concentrations by 2020.

It is possible therefore that the $PM_{2.5}$ exposure reduction target set in 2008/50/EC may not be measurable with sufficient confidence.

[1] prEN12341:May 2011 – Ambient Air Quality - Standard Gravimetric Measurement Method For The Determination of the PM10 and PM2.5 Mass Fraction Of Suspended Particulate Matter, CEN TC264 WG15. NOT FOR PUBLICATION.

Table of contents

1 Introduction

As part of the EC Directive 2008/50/EC on ambient air quality and cleaner air for Europe[2], Member States are required to undertake measurements of $PM_{2.5}$. This Directive, known as the Air Quality Directive requires Member States to make measurements of $PM_{2.5}$ over a ten year period. Member States are required to determine a national average concentration (the Average Exposure Index - AEI), which is then used to determine a national exposure reduction target (NERT) in AEI for 2020. Measurements have to be made at background locations and reported either for the periods between 2008-2010, 2009-2011 (or exceptionally, 2009-2010). This calculated 2010 AEI will be compared to a 2020 AEI which will be calculated from measurements made between 2018-2020

There are a number of significant challenges associated with these requirements. Using a broadly GUM[3]-based assessment of the contributing components, these are summarised below:

1. The performance of the analysers used to establish the AEI.
2. The uncertainty of the analyser measurements individually and in combination to form the AEI itself.
3. The effect of changing analysers/maintenance on performance.
4. The possible effects of different meteorology during the two AEI assessment periods.
5. Changes in analyser performance with respect to the PM Reference Method[4] (RM), or any effects of changes to the RM itself.
6. The magnitude of the required reduction and whether any measured reductions can be identified as real or significant.

This review will examine these challenges and possible consequences in an attempt to answer the fundamental question:

"Can any measured change in the AEI between 2010 and 2020 be reliably attributed to a genuine reduction in PM, or is the method unsuitable given the variables associated with making the measurements?"

The UK Automatic Urban and Rural Network (AURN) has deployed Thermo Filter Dynamic Measurement System (FDMS) automatic analysers at AEI sites. This analyser allows near real time measurement of PM to be undertaken and has demonstrated equivalence to the Reference Method. The exact number of sites established and their locations was determined following a comprehensive assessment of the requirements of the Directive[5].

[2] EC Directive 2008/50/EC on ambient air quality and cleaner air for Europe http://ec.europa.eu/environment/air/quality/legislation/existing_leg.htm
[3] Guide to the Expression of Uncertainty in Measurement, ISO, JCGM http://www.iso.org/sites/JCGM/GUM-JCGM100.htm
[4] BS EN14907:2005 – Standard Gravimetric Measurement Method For The Determination of the PM2.5 Mass Fraction Of Suspended Particulate Matter, CEN TC264 WG15. www.bsigroup.com
[5] http://uk-air.defra.gov.uk/reports/cat09/1101181027_Prelim_rpt_for_CAFE_(8).pdf

2 The Average Exposure Index – what it is and how to calculate it

The AEI is an averaged $PM_{2.5}$ concentration, taken from 47 AURN background sites and averaged over a three year period between 2009 and 2011. The sites used for this calculation are presented in Annex I.

The Air Quality Directive requires Member States to calculate the AEI and use this to determine the required reduction target, to be achieved when comparing the 2009-2011 result to a period between 2018-2020. Annex XIV of the AQD sets out the required reduction targets as follows:

Table 1 – National exposure reduction target

Initial concentration (µg/m^3)	2020 reduction target (%)
< 8.5 = 8.5	0%
> 8.5 - < 13	10%
= 13 - < 18	15%
= 18 - < 22	20%
> 22	All appropriate measures to achieve 18 µg/m^3

For the UK, the AEI has been estimated, together with the likely required reduction target, using ratified $PM_{2.5}$ data for 2009 and 2010, together with provisional data for January to July 2011, this is presented in the table below:

Table 2 – Estimated UK AEI, Jan 2009 to Jul 2011

UK AEI, Jan 2009 - Jul 2011	Likely exposure reduction target
13.6 µg/m^3	15% (2.0 µg/m^3)

If this AEI value is confirmed in the fully ratified dataset, the UK will need to reduce average concentrations of $PM_{2.5}$ by 2.0 µg/m^3 by 2020.

From a Quality Assurance and Quality Control perspective, there is an additional important question to ask:

Is the measurement of the AEI values in 2010 and 2020 sufficiently robust to identify any differences in measurement as valid changes in concentrations, or are the uncertainties too large to permit this?

In order to answer this question, all the contributors to the calculations need to be investigated.

3 Uncertainty Contributions

There are many individual components that could possibly contribute to the overall uncertainty of measuring the AEIs. The following list presents a comprehensive (though by no means exhaustive) list of the main areas to consider:

1. Analyser measurement uncertainty
2. Combining analyser uncertainties into AEI
3. Effect of meteorology on measured concentrations
4. Effect of analyser maintenance
5. Effect of analyser replacement
6. Relationship between automatic and manual methods
7. Changes to Reference Method
8. Relocation of monitoring stations

Each component and its associated uncertainty (at the level of the UK AEI (13.6 µg/m^3)) is assessed in the following sections.

3.1 Analyser measurement uncertainty

As noted earlier, the AURN uses the Thermo FDMS analyser for determination of the AEI. The analyser has been extensively tested[6] in UK trials, with many different sample dryer configurations, to demonstrate equivalence to the Reference Method. These tests are summarised below:

Table 3 – Results of FDMS equivalence trials

Instrument type ($PM_{2.5}$)	Calibration factor	Calibration offset (µg/m^3)	Standard Uncertainty
FDMS (B)	1.036	-1.46	8.2%
FDMS (BB)	0.943	-0.28	7.25%
FDMS (CB)	0.932	+0.77	4.4%*
FDMS (C)	0.852	+2.65	8.35%

*Should be interpreted cautiously as based on a relatively small dataset

The quoted standard uncertainties in Table 3 are the product of at least 40 days monitoring trials, using duplicate candidate methods and duplicate RM samplers. Uncertainties are calculated using guidance provided in the Guide to Demonstration of Equivalence (GDE)[7].

There is a mixture of drier types in use on the network with B, BB, and CB equipped FDMS analysers in use in the UK. For the purposes of this AEI evaluation, the worst case, the B analyser, will be used in all calculations.

[6] UK Particulate Matter Equivalence Trials Data Re-Processed In Accordance With The January 2010 Version of the Guide To Demonstration of Equivalence (GDE). Bureau Veritas, September 2010
[7] Guide to the Demonstration of Equivalence of Ambient Air Quality Monitoring Methods, January 2010, http://ec.europa.eu/environment/air/quality/legislation/pdf/equivalence.pdf

The requirement for measurement uncertainty in 2008/50/EC is ±25%. All of the FDMS analysers fulfil this criterion.

3.2 Combining measurement uncertainties

There are 47 analysers in the UK that will be combined to provide the AEI for 2010 and 2020. The process of combining the averages from 47 analysers will markedly reduce the uncertainty of the averaged concentration.

It is standard statistical practice to combine the individual uncertainties by dividing the uncertainty by the square root of the number of analysers.

If it is assumed the B dryer is used throughout the network *and there are no significant changes that affect analyser performance*, the calculation is as follows:

AEI uncertainty = 8.2 / $\overline{\quad}$ = 1.20% (±0.2 ug/m^3) (var 1)

Where:

8.2 is the standard uncertainty of measurement of the FDMS (B) in the equivalence trials

47 is the number of sites used for the AEI comparison

Therefore for Jan 09 to Jul 11, the AEI would be 13.6 $\mu g/m^3$ ±1.20% (±0.2 ug/m^3).

Assuming the same instrumentation is in place for the 2018-2020 assessment, the calculation would be identical.

3.3 Effect of meteorology on measured concentrations

It is possible that extremes of temperature and high winds have a significant effect on PM concentrations. According to a report by RIVM in The Netherlands[8], meteorology could contribute to annual mean concentrations by up to 9%.

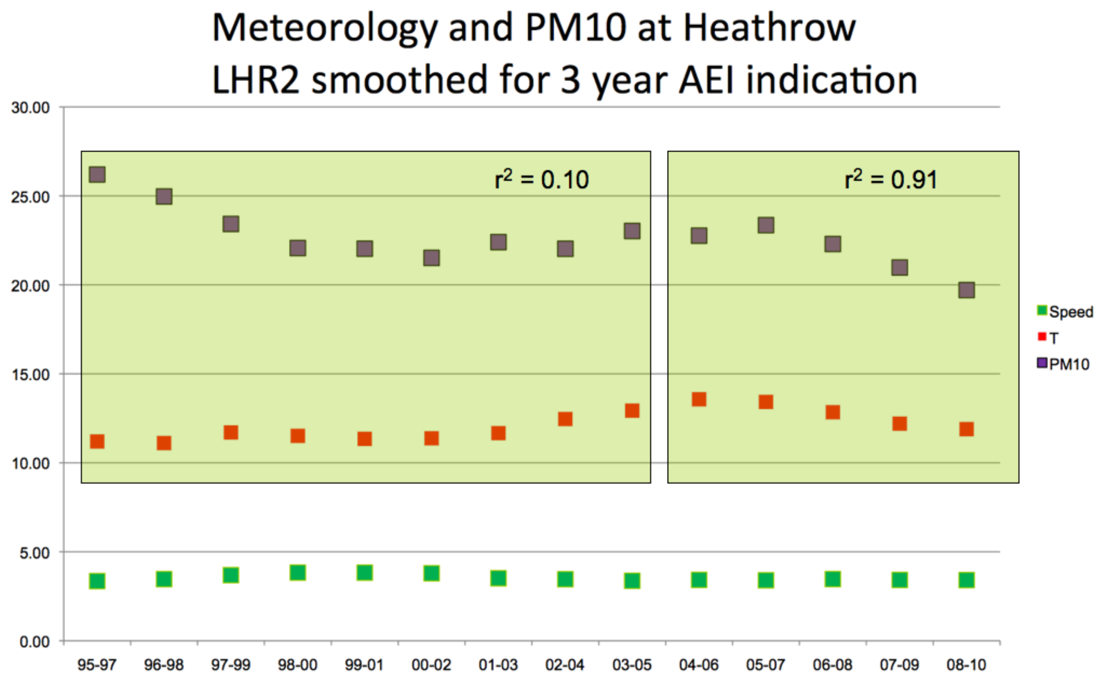
If this assumption is true, at the current AEI concentration (13.6 $\mu g/m^3$), the contribution of meteorological variation to the 2020 AEI could be:

$13.6 * 0.09 = 1.2\ \mu g/m^3$ (var 2)

Using data from a long term monitoring station at Heathrow Airport, owned by BAA, but operated and managed by AEA, it is possible to examine the relationships between PM, temperature and wind speeds over a long period of time[9]. The plot below examines these relationships:

[8] Attainability of $PM_{2.5}$ air quality standards, situation for the Netherlands in a European context, RIVM, Report number 500099015. www.**rivm**.nl/bibliotheek/rapporten/500099015.pdf

[9] Data from Heathrow LHR2 monitoring station generously provided for this investigation by David Vowles and Mark Tomkins at Heathrow Airport Limited – email correspondence, 11 August 2011



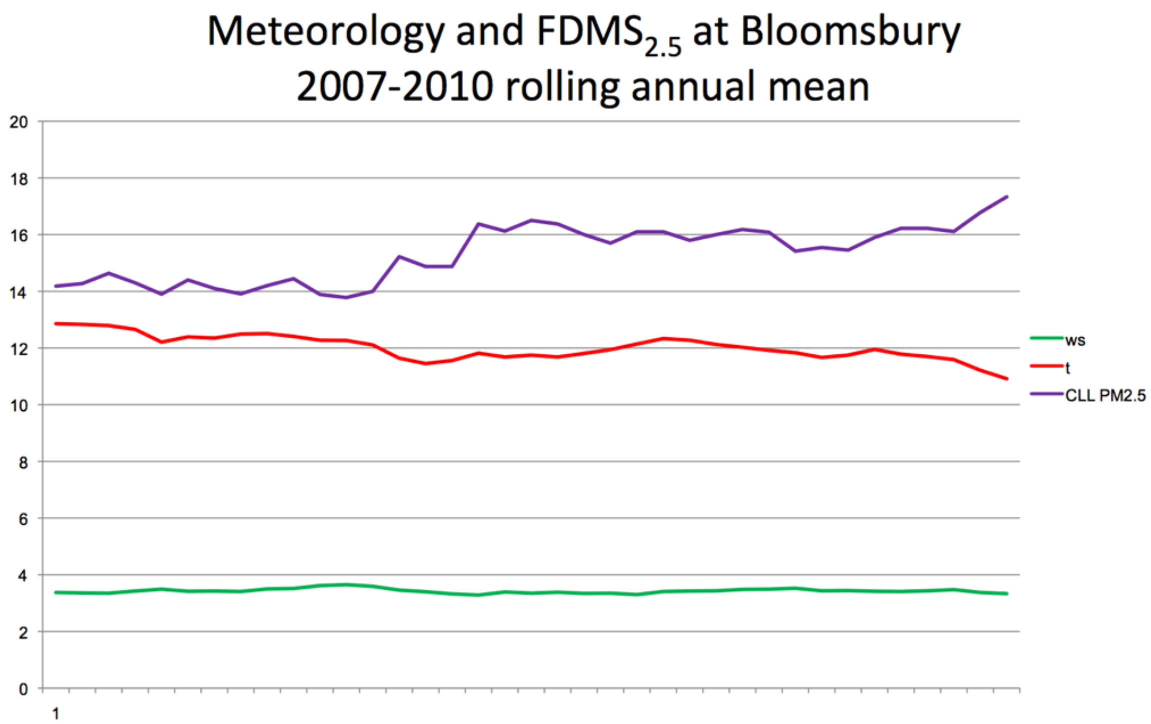
Each point on the plot represents a 3 year averaged value for PM_{10}, wind speed or temperature. The PM_{10} data throughout the entire period is collected from an unmodified TEOM analyser.

It is clear from the plot that average wind speed has not shown any obvious trend in the last 15 years, so any comparison with changing PM_{10} concentrations will be difficult.

It is possible to examine the relationship between PM_{10} and temperature, as both show some variance over time.

It is fair to say that up until about 2005, the correlation between PM and temperature was very poor. There is no obvious identifiable relationship between the measurements. After 2005, there is much better correlation. PM concentrations are seen to fall as temperatures fall over the last 5 years.

However, this relationship is not repeated at other sites. The plot below examines the relationship between temperature at Heathrow and $PM_{2.5}$ at the London Bloomsbury AURN site:



In this plot, correlation is still good, but the $PM_{2.5}$ concentration is clearly increasing while temperature decreases.

In summary, changing meteorology has an unknown and likely variable local effect on measured PM concentrations. The predominant effect is likely to be due to temperature changes, but due to conflicting evidence about trends, it is very difficult to quantify any effect and associated uncertainty with any accuracy. The suggested effect put forward by RIVM needs to be treated with some caution.

3.4 Effects of analyser maintenance and replacement

With any analyser, changing critical components can have a significant effect on performance characteristics. For an FDMS analyser, changing even apparently minor components can materially affect performance.

For example, from Table 3 above, just using a different dryer type could change the analyser characteristics. Preliminary evidence collected to date suggests that the analyser baseline responses can change by 4 µg/m^3 when a new dryer is installed. For the purposes of this investigation, the following worst case standard deviation is estimated:

Effect of routine analyser maintenance: 2 µg/m^3 (var 3)

An assessment of the slope and offset Standard Deviations for B dryers commonly available produces the following results:

Instrument baseline: 1.1 µg/m^3 (var 4)

Instrument calibration factor: 4.7% (0.65 µg/m^3) (var 5)

This is a significant issue, especially as the dryer is a replaceable component with, at best, a 2 year life expectancy.

In addition, the quality of other consumables needs to be carefully managed. The rubber air seals, filter materials and filter mountings can play a significant part in determining analyser performance, especially in an FDMS analyser which is very sensitive to small imperfections. Rigorous ongoing QC tests are required to ensure correct operation of the equipment.

The FDMS analyser itself will have an average life expectancy in the region of ten years. The majority of the analysers currently deployed in the AURN are already at least four or five years old. It is therefore very likely that a fair proportion of these analysers will need to be replaced before 2020, which will have an impact on the calculation of the AEI. Coupled with this is the fact that a direct like for like replacement will not be possible: the exact model of analyser currently used in the AURN has been discontinued. Therefore any sites that require replacement instruments will inevitably perform differently.

From the extensive FDMS monitoring undertaken in the UK, it has become clear that dryer replacement is likely to be the largest contributor to changes in the performance of an otherwise satisfactorily performing analyser.

It is inevitable that the performance of FDMS analysers will be different in 2020 to those analysers in use today. This will need to be accounted for in the assessment of the attainability of the AEI.

3.5 Relationship between manual and automatic methods

It is important to understand the relationship between data collected using FDMS and the Reference Method. The Reference Method for $PM_{2.5}$ is the KFG/SEQ manual sampler, which draws a known volume of air through a pre and post weighed filter to determine a daily average mass concentration.

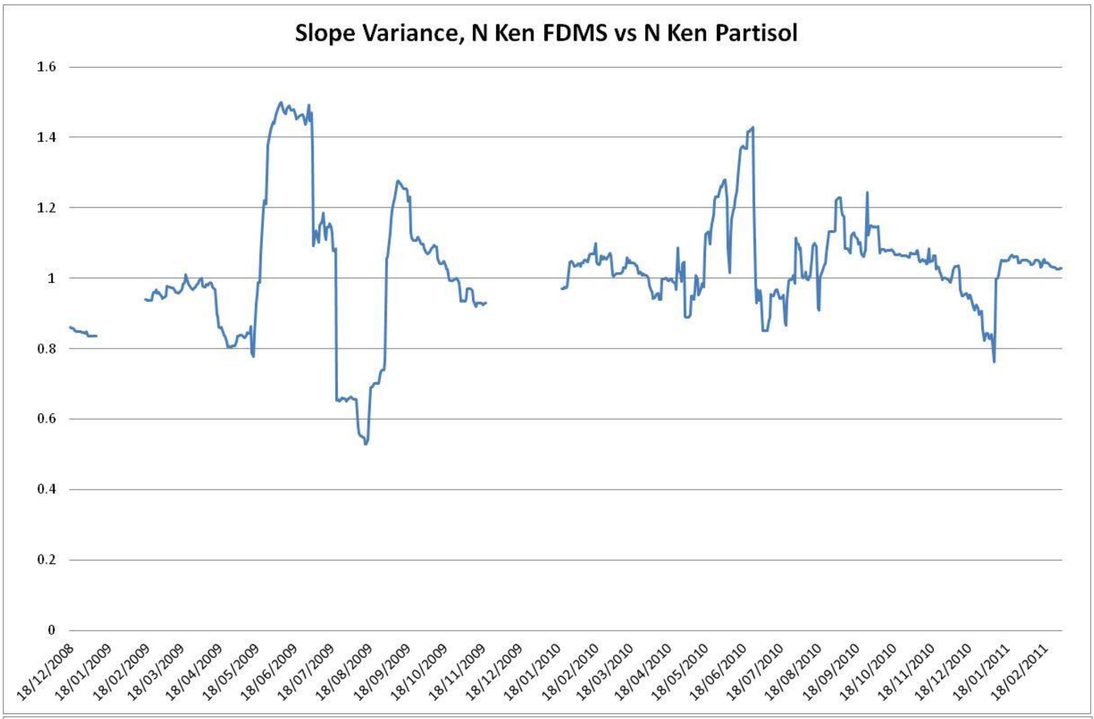
Data from FDMS analysers have been compared with the RM on many occasions since 2005, and have demonstrated equivalence under the requirements of the Guide to Demonstration of Equivalence (GDE).

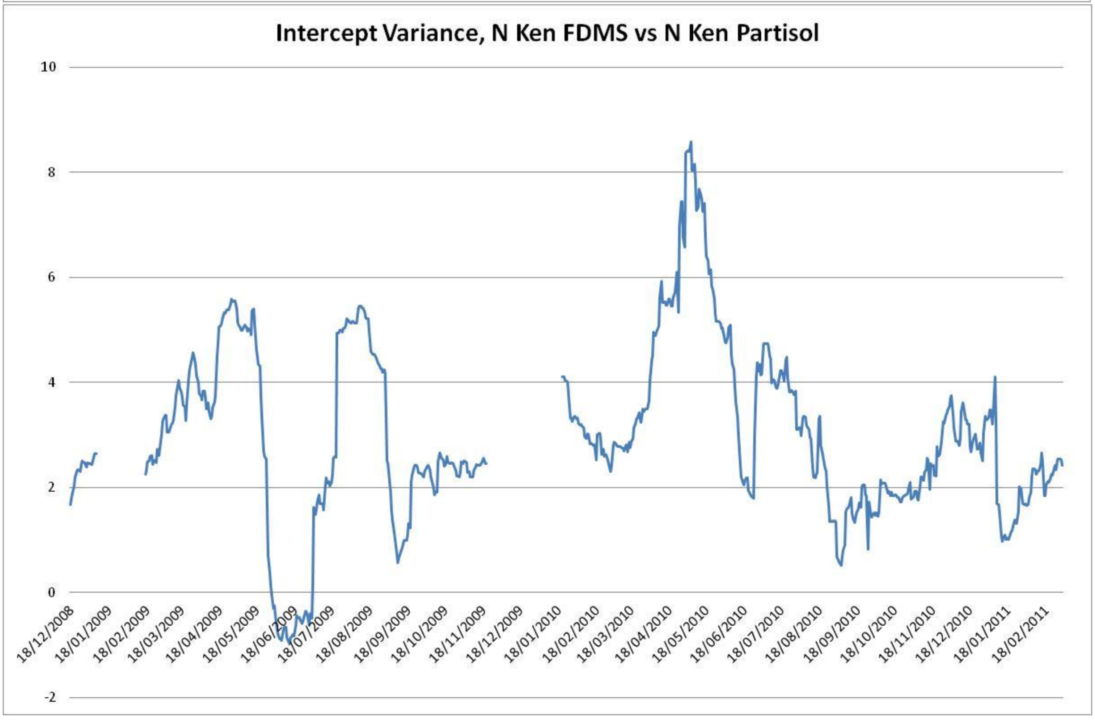
As noted earlier, the UK network makes exclusive use of automatic FDMS analysers to evaluate the AEI. While the RM is not routinely used at any AURN site, there are a number of sites that make co-located manual measurements with a Partisol 2025. This analyser has not yet demonstrated equivalence with the RM, but their presence allows for a comparison of manual and automatic measurement methods.

The equivalence trials were undertaken in a wide range of sampling and geographic locations, as well as in differing seasons, over the past three to five years.

The tests are extremely rigorous; the long term relationship between automatic and manual daily averages needs to conform to very tight requirements in order to pass the equivalence test.

As the tests were undertaken over a number of years, it is not unreasonable to assume that the relationship between automatic and manual methods would remain relatively constant. The following plots examine this assumption at a site where FDMS and manual measurement methods are routinely made.





These plots present rolling comparisons of the slope and offset correlation between the two measurement techniques. Ideally, both plots should be flat – no changes in the relationship between the devices with time. However, it is very clear that the relationship between the two techniques is anything but constant.

This is of concern when trying to evaluate the ongoing equivalence of the FDMS. Close examination of the data in the above plots suggests that:

Standard deviation of the slope is about 18% (2.5 µg/m^3) (var 6)
Standard deviation of the offset is about 1.7µg/m^3 (var 7)

These values may or may not be representative of all FDMS analyser comparisons, but will have to be included in any evaluation of AEI attainability.

3.6 Changes to the Reference Method

The CEN PM standard document is currently undergoing a major revision, which is expected to be ratified in the next 12 months. Throughout the revision process, it has become clear that there are a significant number of potential variables in the method that could lead to large uncertainties in the results.

As a result of these findings, further work is now planned to better understand and quantify the difficulties in a number of key areas:

- Filter handling – quantifying any losses or gains in mass as a result of filter preparation and transportation.
- Filter weighing – to understand the issues around weighing filters.
- Storage – quantifying any losses or gains in mass as a result of extremes in storage conditions
- Conditioning – Understanding weighing performance as a result of changes to environmental conditions used during filter conditioning.
- Different filter media – quantification of the differences in masses that arise as a result of using different filter media.

This further work will inform a subsequent revision of the CEN standard, which is likely to be ratified before the 2020 AEI deadline.

It is very likely that any future CEN standard will be significantly different to the current version and the next published revision. This will certainly have implications for equivalence of non-reference techniques, as well as backward comparability of historic RM datasets. At present, it is only possible to speculate on the scale that these changes will have on measurement uncertainties, but they will need to be accounted for in any evaluation of AEI attainability.

For the purposes of this assessment, the following estimation is made:

Effect of changes to the Reference Method: 1.5 µg/m^3 (var 8)

3.7 Relocation / Closure of Monitoring Stations

It is inevitable that a proportion of the sites in use in 2010 will not be operational in 2020. Any sites that are required to be closed and no longer operated at that location, will generally have to be relocated to a similar location in the zone or agglomeration. For the purposes of the AEI, data from sites which are not present throughout both three year periods 2009-2011 and 2018-2020, would not strictly conform to the requirements for generating the AEI, so it would be unwise to include them in the production and comparison of results.

If this approach is taken, the only effect on the calculation of overall uncertainties would lie in the calculation of the AEI uncertainty in section 3.2. It is not inconceivable that 5-7 sites could be relocated between 2010 and 2020 – this would have the effect of changing the uncertainty calculation (from (var 1)) as follows assuming 40 sites remain:

AEI uncertainty = 8.2 / ‾‾ = 1.30% / 0.2 ug/m^3 (compared to 1.20% / 0.2 ug/m^3 for a 40 site network)Thus, the effect of site closures is unlikely to make a significant contribution to the overall uncertainty calculation. However, this reduction in site numbers for the AEI comparison may make the process non-compliant, especially if the number of sites used falls below the number of UK sites required for minimum compliance.

4 Combination of Uncertainty Components

The final challenge is to determine the impact of these individual components in the final assessment of the AEI in 2020.

The following tables itemise the components described above, together with their impacts in 2010 and 2020 (when compared to the original assessment), before arriving at the headline uncertainty for the attainability of the AEI. The individual components are combined in a standard root-sum-square calculation (assuming a normal distribution for all components), to arrive at the standard uncertainty. This result is then multiplied by a coverage factor of 2 to produce an expanded uncertainty with 95% confidence.

Table 4 – Likely best case for AEI attainability

Component	AEI Uncertainty for 2010 (µg/m^3)	AEI Uncertainty for 2020 (µg/m^3)	Calculation reference	Comment	Impact - AEI attainability (µg/m^3)
Averaging annual mean for AEI	0.2	0.2	(var 1)	Assumes that the same analysers are used throughout the network in 2010 and 2020. If true, this component cancels out	0
Changes to analyser type – slope	0	0.65	(var 5)	Assumes that analyser remains in place throughout assessment in 2009-2011 (with only one dryer used) and significant numbers are replaced (with a similar dryer type) before 2018-2020. Likely to contribute to AEI attainability calculation	0.65
Changes to analyser type – offset	0	1.1	(var 4)	Assumes that analyser remains in place throughout assessment in 2009-2011 (with only one dryer used) and significant numbers are replaced (with a similar dryer type) before 2018-2020. Likely to contribute to AEI attainability calculation	1.1
Standard uncertainty	0.2	1.3			1.3
Expanded Uncertainty	**0.4**	**2.5**			**2.5**

Table 5 – Likely worst case for AEI attainability

Component	AEI 2010 (µg/m^3)	AEI 2020 (µg/m^3)	Calculation reference	Comment	Impact - AEI attainability (µg/m^3)
Averaging annual mean for AEI	0.2	0.2	(var 1)	Assumes same analysers used in both periods. If true, this component cancels out	0
Changes to analyser type – slope	0	0.65	(var 5)	Assumes that analyser remains in place throughout assessment in 2009-2011 (with only one dryer used) and significant numbers are replaced (with a similar dryer type) before 2018-2020. Likely to contribute to AEI attainability calculation	0.65
Changes to analyser type – offset	0	1.1	(var 4)	Assumes that analyser remains in place throughout assessment in 2009-2011 (with only one dryer used) and significant numbers are replaced (with a similar dryer type) before 2018-2020. Likely to contribute to AEI attainability calculation	1.1
Analyser maintenance	2	2	(var 3)	Worst case assumed: dryer replaced at least once during each AEI assessment period. Contributions *might* cancel out, but it is not clear at present whether this can be achieved	2
Meteorological variations	0	1.2	(var 2)	Complete unknown: Insufficient data to form any opinion at present. Worst case assumed.	1.25
Ongoing RM equivalence – slope	0	2.5	(var 6)	Assumes that the ongoing relationship between the analyser and the RM remains constant with time. Not true, but will only be able to accurately assess this impact after both AEIs completed. Worst case assumed	2.5
Ongoing RM equivalence – offset	0	1.7	(var 7)	Assumes that the ongoing relationship between the analyser and the RM remains constant with time. Not true, but will only be able to accurately assess this impact after both AEIs completed. Worst case assumed	1.7
Changes to RM Standard	0	1.5	(var 8)	Worst case assumptions about likely changes to RM standard. In any case, Directive requires change to be accounted for and adjusted in reporting, so the impact *should* cancel out. Worst case assumed currently.	1.5
Standard uncertainty	2.0	4.3			4.3
Expanded Uncertainty	**4.0**	**8.6**			**8.6**

The final column in each table is of most importance.

If:

- All the analysers currently in operation remain in use for 2018-2020
- Routine maintenance has only a minimal impact (dryers produce largest error)
- Meteorology causes no measurable difference
- The analysers currently in use show the same agreement to the RM over the ten year assessment
- Changes to the RM have a negligible effect

The final headline uncertainty for the AEI comparison will be ±2.5 µg/m^3 (the result from Table 4).

In the event of all of the above parameters having an impact on measurements, the final headline uncertainty for the AEI comparison will be ±8.6 µg/m^3.

It is likely that the UK exposure reduction target will be 2.0 µg/m^3. The evidence collected to date for the variables that could affect the measurement of the AEI in 2020 suggests that, at best, unless the concentration reduction is more than 2.5 µg/m^3, this target will not be measurable as a genuine change with any confidence.

5 Summary

The EC Directive 2008/50/EC on ambient air quality and cleaner air for Europe places a requirement on Member States to assess and reduce population exposure to concentrations of $PM_{2.5}$ by 2020. The magnitude of the required reduction depends on national average concentrations between 2009 and 2011.

For the UK, it is likely that average $PM_{2.5}$ concentrations for 2009-2011 will be between 13-14 µg/m^3 from the 47 $PM_{2.5}$ stations used in this assessment. This would require the UK to comply with a 15% reduction target for 2020, equating to a required reduction in average concentrations of around 2.0µg/m^3.

AEA has undertaken an assessment of the factors that are likely to make a contribution to the uncertainty of measurement of $PM_{2.5}$, both now and in 2020.

Measurement of the AEI for the period 2009-2011 is likely to yield a result with an uncertainty in the order of ±0.2µg/m^3.

Measurement of the AEI for the period 2018-2020 would normally carry a similar level of uncertainty, but the comparability of this measurement to the value for 2010 will be affected by a number of uncontrollable factors: meteorology, new analysers, service and maintenance, variability in analyser performance and changes to the Reference Method could all play a significant part in compromising the robustness of any comparisons between 2010 and 2020 AEI values.

AEA has estimated that the scale of this uncertainty could be between ±2.5 and 8.6 µg/m^3. Neither of these results would produce data with a low enough uncertainty to robustly assess a required reduction of 2.0 µg/m^3 in $PM_{2.5}$ concentrations by 2020.

It is possible therefore that the $PM_{2.5}$ exposure reduction target set in 2008/50/EC may not be measurable with sufficient confidence.

Annex I – Sites used for 2010 AEI

Aberdeen	London Teddington
Belfast Centre	Manchester Piccadilly
Birmingham Tyburn	Middlesbrough
Blackpool Marton	Newcastle Centre
Bristol St Paul's	Newport
Cardiff Centre	Norwich Lakenfields
Chesterfield	Nottingham Centre
Coventry Memorial Park	Oxford St Ebbes
Derry	Plymouth Centre
Eastbourne	Port Talbot Margam
Edinburgh St Leonards	Portsmouth
Glasgow Centre	Preston
Grangemouth	Reading New Town
Hull Freetown	Salford Eccles
Leamington Spa	Sheffield Centre
Leeds Centre	Southampton Centre
Leicester Centre	Southend-on-Sea
Liverpool Speke	Stoke-on-Trent Centre
London Bexley	Sunderland Silksworth
London Bloomsbury	Warrington
London Eltham	Wigan Centre
London Harlington	Wirral Tranmere
London Harrow Stanmore	York Bootham
London N. Kensington	

AEA
The Gemini Building
Fermi Avenue
Harwell
Didcot
Oxfordshire
OX11 0QR

Tel: 0870 190 1900
Fax: 0870 190 6318

www.aeat.co.uk