UK Equivalence Working Group

$PM_{2.5}$ Equivalence Programme

A Working Group Position Paper

March 2024

Terms of Reference

The United Kingdom Equivalence Working Group (UK EWG) was established in June 2022 and is a panel comprising experts from the contractors who currently operate the air quality monitoring networks on behalf of the Environment Agency (EA) and Department for Environment Food and Rural Affairs (Defra) alongside policy, evidence and operational experts from Defra's Air Quality and Industrial Emissions (AQIE) team and the EA.

1. The objectives of the overall program of UK EWG were to assess how:
   - to be able to continually demonstrate quantifiable performance of instruments measuring fine particulate matter ($PM_{2.5}$) deployed on the network to underpin and give confidence in the measurements and assessment against legally binding targets.
   - to establish a UK position on future requirements for equivalence ahead of formal revision of the CEN BS EN 16450 to enable effective input from the UK.
   - to consider requirements for updates and/or revisions to the EA Monitoring and Certification Scheme (MCERTS) for UK PM document which was last produced in 2012 and underpins the current equivalence system.

2. In delivering the key objectives the work should consider opportunities:
   - to potentially, reduce uncertainty in, and improve performance of, the current/future pool of instruments utilised and available for use on the network.
   - to be open to opportunities to open up the market to expand the breadth of instruments available on the network in the future.
   - to undertake workstreams and/or identify potential future workstreams which support better understanding of how instruments perform in specific environments and locations (i.e., Urban Background, Rural Background and near source).

Membership

Richard Maggs	Bureau Veritas – Technical Director (Joint Chair)
Paul Willis	Ricardo – Technical Director (Joint Chair)
Jo Solan	Ricardo – Senior Air Quality Consultant
Brian Stacey	Ricardo – Knowledge Leader
David Butterfield	National Physical Laboratory – Senior Research Scientist
David Harrison	Bureau Veritas – Technical Director
Tania Stratford	Environment Agency – Senior Advisor Ambient Air Quality
Rob Kinnersley	Environment Agency – Senior Air Quality Scientist
Daniel Waterman	Defra – Air Quality Industrial Emissions – Head of Targets and Governance
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Scope of the Working Group Position Statement

In compiling this Position Statement, the UK EWG addressed the following set of questions which have been organised according to subject headings:

1. **Determination of $PM_{2.5}$ Instrument Equivalence**

- Position on influencing international standards.
- Position on changing UK equivalence mechanism in the future (Certification).

2. **Determination of Ongoing $PM_{2.5}$ Instrument Equivalence**

- Position on ongoing equivalence monitoring.
- Position on our ability to continually demonstrate quantifiable performance of $PM_{2.5}$ instruments.
- Position on data needs for equivalence and equivalence assessments in the future.

3. **Instrument Performance**

- Position on what is the uncertainty of a $PM_{2.5}$ annual average.
- Position on potential modifications to network operational performance.
- Position on previous instrument performance.

4. **Future Activities**

- Position on the role of the UK EWG in the future.

1. Determination of $PM_{2.5}$ Instrument Equivalence

Position on Influencing International Standards

The European Committee for Standardisation (CEN) has produced a series of Standard Methods for monitoring of air pollutants in ambient air. These form part of the British Standards Institution (BSI) standards documentation, and they outline minimum performance requirements for analysers to ensure measurement methods comply with the Data Quality Objectives (DQO) and Air Quality Limit Values, as set out in Air Quality Standards Regulations 2010 (and amending regulations). These also include the methodology for determining uncertainty.

For $PM_{2.5}$ and PM_{10} the standard methods are as follows:

- **BS EN 12341:2023 Ambient Air.** Standard gravimetric measurement method for the determination of the PM_{10} or $PM_{2.5}$ mass concentration of suspended particulate matter – the "Reference Method".
- **BS EN 16450:2017 Ambient Air.** Automated measuring systems for the measurement of the concentration of particulate matter (PM_{10}; $PM_{2.5}$)

The original BS EN 12341:2014 standard was updated and published in August 2023 and BS EN 16450:2017 is in the process of redevelopment and will be revised over future years. In the meantime, the current equivalence framework will continue to operate in its current format to maintain consistency in supporting the requirements of the new $PM_{2.5}$ Target legislation[1]. However, this position paper forms part of the UK Equivalence Working Group review process to ensure the ongoing suitability of the current equivalence processes and the evolution of these in advance of further revision of the BS EN 16450 standard.

CEN Background

The CEN standards (BS EN 12341 and BS EN 16450) set out how to calculate the measurement uncertainty associated with a measurement of particulate matter at the current Air Quality Limit values[2]. The calculation evaluates and combines all the individual contributions to measurement uncertainty, following a strictly defined process.

The uncertainty expressed as a % gets higher as the concentration gets lower, but the uncertainty expressed in µg m^{-3} remains relatively similar irrespective of the concentration. This is because factors such as uncertainty of the zero response remain relatively constant, irrespective of measured concentrations, and therefore can play a more significant part in the uncertainty calculated as concentrations decrease. This may present difficulties when trying to ensure measurements and measurement uncertainties remain fit for purpose and meet legislative drivers at lower concentrations. The challenge for CEN and this working group is to

[1] The Environmental Targets (Fine Particulate Matter) (England) Regulations 2023

[2] The Air Quality Standards Regulations 2010 require that concentrations of PM in the UK must not exceed an annual average of 20 µg m^{-3} for $PM_{2.5}$.

identify and quantify the significance of these contributions and propose mitigation for their impact.

1.1. What is the position as to how the work of the UK EWG sits with respect to the CEN standards and the ongoing revision of BS EN 16450?

The UK should continue to actively engage and provide input to the CEN process through participation of the members of the UK EWG to ensure future standards are fit for purpose in the UK. This approach maximises the collective scientific knowledge across Europe (for what is a common, but difficult technical challenge), avoids unnecessary duplication of scientific effort, avoids unnecessary divergence, and minimises burden on instrument manufacturers to operate in the UK market.

The review of BS EN 16450 was instigated in March 2023 through the European CEN Working Group Process (Working Group 15) and this working group is chaired by a UK representative. It is expected that this revision process will take up to 5 years with revisions unlikely to be published before 2028. The UK EWG is seeking to understand key elements that could be input into this process to ensure any revision accounts for the range of different European meteorological environments including those of the UK. It has been commonplace to share UK data with CEN from our existing equivalence sites at London Teddington and Manchester Piccadilly, and in the future, we intend to share further equivalence data.

Any UK EWG assessments will be complementary to the work undertaken by the formal CEN standard review process and will aid harmonisation with the outputs of this work. The convening of the UK EWG provides the opportunity to undertake close examination of the relevant datasets which are representative of the UK environment in advance and ensure that these are factored into the future standard. Technical experts within UK EWG are well placed to provide relevant input during the CEN revision process. The Membership of the UK EWG will be reviewed on an annual basis to ensure that we continue to have suitable representation.

1.2. What is the position of the UK EWG on potentially developing our own version of BS EN 16450 in advance?

The UK EWG does not consider it favourable to work independently of the CEN process to develop our own version of BS EN 16450; but rather to continue the work of the UK EWG to develop a clear understanding of the specific challenges in the UK. It is intended that the CEN process is appropriately informed by our data and findings such that the revised standard can be adopted for use in the UK.

The British Standards Institute (BSI) is a member of the European Committee for Standardisation (CEN) which drafts and maintain the EN Standards. This is to ensure that there is technical harmonisation across Europe and with other worldwide bodies. UK membership reflects the need for a strong focus on good practices for products and services with an aim for international consistency wherever possible. Whilst all standards are developed to meet a defined need, there is no strong case to focus on a national only criterion, if there is already a wider European interest or process.

Technical harmonisation avoids the potential for a new UK only system to be incompatible with an updated process instigated through CEN. This also removes an additional burden on instrument manufacturers and the risk that the UK would have access to a smaller market. Membership of CEN also ensures UK gains the benefits of wider technical expertise from other countries who are undertaking similar $PM_{2.5}$ monitoring activities as part of the CEN revision process. Whilst it is important that the UK EWG develops its position to input into CEN, moving in advance to create a new system could leave the UK exposed to designing something non-comparable for certification of the same instrument and missing key elements which could require a further standard revision in due course.

1.3. What is the position of UK EWG on how suitable the CEN standards will be for the UK given that the EU has proposed new limit values in 2024 and that England has set new targets in 2023?

UK representatives have a strong track record in helping to develop Standards and promoting them for development and adoption. The UK EWG can provide insight in this area to identify the potential amendments that may be needed to BS EN 16450 to meet both the UK and CEN requirements. Through active engagement in the CEN process the UK EWG are confident that the UK will continue to play a key role and that the CEN standard could be developed to be fit for purpose for UK applications.

The current standard BS EN 16450 was drafted to meet the requirements of the $PM_{2.5}$ limit values that are stated in the EU Directive (2008/50/EC) and the Air Quality Standard Regulations 2010. In February 2024, the European Commission set out a new Directive which will seek to establish a new target of an annual limit value for fine particulate matter ($PM_{2.5}$) of 10 µg m^{-3} which aligns to the level of the new Annual Mean Concentration Target (AMCT) in England. BS EN 16450 is therefore likely to be revised to incorporate the new European Commission requirements but there is an opportunity to ensure that it is also suitable for the UK. The European CEN Working Group Process (Working Group 15) is chaired by a UK representative and has other members of the UK EWG represented. Therefore, there is a route to express the need for flexibility in the new standard to take account of the UK situation.

1.4. What is the position of the UK EWG on how the United States Environmental Protection Agency (USEPA) currently assess Equivalence and calculate uncertainty?

The UK EWG does not recommend adopting any of the procedures used by USEPA for measurement of $PM_{2.5}$.

The United States (US), through their Agency, take a different approach to $PM_{2.5}$ measurements that is not compatible with the procedures in use throughout Europe. For example, the US operate gravimetric analysers at less than half the flow rate used in the UK, their filters are conditioned in a much dryer environment, and they use a filter material that can be known to be inefficient for collecting certain types of particles.

All of this means that US and UK measurements are not directly comparable and implementing changes to match the US protocols would introduce a significant step change

in the mass of particles on the filter and the resulting uncertainty of measurement. It would also represent a departure from the development of standards produced by CEN and the harmonisation of measurements across Europe. Further, it would result in all prior UK and EU data being sufficiently different from the US methodology that it would effectively restart the clock on our understanding.

1.5. What is the position of the UK EWG on what may need to be further assessed in advance of the revision of BS EN 16450?

The UK EWG will continue to advise and input datasets in addition to opinion on mathematical approaches throughout the development of the new CEN standard.

In advance of the revision of BS EN 16450, the UK representatives of the CEN Working Group have already been inputting data and information to inform ongoing CEN discussions. Sharing UK expertise will enable the most recent work from UK EWG to be considered alongside information from other countries. The UK EWG have identified a number of areas they would recommend for revision including:

- the suitability of annual averages for equivalence assessments (which would potentially simplify the approach and make it more comparable with metrics used for targets, epidemiology, and longer-term impacts)
- an allowance for fewer than 32 high concentration points (18 µg m^{-3} for $PM_{2.5}$ and 30 µg m^{-3} for PM_{10}) if evidence shows the relationship is acceptable.
- that co-location studies between Reference Method and Candidate instruments could primarily be undertaken in winter and at locations where PM concentrations should fulfil the required range.

The UK EWG will continue to review what further research may need to be undertaken and input into the CEN Working Group as the revision progresses.

1.6. What is the position of the UK EWG on how we best update our data and ongoing position to inform the future Working Groups and CEN processes?

Our continued active engagement in the CEN process provides an opportunity for the UK to provide input during the development of the future standard. To ensure that this is maximised and most effective, it is recommended that we have a continued UK Equivalence Working Group to provide on-going data analysis, research and to help develop the UK's position.

The European CEN Working Group Process (Working Group 15) is chaired by a UK delegate and has other members of the UK EWG represented. Therefore, there is an effective input mechanism to ensure that any potential changes to BS EN 16450 are reflective of UK requirements. However, it would be beneficial to continue the meetings of the UK Equivalence Working Group at suitable points to input into the CEN Working Group timetable. During the period the UK EWG is in place and following the implementation of an increased number of UK equivalence sites, the UK EWG should continue to review annual equivalence data to provide assurance that analysers on the national network continue to operate within required uncertainty requirements. They should also assess whether additional evidence is

required. This would be a similar approach to that which is currently adopted by other countries e.g., Germany's WG15 Mirror Group.

Position on Changing our Equivalence Mechanism in the future (Certification)

1.7. What is the position of the UK Equivalence Working Group on revising the Environment Agency MCERTS for UK PM document which was last produced in 2012?

Any evolution of MCERTS for UK Particulate Matter, should be informed by, and ideally follow the process of developing the updated BS EN 16450 standard.

In 2012, the EA worked with Defra to create a process to ensure that all instruments that are used on the Automatic Urban and Rural Network (AURN) have been demonstrated to be equivalent to the Reference Method in a representative particulate matter pollution climate for the UK. This certification is called 'MCERTS for Particulate Matter UK'[3] and it requires equivalence testing is undertaken in the UK, if not already completed as part of an instrument's BS EN 16450 certification. Since 2012, instruments have been certified according to this process, which was modified in 2020.

Whilst the terms of reference of the UK EWG refers to an objective to update and revise the original 'MCERTS for Particulate Matter UK' produced in 2012 it is felt this may not be timely and the 2020 update that was published[4] suffices.

The UK EWG recognise that the current UK pollution climate is changing as concentrations of $PM_{2.5}$ reduce, hot summers become longer and drier, winters warmer and wetter, and it becomes less certain that the UK conditions are wholly different to that recorded across Europe. The CEN Working Group (Working Group 15) are aware that both reduced $PM_{2.5}$ levels and particle composition changes are impacting instrument performance not only in the UK and but also across Europe. Therefore, there will be an opportunity to consider what changes may be needed to the UK certification system during the BS EN 16450 standard revision process. This could include whether this additional UK requirement is still appropriate or if further UK pollution amendments are required in addition to the 2020 update.

In advance of any CEN Working Group recommendations, an assessment will be made on the current 'MCERTS for Particulate Matter UK' process, the available facilities used for UK certification and whether there are any opportunities for evolution of the system. Any changes that are proposed of BS EN 16450 would require a transitional period and would need to be undertaken through a consultation process and informed by the views of stakeholders.

[3] Type testing is currently assessed through the MCERTS performance standards for ambient monitoring equipment. MCERTS performance standards for ambient monitoring equipment - GOV.UK (www.gov.uk)
[4] MCERTS performance standards for ambient monitoring equipment - GOV.UK (www.gov.uk)

1.8. What is the position of the UK Equivalence Working Group on instrument certification requirements that are needed to gain access to the AURN?

The UK EWG recognises that the development of the new BS EN 16450 standard may require the mathematical assessment process to change as a result of lower $PM_{2.5}$ concentrations across Europe and the challenges of monitoring a sufficient number of high points required by the current process. The UK EWG will continue to evaluate the performance of automatic analysers in a range of pollution climates in the UK and feed the evidence from these tests into the development of EN 16450. Any evolution of MCERTS for UK Particulate Matter, should be informed by, and ideally follow the process of developing the updated BS EN 16450 standard.

Lower $PM_{2.5}$ concentrations across Europe mean that it is becoming challenging to collect data that meets the specific requirements (to record 32 or more valid data points for concentrations greater than or equal to 18 µg m^{-3}) to achieve certification. For EU instrument certification, equipment manufacturers now have to either monitor for longer periods and/or move their testing location to the last remaining locations that have these higher concentrations such as Northern Italy. In mirroring the BS EN 16450 process, MCERTS suffers from the similar challenges, but restricts the assessment within the UK.

The UK EWG recognises that the current methodology has some limitations due to the current requirement to assess equivalent instrument performance at a pseudo daily concentration level of 30 µg m^{-3}. Whilst the current statistical approach of linear models is adequate, alternative approaches such as considering moving towards annual mean assessments should be considered and may be more in-line with the current legislative requirements and epidemiological assessment to determine long term health impacts.

The requirements of 'MCERTS for UK Particulate Matter' currently go beyond what is needed to meet BS EN 16450. MCERTS for UK Particulate Matter asks for instruments to be able to demonstrate equivalence in a representative particulate matter pollution climate for the UK. It does not require specific monitoring at a particular site environment type in the UK pollution climate, e.g., urban traffic site. The evaluation of instruments in a selection of locations will be considered as part of the review of BS EN 16450, and any updates to MCERTS for UK PM should be informed by this process to avoid any unnecessary duplication of effort. In the meantime, it continues to be the responsibility of the UK to assess and reassure themselves that the equipment performs in the national environment.

1.9. What is the position of the UK EWG on what instrument certification testing would be required at sites dominated by industrial sources, where the aerosol composition is likely to be specific to that site?

The UK EWG does not consider it appropriate to add certification requirements for a general industrial type at this time. Instead, the deployment of monitors at industrial sites should be reviewed on a case-by-case basis. This reflects the large variability in industrial PM compositions that can be found, and in turn how a sites unique PM composition may affect a particular instruments performance. Where greater confidence in real time data is

beneficial, equivalence instruments may be collocated against a reference monitor to provide added reassurance of equivalence.

Evidence from industrial locations has shown that it can prove difficult to monitor $PM_{2.5}$ concentrations where the sources are heavily industrialised as the aerosol composition is often atypical and dominated by large and often unusual local emissions. Therefore, it would be unhelpful to require specific certification of an instrument based on a unique $PM_{2.5}$ signal and composition (unless intended for that exact location). Additional evidence may be collected on a case-by-case basis to solidify decisions on the suitability of an equivalence instrument at any specific industrial site.

2. Determination of Ongoing $PM_{2.5}$ Instrument Equivalence

Ongoing Equivalence Background

BS EN 16450 sets out the requirement that once instruments have been certified and deployed as part of a national network, an ongoing assessment needs to occur. This is to check instruments are still equivalent to a reference method in recognition that environments change over time and may be different to initial approval tests and suitability evaluation. This ongoing field testing requires operating the instruments alongside one reference instrument. BS EN 16450 currently requires a minimum of 2 to 5 ongoing equivalence sites depending on the expanded relative uncertainty of each monitor type on a network. In the 2021 UK Report for ongoing Particulate Matter (PM_{10} and $PM_{2.5}$) Equivalence[5], three sites were used for ongoing equivalence testing. These were at the Urban Background locations of Manchester Piccadilly and London Teddington and the industrial location in Port Talbot Margam (for the PM_{10} BAM 1020 instrument only). This latter work was used to inform the position in 1.9. More recently, London Marylebone Road has also started to be used as an ongoing equivalence site, and its data is included in the 2022 report[6].

The work to date, as part of the Equivalence Working Group programme, looked at an 18-month study of several 'mini equivalence sites' located in Urban Traffic (Birmingham A4540, Barnstaple, Storrington), Urban Background (University of Birmingham, University of Manchester, Honor Oak Park Supersites) and Rural Background locations (Chilbolton). This was the first-time equivalence monitoring was carried out at a rural background site in the UK.

Position on ongoing Equivalence Monitoring

2.1 What is the position of the UK EWG on whether the UK should focus on demonstrating suitable performance of an instrument type in a select range of representative locations or must it consider specific performance in all locations (or as many as possible i.e., round robin)?

The UK EWG supports continuing equivalence testing in a selection of representative locations in the UK. Whilst carrying out ongoing testing at every site may provide some confidence that every monitor on the network continues to be equivalent, there is insufficient evidence that this should be the preferred approach or provides any added value.

The UK EWG recognises that adopting a 'round robin' approach is simply not practical. The current network configuration and UK planning requirements mean it is unrealistic to

[5] **Report: 2021 UK Report for On-going Particulate Matter (PM_{10} and $PM_{2.5}$) Equivalence:**

[6] **Report: 2022 UK Report for On-going Particulate Matter (PM_{10} and $PM_{2.5}$) Equivalence**

undertake equivalence testing at all sites in the UK. Therefore, a practical solution for the UK is to continue with the current methodology of operating permanent ongoing equivalence sites at a selection of representative locations. However, recommendations on what is considered suitable representative locations, and the minimum number of sites form part of additional responses below.

2.2 What is the position of the UK EWG on requirements for ongoing equivalence sites that are suitably representative of conditions in the UK?

The UK EWG considers the established environment site type classification of urban background, rural background and urban traffic to be a suitable method to assess ongoing equivalence in the range of conditions representative of where instruments are being operated in the UK. As covered in 1.9 industrial site equivalence locations shall be considered on a case-by-case basis.

Results have not shown any clear differences in instrument equivalence per site type in the current pollution climate. However, the UK EWG believes the three environment site types; urban background, urban traffic and rural background, cover the ranges of particulate composition reflective of the national network and will be suitably challenging of an instrument's performance in the future. Sites with a local industrial source will be considered on a site-by-site basis.

$PM_{2.5}$ composition is complex including transboundary and secondary aerosols, which all need to be considered in the context of an instrument's ability to be equivalent with the Reference Method. Comparisons between the current network instruments and the reference method have shown that their performance can be affected by increased concentrations of ammonium nitrate and Black Carbon. This is initial analysis that may require further investigation. Ammonium nitrate is found in highest concentrations across the southeast of England with concentrations dropping further west or north. This would suggest that a distribution of urban and rural background equivalence sites is needed to be reflective of this range. Black Carbon is mostly detected from local sources with measured concentrations typically influenced by traffic flow, vehicle fleet type and domestic heating. This supports maintaining the need for equivalence sites in both urban background and urban traffic locations.

2.3 What is the position of the UK EWG on the number and location of equivalence sites required?

The UK EWG recognises the practicality and value of having permanent ongoing equivalence sites to assess performance of instruments deployed into the AURN. The UK EWG recommends ideally a minimum of 3 urban traffic, 3 urban background and 2 rural background equivalence sites. Where possible these should be collocated with Black Carbon and ammonium nitrate monitoring. Further information/research may change these future requirements. But presently, this provides the reassurance and resilience that instruments on the $PM_{2.5}$ AURN network remain equivalent.

The minimum number of ongoing equivalence sites required needs to be able to cover the range of particulate compositions and concentrations experienced across UK. For urban background and urban traffic sites three groupings of areas have been identified across the UK that are sufficiently different from each other, but cover the ranges of low, medium and high key factors likely to impact instrument performance including Ammonium Nitrate, Black Carbon and $PM_{2.5}$ concentration.

Ideally, for each grouping an urban background and traffic site should be paired to further support any investigations in the unlikely event an instrument fails the required uncertainty tolerances following the annual on-ongoing equivalence assessment. Pairing means that the regional secondary aerosol influences are similar, such that you could identify if the roadside increment caused an effect.

Therefore, as the sites chosen in each group will be representative of the types of environments monitored on the AURN, it should be possible to equate from these, the overall performance of analysers throughout the UK.

Monitoring equivalence at rural background locations is considered helpful due to the differences in particulate mix at these locations compared to urban background locations. They also typically measure lower concentrations which may provide insights into how a future network may perform as concentration changes. Due to the $PM_{2.5}$ composition for rural background areas being similar over much larger distances, ideally a minimum of two sites is recommended; one in the south to capture any long-range secondary aerosols due to trajectories from continental Europe and one in the north where these influences are less prevalent. If it was possible to locate a site to pair with an urban background site, it could also be used to determine any increments from urban background sources.

All equivalence sites should use the Reference Method rather than a pseudo-Reference Method such as a Partisol 2025. To further enhance any investigations, two $PM_{2.5}$ Reference Methods plus daily nitrate and continuous Black Carbon measurements could be installed, space allowing. However, for ammonium nitrate due to its transboundary distribution, if it is not possible to measure at all sites, then monitoring could be at one of the paired urban traffic or background sites. Further information/research may change these future requirements, but the current evidence points to this additional pollutant monitoring being helpful.

At least one of the urban background and/or one of the urban traffic equivalence sites should have sufficient space to install additional instrumentation should new instruments require certification (both for $PM_{2.5}$ and PM_{10}) or to run bespoke tests.

Additional equivalence sites could add further resilience to assessments. However, any increase in equivalence sites should follow an evidence need to either further investigate if any equivalence failure is unique or more widespread, or to provide additional geographical coverage following identification of any new conditions not currently being tested. It should not simply increase as the national $PM_{2.5}$ network expands, but be evidence driven,

demonstrating the likely incremental benefit of additional sites in reducing uncertainty in equivalence decisions.

2.4 What is the position of the UK Equivalence Working Group on the frequency of monitoring required at each equivalence site (i.e., number of data points captured within a year)?

The UK EWG recommends capturing equivalence on a continuous, not periodic basis, to maximise the value of the data for an annual mean assessment and to avoid issues with missed data sets, i.e., during heat waves, Saharan dust clouds, secondary inorganic episodes etc.

BS EN 16450 requires a minimum of 80 valid data pairs. However, due to seasonal variability, even if data were captured every 4 days, this can be limiting. In the UK, measurements at equivalence sites have now been increased from 50% of the year to every day of the year since 2022. This has increased our understanding of the equivalence relationship and would continue to be beneficial going forward. This timeframe also mirrors the annual requirements for $PM_{2.5}$ compliance assessment and data capture[7].

2.5 What is the position of the UK EWG on how useful the temporary 'mini equivalence sites' have been to date and what should their role be for ongoing equivalence in the future, if any?

The UK EWG does not recommend for all of the long term 'mini equivalence' sites to be maintained in their current form.

The learning from operation of these sites has informed the earlier recommendations about the helpfulness of establishing additional permanent equivalence sites, particularly at a wider range of site environments. The candidates for any expansion of these sites, may include one or more of the mini equivalence site locations, should they be appropriate or feasible.

2.6 What is the position of the UK EWG on whether the current on-going equivalence sites in London Teddington, Manchester Piccadilly and London Marylebone are suitable for the future?

The existing equivalence sites of London Teddington, Manchester Piccadilly and London Marylebone Road, currently remain suitable equivalence sites. However, due to the redevelopment of the square in which the Manchester Piccadilly site sits, combined with the proximity of local sources from food stalls, trams and a bus station, it is felt that this site should no longer be used for equivalence testing purposes once a suitable replacement has been found.

The analysis indicates that the ongoing equivalence site at London Teddington has been helpful in representing an urban background location. It is the site where all MCERTS for UK

[7] Representative over the period of measurement; for most purposes, a yearly data capture rate of not less than 90% is usually required for determining compliance with limit values where applicable. An allowance of 5% is made in some cases for down-time due to planned maintenance. This is the same data capture requirement as specified in the Environmental Targets (Fine Particulate Matter) (England) Regulations (2023) for at least 85% of the hours in a year.

Particulate Matter certified instruments have undergone at least a part of their initial instrument certification and therefore maintaining a site with the capability for this testing, and for future equivalence comparisons is of scientific interest.

Manchester Piccadilly's continued suitability as an ongoing equivalence site is in doubt as the local sources of a large food market and bus and tram have potentially changed its urban background classification. The location is due to be redeveloped from late 2025 and so this means that an alternative site should be sought. It is recommended that any new site continues to have the capability for certification of new instruments.

The urban traffic site at London Marylebone Road is essential for its high traffic flow and wide blend of traffic emissions within an emission control area and should remain. However, space is limited within the enclosure, and it cannot host any new instruments deployed on the network or facilitate certification of new instruments. It is therefore recommended that any additional urban traffic sites that are established have the space and capability for testing of new instruments and ongoing equivalence to be undertaken.

Position on our ability to continually demonstrate quantifiable performance of $PM_{2.5}$ instruments

2.7 What is the position of the UK EWG on our ability to quantify and define instrument performance and data uncertainty in the future?

The work of the UK EWG has progressed our understanding of uncertainty assessment at lower concentrations and environment types and will be helpful to inform future CEN Working Group meetings to refine future approaches.

The work of the UK EWG has demonstrated both the complexity of uncertainty assessment and the challenges of measuring $PM_{2.5}$ with a degree of confidence. The group is supportive of the need to refine existing approaches to assessment and progress has been made in our understanding, particularly with respect to constraining key variables that contribute to the uncertainty. This has established a good platform to develop the UK approach and to underpin learning and recommendations within the wider CEN process. One area where the UK EWG feel there is scope to improve assessment of uncertainty in the future relates to the fact that to date the uncertainty of instruments has been defined against the pseudo daily limit value which makes equivalence assessment highly dependent on the range of daily concentrations. The use of annual means for the future for uncertainty calculations would be more in-line with the current legislative requirements and epidemiological assessment to determine long term health impacts.

2.8 What is the position of the UK EWG on quantifying and defining instrument and data uncertainty in respect of annual mean concentrations values of $PM_{2.5}$ at or below 10 $\mu g\ m^{-3}$?

Assessment of uncertainty at 10 µg m^{-3} shows measurement at such levels is challenging and current assessment methods will likely need refining as part of the BS EN 16450 revision. It is also apparent that this challenge is not one that is associated to a specific instrument or instrument type but is a wider challenge associated to the nature of $PM_{2.5}$ as a complex pollutant.

Using original certification data, the uncertainty using different pseudo daily limit value including 10, 15 and 20 µg m^{-3}, rather than the original 30 µg m^{-3} for daily uncertainty calculations was explored. In addition, the approach of comparing the annual average reference method to the annual average equivalent method value was also explored. The latter shows greater potential and is also more applicable for seeking to meet a 25% Expanded Uncertainty requirement whilst also being suitable for comparison to the new target's legislation.

2.9 What is the position of the UK EWG on what will be needed if an existing instrument type fails equivalence criteria consistently at a specific location?

The UK EWG recognises that there is potential that a site or instrument may very rarely fail the required uncertainty tolerances following the annual on-ongoing equivalence assessments. Investigative processes would be put in place, but additional speciation monitoring carried out at an equivalence site could improve and further support any evaluation.

There is a requirement to confirm annually that the $PM_{2.5}$ instruments that are part of the AURN are still equivalent to the Reference Monitors and can monitor the continually changing sources of particulate matter across the UK. Each of the approved instruments is tested alongside the Reference Method at a number of sites and the requirement is that the Expanded Uncertainty (as calculated using the equations in BS EN 16450) is less than 25%.

There are two potential scenarios whereby an instrument may be deemed to be not equivalent to the Reference Method. These are as follows:

a) where a single instrument consistently fails over several years at a single location but passes elsewhere; or

b) if an instrument type fails consistently over time at multiple locations

In case a) there would be a need to understand why this had occurred. A benefit of having more than one on-going equivalence site at different site environment locations but the same type (e.g., urban background and urban traffic) enables an understanding as to whether this issue in confined to a single instrument or single location. Once all data quality and maintenance issues have been examined, the next step would be to raise the issue with the instrument supplier to check if this issue had been identified elsewhere e.g., other countries. There may be an opportunity to consider a different instrument or measurement methodology at this location.

In case b) there would be a need to consider why this failure is occurring at multiple sites. This would then need to be discussed with the certification body, to ensure that any

manufacturing factory audits and design changes have been considered and are up to date. This ensures that instruments being purchased today are likely to perform in the same way as those previously type tested. Consideration would need to be given as to whether there has been a substantial instrument change or environment change i.e., were the instruments passing previously.

Position on Data Needs and Equivalence Assessments in the Future

2.10 What is the position of the UK EWG on what data should be captured to assist our understanding of equivalence?

To be in a position to further understand and explain differences in equivalence to reference instruments, particularly at lowering concentrations, the UK EWG recommends that equivalence sites could benefit from accompanying meteorological data. In addition, it would be helpful if Black Carbon and ammonium nitrate could be monitored at as many equivalence sites as possible and ideally where space allows.

This additional speciation and meteorological data may help us to explain any instances where a site fails its annual ongoing equivalence and assist to provide an understanding of the reason why. Further information/research may change these future requirements.

All data captured as part of ongoing equivalence assessments should continue to be in the same format as the CEN process, e.g., 24hr reference data so that it can continue to be examined as part of the revision of BS EN 16450.

2.11 What is the position of the UK EWG on what further work packages/ monitoring exercises should be undertaken?

If the proposed minimum permanent ongoing equivalence sites and enhancements are implemented, this should provide the ongoing evidence that is required to support the UK's position on BS EN 16450 revisions, and assurance of our instruments' performance on the national network.

However, there is further work to be completed which will aid our future understanding on ongoing instrument performance. This includes:

- obtaining further industrial site evidence, particularly where composition and particle shape might differ from those in non-industrial situations. This would need to reflect individual industrial locations in addition to the impacts of more generic sources e.g., airports
- further assessment as to how the UK pollution climate compares to the rest of Europe which was originally considered over 10 years ago.

3. $PM_{2.5}$ Instrument performance

Position on what is the uncertainty of a $PM_{2.5}$ annual average

3.1 What is the position of the UK EWG on how we reduce uncertainty when assessing instrument performance as part of the AURN?

From the analysis undertaken, the evidence indicates that uncertainty calculations should be considered on an annual mean basis and not as a daily limit, as is current practice for $PM_{2.5}$. This view will be input into the work currently being explored by the CEN Working Group 15.

If uncertainty is considered using an annual average, instead of linear regression of daily averaged data, then this has the potential to reduce it relative to the current methodology. This is in part due to an increase in confidence when averaging 365 measurements, and in part due to removing the reliance on mathematics which has the potential to be disproportionately influenced by a limited number of higher concentration days.

Another way to reduce uncertainty across the network could be to limit the number of instrument types available to the network, as this reduces additional instrument uncertainties being introduced. However, this would need to be weighed against the benefits of an instrument mix which includes more resilience in having a supply of parts per monitor type or future unforeseen challenges to a particular instrument. In addition, having different types of instruments allows a more complete assessment of uncertainty as any differences between readings can be further explored. There is also the opportunity if systematic differences are identified in the operational use of an instrument, to correct for this (e.g., zero offset on BAM 1020 instruments) to reduce the uncertainty in the data collected.

3.2 What is the position of the UK EWG on what uncertainty thresholds should be used in the future?

The UK EWG feel that acceptable performance across a range and breadth of environments and countries should inform the setting of an uncertainty threshold, not set within the context of a single instrument, location, country or environment.

Position 3.1 already sets out that in the future uncertainty should be considered as an annual average, instead of linear regression of daily averaged data. This is more realistic for equivalence assessments and would potentially simplify the approach to make it more comparable with metrics used for targets, epidemiology and longer-term impacts.

The current uncertainty bounds for monitoring $PM_{2.5}$ are set as a data quality objective to meet a 25% Expanded Uncertainty requirement. It is recognised that measurement bias in this requirement can play a higher influence at lower concentrations for $PM_{2.5}$ monitoring and also for other pollutants. Therefore, we will look to understand how this is likely to be assessed in the future by contributing to CEN Working Group 15 considerations.

3.3 What is the position of the UK EWG on how uncertainty can be communicated best to the public?

The UK EWG recommends further examining how best to publish information on instrument uncertainty to explain how it is assessed and applied to the UK AIR $PM_{2.5}$ datasets once the approach has been determined through the revision of BS EN 16450.

The UK EWG feel that the communication of $PM_{2.5}$ equivalence information and uncertainty is a difficult concept that may not always aid public understanding of the concentrations of $PM_{2.5}$ and how it fits with the new targets. The use of measurement uncertainty relates to the certification of equipment accuracy and is not used specifically in the context of assessing target compliance.

A summary report of the annual on-going instrument equivalence assessments is published on UK AIR. If a new approach on calculating uncertainty is forthcoming as part of the revision to BS EN 16450, then there will be an opportunity at that time to further assess how best to communicate this in future reports uploaded to UK AIR.

3.4 What is the position of the UK EWG on the overall 'uncertainty' attributed to the various facets of data collection / calibration (LSOs) / service and maintenance regimes?

The UK EWG recognises the importance of considering a range of factors impacting uncertainty, but it is not feasible or necessarily of value to quantify aspects in relation to other factors, as many are not quantifiable.

The processes of data collection, calibration, servicing, and maintenance will introduce some elements of 'uncertainty' into the integrity of the monitored results, but it is not possible to attribute definitive figures to the single sources listed. Whilst there are no adjustments that are regularly performed on PM instrumentation, some operational activities can help the overall picture, for example all flow / leak / particle size spectrometry tests are pass / fail assessments to determine if a maintenance intervention is required. Corrections for zero offsets may reduce the bias of measurements, but these changes are not metrologically traceable so determining their effect on uncertainty is extremely difficult. However, the UK EWG do not feel that the uncertainties associated with various facets of data collection / calibration (LSOs) / service and maintenance regimes interfere with the robustness of instrument certification.

Position on potential modifications to network operational performance.

3.5 What is the position of the UK EWG on how specific instruments perform in specific environments and locations (i.e., Urban Background, Rural Background and near source)?

There is no obvious systematic difference between the Fidas 200 or BAM 1020 and the Reference (or pseudo reference) Method at different site types. Both instruments have previously met the instrument certification requirements for operation on the AURN.

Both instruments had variable performance at urban background and urban traffic locations. This included a review of an instrument's uncertainty using different mathematical methods. Due to there being only one rural background site it is also not possible to say with certainty if one of the two instruments would perform better at this environment.

The Fidas 200 was shown to be more repeatable than the BAM 1020 across all sites due to the BAM 1020 being prone to an unstable baseline which gives a lower confidence over measured concentrations. Routinely baseline correcting a BAM during the normal data ratification process typically improves its performance.

3.6 What is the position of the UK EWG on whether there are any different Fidas algorithms that would be suitable?

The UK Equivalence Working Group recommends the continued use of the Fidas Method 11 algorithm which has been previously adopted as part of the AURN through the equivalence certification process.

The Fidas 200 is a fine dust ambient air quality monitoring device, developed to provide continuous and simultaneous measurement of PM1, $PM_{2.5}$, and PM_{10}. For particles smaller than 180 nm the Fidas uses an algorithm to estimate their contribution. The current approved calculation algorithm for converting particle numbers to mass concentrations is Method 11. Other algorithms which are available as part of the Fidas monitoring set-up are not currently approved for use via the equivalence certification process.

An assessment was undertaken of the different Fidas algorithms as compared to the reference method. This was both at the permanent sites and the 'mini-equivalence' sites. The UK EWG felt that this exercise was useful particularly to assess whether there were any alternatives particularly when using the monitor at urban traffic sites. However, the evidence showed that using a different algorithm did not make the Fidas any more similar to the Reference Method relative to the data obtained by using the already equivalence certified Method 11.

3.7 Are there any other operational changes that may provide improvements to the data and how we monitor $PM_{2.5}$?

There were no operational improvements identified for the Fidas 200. However, for the BAM 1020s research has shown that replacing the tape type and using improved baseline correction techniques can lead to increased confidence of the data.

The following are a number of changes that have been trialled or are now proposed since the assessment process began.

- For the BAM 1020 evidence supports switching to use Whatman instead of the original Sibata tapes (both are certified for use). Whatman tapes experienced less change in zero offset than the Sibata tapes and therefore these have now been put in operation across the network since Spring 2023.

- Evidence also supports a new baseline correction procedure for BAM 1020 instruments using Fidas 200 data at locations within a defined distance radius. This is a future improvement yet to be applied.

- Continuing to ensure consistency in the servicing and maintenance approach across the network is important. Every opportunity should be taken to ensure a consistency of approach including at affiliated sites to the network that may have different operational routines.

- The UK EWG were keen to understand whether there were any other pollutants determined through speciation that might be having an impact on recorded $PM_{2.5}$ concentrations. This was assessed at those 'mini-equivalence' sites that had equipment able to ascertain particulate matter speciation and composition. From the limited data available there was some affects seen on those $PM_{2.5}$ results that were atypical where there were elevated Black Carbon and ammonium nitrate concentrations. Further analysis using the proposed annual means as a metric, and at any additional supersites, may provide a further indicator as to the number of sites and which type this may be applicable.

- The UK EWG recognises that continued engagement with equipment manufacturers is useful to better understand instrument developments (e.g. design or consumable changes) and how practical modifications could help performance. The UK EWG can continue to provide a platform for consideration of equivalence in the future and on-going engagement with manufacturers will continue to be important. This role could also encompass highlighting the opportunity to increase the breadth of instruments such that they can then be tested through the certification process against the reference method. This could also help suppliers when developing their next generation of instruments such that there is recognition of what would be helpful to include.

Position on Previous Instrument Performance

3.8 What is the position of the UK EWG on historical instrument changes on the network?

All current instruments or those that have been part of the network previously have been assessed as meeting the requirements of the equivalence certification process. Analysis of historical and recent data has confirmed that instruments operated on the network were in reasonable agreement with the reference method.

The Equivalence Certification process ensures that all instruments that are used on the Automatic Urban and Rural Network (AURN) have already been assessed and have demonstrated to be equivalent to the Reference Method in a representative particulate matter pollution climate for the UK. Certified instruments once deployed as part of a national network, are checked through an ongoing assessment to ensure they continue to be equivalent to the Reference Method in recognition that environments change over time and may be different to initial approval tests and suitability evaluation.

There is no evidence that indicates that one automatic analyser is more 'equivalent' to the reference monitor than another.

Equipment changes have taken place on the AURN throughout its operation and are based on the available instrumentation at the time. The procurement of new analysers always follows a robust tender process, and all new analysers must comply with the tender specification and certification processes.

There are differences between instruments, but these should be seen in light of the fact that a technical complexity of monitoring $PM_{2.5}$ is that none of the automatic instruments provide a 100% perfect result all of the time and at all locations. The equivalence certification process is there to provide the assurance and validate that the instrument consistently meets the standardised requirements which includes an uncertainty parameter.

4. Future

Position on the role of the UK Equivalence Group in the future.

4.1 What is the position of the UK EWG with regards to what role it needs to play with regards to future equivalence and uncertainty assessments?

During the development of the revised BS EN 16450 standard a UK EWG EN 16450 mirror group should be in place to review evidence and put forward a UK position. The frequency of meetings will be driven by the schedule of BS EN 16450 meetings, and the membership should be reviewed annually.

The role of the group will primarily be to ensure that any future BS EN 16450 revisions will be able to be adopted in the UK without amendments, and to provide a view on any subsequent MCERTS for UK particulate matter changes following final BS EN 16450 revisions. During the period the UK EWG is in place and following the implementation of an increased number of UK equivalence sites, the UK EWG should continue to review annual equivalence data to provide assurance that analysers on the national network continue to operate within required uncertainty requirements, or if additional evidence is required. The UK EWG also recognises that continued engagement with equipment manufacturers is useful to better understand instrument developments (e.g., design or consumable changes) and how practical modifications could help performance. This role could also encompass highlighting the opportunity to increase the breadth of instruments and liaising with suppliers when developing their next generation of instruments such that there is recognition of what could be helpful to evolve.