CLEAN AIR ADVISORY PANEL

Comments and suggested edits are provided following review by the COMEAP Secretariat and several COMEAP Members (combined comments /edits tracked as "Alison Gowers") and the COMEAP Chair.

Provided to Welsh Govt 19 December 2024

Advice Note (2024): Development of New $PM_{2.5}$ Air Quality Targets for Wales

Prepared for:

Welsh Government Clean Air Programme

July 2025

Terms of Reference

The Clean Air Advisory Panel (CAAP) is an independent committee which provides evidence-based advice and recommendations, on air quality matters in Wales to Welsh Government. At the request of the Welsh Government, independent and expert advice provided by CAAP informs and supports the development of Welsh Government air quality policy. Members of CAAP consist of multi-disciplinary policy makers, academia and air quality and public health practitioners.

CAAP's functions are to:

- Independently advise on and provide scientific evidence to support the development of Welsh Government clean air policy.
- Advise on current evidence in relation to air quality and its relationship with associated environmental, public health and economic factors.
- Work collaboratively across government, industry and academia, to ensure actions taken to improve airborne pollution in Wales are based on robust evidence.
- Encourage and maximise opportunities for innovative solutions which help to improve levels of airborne pollution.
- Advise the Welsh Government on future evidence needs and how they can be met.

Membership

Member	Organisation
Prof. Paul Lewis (Chair)	Chief Scientific Officer, Raven Delta Group; Professor Emeritus at Swansea University Medical School; UKRI Clean Air Programme Regional Champion for Wales.
Prof. Dudley Shallcross	University of Bristol
Dr James Heydon	University of Nottingham
Prof. Martin Clift	Swansea University
Prof. Gavin Shaddick	Cardiff University
Dr Ulli Dragosits	UK Centre for Ecology & Hydrology
Kieran Laxen	Kalaco Group Ltd and Institute of Air Quality Management
Dr Rachel Adams	Cardiff Metropolitan University
Dr Iq Mohammed Mead	Imperial College London
Prof. Enda Hayes	UWE Bristol
Dr Ed Rowe	UK Centre for Ecology & Hydrology
Prof. Sarah Jones	Public Health Wales
Gary Evans	Natural Resources Wales
Dr Ji Ping Shi	Natural Resources Wales
Natalie Rees	Transport for Wales
Tom Price	Welsh Air Quality Forum
Joseph Carter	Healthy Air Cymru, Asthma and Lung UK Cymru
Noel Nelson	Met Office

Executive summary

The strongest body of evidence connecting an air pollutant with mortality and other morbidity effects involves fine particulate, $PM_{2.5}$. Advice from COMEAP indicates that continuing to reduce $PM_{2.5}$ concentrations below 10 µg/m^3 will be beneficial to public health.

The CAAP recommend that $PM_{2.5}$ compliance assessment should be based on fixed monitoring using standard methods deployed at appropriate site locations, at a sufficient number of sites and be based on mass concentration. A suitable candidate for reporting a limit value is the 'Annual Mean Concentration Target' (AMCT) based on fixed monitoring, using suitable monitoring devices and taking account of measurement uncertainty.

The CAAP suggest that the most suitable exposure reduction target for consideration is the Population Exposure Reduction Target (PERT) based on fixed monitoring at suitable locations with enough monitoring points for a robust assessment.

The CAAP agreed that if Welsh Government wanted to consider subtracting of natural sources of $PM_{2.5}$ for compliance, then, in addition to acknowledgement of the concerns expressed by CAAP in the advice note, there would need to be a robust method of assessment and justification for subtracting, with the possibility of revisiting the issue if new evidence or methods became available.

Introduction

Welsh Government asked the Clean Air Advisory Panel (CAAP) for its expert scientific evidence and advice in relation to the setting of new national targets for air pollutants listed in the Environment (Air Quality and Soundscapes) (Wales) Act 2024 ("the Act"). The pollutants include: $PM_{2.5}$; ammonia; PM_{10}; ground level ozone; nitrogen dioxide; carbon monoxide; and sulphur dioxide. Advice should also have regard to any guidelines for that pollutant published by the World Health Organization in its most recent global air quality guidelines and include consideration of any additional pollutants the CAAP believe pose significant risk at the national scale.

Given the significance of, and complexity in, the development of air quality target setting, it was expected this would be an iterative process. $PM_{2.5}$ is the pollutant for which there is the greatest body evidence of harm to public health among those that are widely measured by monitoring stations. There may be others (e.g., various sources of ultrafine particulates) that could be more harmful, but there is not real-world human data available to support this. At the request of Welsh Government, an initial advisory paper on the rationale for the setting of new legislative targets for $PM_{2.5}$ was developed in December 2020 prior to publication of the current World Health Organisation (WHO) guidelines on the health risks of air pollution. The paper summarised the CAAP's position at that time. This current paper updates the CAAP's advice to reflect the current WHO guidelines as well as advice provided to Defra in relation to the setting of $PM_{2.5}$ targets in England by the Committee on the Medical Effects of Air Pollutants (COMEAP) and Air Quality Expert Group (AQEG). Further papers are likely to be developed to provide full and necessary consideration of all the pollutants listed in the Act.

The areas of the air quality target setting process considered by the CAAP in this paper include:

1. Target purpose

2. Target setting approach

    2.1. The form of the targets

    2.2. Pollutant assessment method

    2.3. Pollutant type

3. Target metrics, measurements, modelling and compliance assessment

    3.1. Limit Value

    3.2. Exposure Reduction target

    3.3. Considerations in setting a target and achieving compliance

1. Target purpose

There is significant evidence connecting both mortality and other morbidity effects of human health along with effects of ecosystem in the natural environment due to exposure to air pollutants. The human health related evidence has been comprehensively reviewed by the World Health Organization (WHO) who published its updated Global Air Quality Guidelines in September 2021[1]. The updated WHO Guidelines included reviews of the evidence linking adverse effects on health with concentrations of the following pollutants in ambient air: particulate matter (PM_{10} and $PM_{2.5}$), Ozone (O_3), Nitrogen Dioxide (NO_2), Sulphur Dioxide (SO_2) and Carbon Monoxide (CO).

The strongest body of evidence connecting an air pollutant with mortality and other morbidity effects involves fine particulate matter, $PM_{2.5}$, where the associations with many outcomes found in epidemiological studies are now widely considered to be causal (see for example the assessment by the USEPA[2]). The Committee on the Medical Effects of Air Pollutants (COMEAP) has provided advice on the health effects of exposure to fine particulate air pollution ($PM_{2.5}$) to the Department for Environment, Food and Rural Affairs (Defra), to inform the development of targets under the Environment Act 2021[3]. COMEAP's advice includes that:

- a focus on reducing long-term average concentrations of $PM_{2.5}$ is appropriate
- newer evidence indicates that $PM_{2.5}$ pollution can have harmful effects on people's health at lower concentrations than had been studied previously
- continuing to reduce concentrations to, or below, the World Health Organization's new Air Quality Guideline (AQG) of 5 $\mu g/m^3$ would benefit public health
- there is less evidence for benefits of reductions below this level, although the available studies have not indicated a concentration of effect below which there is no harm
- reducing exposure of the whole population would achieve the greatest overall public health benefit
- some individuals or groups are more at risk, but it might be difficult to reflect this in a national targets framework
- reducing air pollution to low levels is likely to be challenging and cost-benefit assessments may play a role in defining targets; and
- the health benefits of reducing other pollutants, such as nitrogen dioxide and ozone, should not be overlooked

The priority therefore is to consider the approach to strengthening $PM_{2.5}$ targets.

The previous (2005) WHO Guidelines had already been implemented in some countries when the original advisory note on $PM_{2.5}$ was prepared for Welsh Government in 2020. In Scotland, for example, the previous WHO guidelines for $PM_{2.5}$ were included as Local Air Quality Management

---

[1] World Health Organization. (2021). WHO global air quality guidelines: particulate matter ($PM_{2.5}$and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. World Health Organization. Available at: https://iris.who.int/handle/10665/345329.

[2] USEPA Integrated Science Assessment for Particulate Matter, Dec. 2019, available at https://cfpub.epa.gov/ncea/isa/recordisplay.cfm?deid=347534#tab-3

[3] COMEAP: Fine particulate air pollution (PM2.5): setting targets - GOV.UK)

objectives. Elsewhere in the world, notably in developing countries, the Interim Targets set by WHO for PM had also been implemented.

The WHO Guidelines, however, are set purely based on health impacts and take no account of the technical, economic, social or political feasibility of achieving them.

The existing target concentrations set for $PM_{2.5}$ in Wales were transposed from the EC Ambient Air Quality and Cleaner Air for Europe Directive 2008/50/EC which includes an annual mean limit target of 25µg/m^3 which is above (less stringent than) the 2021 WHO Guideline levels. It is logical that any new target setting is established with consideration of the 2021 WHO Guidelines, as well as health-based evidence such as set out by COMEAP, alongside consideration of the practicalities of measuring and assessing compliance of a target.

The available evidence for $PM_{2.5}$ has not identified a threshold for effect at the population level, due to exposure (*i.e.* there is no exposure threshold relative to human health effects). This is particularly true of most epidemiological studies in the last decade or more where 'no-effect' concentrations have not been clearly identified for human health. WHO recognises that the new guidelines may be challenging to meet immediately and recommend the use of interim targets on the path to reduce $PM_{2.5}$ exposures to as low as possible. Therefore, there is merit in any target value being set as low as possible to maximise the benefit.

2. Target setting approach

2.1. The form of the targets

The 2021 WHO Guidelines are still set without reference to technical, economic, social or political feasibility of achieving them. As recognised by the WHO, when national governments or authorities set standards, the process needs to aim at achieving the lowest concentrations possible in the context of local constraints, capabilities and public health priorities.

Historically, statutory air quality targets for outdoor air have been formulated as standards or Limit Values which must be met everywhere in countries. The main advantage of this approach is that it ensures a form of environmental equity or 'level playing field' by adopting a consistent air quality benchmark for all geographical regions in Wales. This form of legislative targets is easily understandable by the public and the media and provides a convenient metric for assessing the extent of progress towards cleaner air. This public interest and high profile of standards such as the guidelines produced by the WHO are such that it would be almost impossible to not consider the use of this type of metric.

Limit Value compliance reporting refers specifically to ambient air (i.e. outdoors). However, compliance reporting can exempt extremely small ambient micro-environments e.g. within carriageways or the area near to road junctions, along short roads (less than 100m in length) etc.

A legal target of the form of a single standard to be achieved everywhere will not in general drive optimal improvements in public health. This situation arises because, as mentioned above, legal standards are in general higher than levels where adverse effects could still be experienced. Policies to achieve compliance of a single standard or Limit Value over an increasingly small area will improve public health for an increasingly small number of people with a disproportionate focus on small hot spots that exceed those limits but permit concentrations to increase elsewhere. Another issue with the use of a Limit Value on its own is that, if pollutant levels are seen by the public to remain below the target set then any increases of concentrations that occur in the future risk not being realised as a public health concern.

This was recognised in the formulation of the original EU Ambient Air Quality Directive (2008/50/EC)[4] and it led to the incorporation of the 'exposure reduction' concept where reductions were required, not at single points in a country, but over an average of monitoring locations. The concept is applicable to $PM_{2.5}$, where adverse effects would be expected even below a single value standard or Limit Value. This concept formed a 'twin track' approach with the traditional Limit Value running alongside the 'exposure reduction' approach which is broadly supported by scientific evidence. Use of a twin target approach could ensure that local as well as distant sources are considered in mitigation to reduce $PM_{2.5}$ exposure. It should be noted however that a reduction of emissions at local, national and international levels is still required. The CAAP have also considered the target setting process used by Defra, as applied to England, as detailed in The Environmental Targets (Fine Particulate Matter) (England) Regulations 2023[5].

The CAAP agree with COMEAP's advice to Defra in that setting long term annual average targets for $PM_{2.5}$ would broadly be protective of short-term acute health impacts[6]. The CAAP are also mindful of the advice that COMEAP provided to Defra on the $PM_{2.5}$ target for England, where the available evidence indicates that continuing to reduce $PM_{2.5}$ concentrations below 10μg/m^3 will be beneficial to public health[5].It is important however to stress that there will still be health benefits of (even small) concentration reductions of $PM_{2.5}$ when levels remain above 10μg/m^3, particularly in areas of larger populations and thus greater exposure.

The CAAP **agree that a twin track approach should be used in Wales as the best way of ensuring continued improvements in public health.**

2.2 Pollutant assessment method

Measurements of $PM_{2.5}$ concentrations using appropriate reference monitoring provide quantitative measures of concentrations traceable to known physical quantities of pollutants at specific locations. Although monitors can provide us with a record of pollution levels at specific locations, they are not without their own drawbacks. Measurements made at these sites generally tend to be representative of point locations (with slight exceptions for background sites). This should not necessarily present a problem if there are many monitors to give good spatial coverage. However, installing and maintaining a dense network of monitors is expensive – consequently we tend to limit the number of monitors used - calling into question their level of spatial coverage – where rural locations are often affected most by this inadequacy. Over extended periods of time some monitoring stations are set up or removed and instrument faults as well as maintenance issues may lead to gaps in the monitoring record. Not all stations record the same pollutants, which again can lead to inconsistencies. It is for this reason that the European Directive on Ambient Air Quality and Cleaner Air for Europe (2008) indicated a desire to move away from the sole use of monitoring to assist policy development and placed more of an emphasis on the use of models to complement the data obtained from observation sites. That said, atmospheric dispersion models have their own set of limitations which may lead to

[4] https://eur-lex.europa.eu/eli/dir/2008/50/oj
[5] https://www.legislation.gov.uk/uksi/2023/96/contents/made the spatial coverage is of concern, with large areas
[6] COMEAP advice note, July 2022, available at: https://www.gov.uk/government/publications/comeap-advice-note-environment-act-pm25-targets/comeap-advice-note#reduction-in-pmsub25sub-concentrations

uncertainties. For the time being, the use of monitoring is potentially considered to be more legally robust than predicted concentrations from modelling. However, it is not possible to monitor everywhere across the country, so a combined approach that uses a combination of monitoring and modelling could add value.

The legal robustness of monitoring is based on the requirement that the legislation would define the Reference Method for monitoring e.g. as defined by CEN standards, or methods which could be shown to be equivalent to that Reference Method. Indeed, measurements from monitoring have broad public acceptance, and have rarely been subject to legal challenge. It is important to also note the uncertainty of measurements at lower concentrations of $PM_{2.5}$ by the Reference Method. Uncertainty in measurements of $PM_{2.5}$ is approximately 1µg/m^3 when the absolute concentration is 5µg/m^3 and 0.5 µg/m^3 when the absolute concentration is 12µg/m^3. Whilst acknowledging that $PM_{2.5}$ is predominantly a regional pollutant (although it does vary spatially at a local level), measurements from monitors are recorded at a limited number of points across Wales (even if the monitoring network were expanded) meaning that most of the population will live in locations where $PM_{2.5}$ is not directly measured.

Modelling has the advantage of providing comprehensive coverage of predicted concentrations compared to the specific (and relatively sparse) number of monitoring locations. Modelling also permits the policy developer to explore potential 'what-if' type scenarios for future policy development – what if we reduce emissions from a specific sector by x% or what proportion of air quality exceedances are due to home-grown emissions rather than transboundary movement? Atmospheric Chemistry Transport models attempt to recreate the processes that dictate the fate of any pollutant emitted to the atmosphere.

Models vary considerably in the level of sophistication embodied in their coding. Some use very basic science and are therefore quick to run and are generally used as 'screening tools' while others employ a range of physics and chemistry to better represent real world conditions. Some of the differences we witness between different model analyses are usually due to the difference in the levels of science they employ. With the range of models accessible for work in this field, it is important that the user is aware of each model's limitations. It is critical, especially with applications for policy development, that they are not used in ways that are beyond their capability.

Given the wide range of questions that could be asked by the policy developer, and the wide range of models with varying degrees of strengths and weaknesses available, matching the correct model to the questions being asked will be important. Usually, the analysis provided by any one model can normally be confirmed by using another similar standard model. There is, at present, no nationally recognised standard or 'approved' modelling approach. However, there are examples of modelling performing well when compared to measurements and modelling can provide important additional spatial and temporal information that will not be available from monitoring alone. It can provide a useful tool for helping to determine how many $PM_{2.5}$ monitors are required, and where they should be located to ensure that they enable statistically sound assessments and are representative of exposures in areas, and populations, that they are intended to reflect. Modelling can also allow additional analyses to be performed, for example how concentrations have changed in areas where no monitors are located with assessments of exposures across the population more broadly, and different scenarios to be assessed, for example projections of future compliance.

However, the uncertainties associated with modelling, specifically the choice of modelling approach, when predicting concentrations and how those predictions should be used in reporting protected compliance and interim progress towards a target both require additional consideration. One option to help reduce this source of uncertainty would be for Welsh Ministers to commit to reporting regularly on model-based metrics, and their improvement, with scrutiny by an expert panel of scientific experts.

Based on current scientific and technical knowledge, as well as the uncertainties around monitoring and modelling referred to above, the CAAP recommend that $PM_{2.5}$ compliance assessment should be based on fixed monitoring using standard methods deployed at appropriate site locations at a sufficient number of sites. Such methods should be undertaken to at least the same standards as referred to by the Air Quality Standards (Wales) Regulations 2010, taking account of any subsequent changes to guidance or developments in best practice.

2.3. Pollutant type

There is a significant history of using $PM_{2.5}$ mass concentrations as the measure of exposure to airborne particulate matter and for reporting against compliance criteria. In particular, the large epidemiological studies linking exposure and poor health outcomes generally rely on measurement of mass concentration and this means that potential differences in toxicity of different components are not fully clear. Therefore, it is most practical to base a target on a mass concentration. The CAAP note however that $PM_{2.5}$ is an aggregated total of different chemical species with different particle sizes and numbers that can have differing impacts on health.

Given that particle concentrations derived from anthropogenic emission sources (as primary or secondary aerosols) are superimposed on other particle components such as dust, future emission reductions from different sources will naturally lead to composition changes. Additionally, the relative importance of non-exhaust particulate matter such as brake dust, tyre wear and microplastics are likely to increase over time and the toxicity of these components has been poorly characterised. In addition, particle number concentration and particle composition could also be useful measurements of particles and something to consider for the future.

The CAAP recommend that $PM_{2.5}$ measurements should be based on mass concentration, however, measurements of particle number concentration and composition should be accounted for as part of supplementary information reported.

3. Target metrics, measurements, modelling and compliance assessment

The Environment (Air Quality and Soundscapes) (Wales) Act 2024 requires that, before making regulations to set or amend a target, Welsh Ministers must be satisfied that any target, or amended target, can be met. The target level chosen would need to depend on what can be achieved feasibly and how success can be evidenced. Also included are duties on Ministers to review targets every 5 years, and thus there could be an option for target levels to be changed subject to Ministerial consideration in the future as technology evolves.

3.1. Limit Value

If assessment is to be based on fixed monitoring with a maximum concentration value at any representative location, and with a goal to reduce short-term as well as long term exposure, then an annual mean metric would be suitable. A suitable candidate to be considered for reporting a Limit Value is the **'Annual Mean Concentration Target'** (AMCT). For testing compliance against Limit Values, it is therefore recommended that an assessment should be carried out for individual calendar years with no averaging over multiple years. Furthermore, the AMCT should not attempt to account for varying levels of population susceptibility.

In setting a long-term reduction target, an annual mean concentration metric is susceptible to large variabilities from year-to-year due to meteorological factors such as lower wind speeds maintaining higher local concentrations, or variations in wind direction leading to varying amounts of transboundary $PM_{2.5}$ input to Wales from the rest of the UK and continental Europe. Therefore, the use of longer-term averaging, for example smoothing out variation over a 3-year period and calculating a rolling mean, would provide a better estimate of the metric for comparison against a baseline.

If modelling were to be used as a supplementary method to estimate $PM_{2.5}$ concentrations at locations where there are no monitors present, then it would be important to ensure the locations reflect those for which the target was set. For example, if an AMCT was set for suburban areas, i.e. it was not set based on the concentrations near to a roadside, then it would not be appropriate to consider modelling of concentrations at near roadside locations in comparison to the target. Furthermore, if modelling were to be used as a supplementary method to estimate $PM_{2.5}$ concentrations at locations where there are no monitors present, then a number of potential metrics could be used and summarised here.

An **'Accumulated Exceedance'** metric is calculated[7] by summing the population in each model grid square (e.g. 1km x 1km although even this resolution might not pick up hot spots) multiplied by the excess concentration above the AMCT, over all grid-cells in which the standard is exceeded. This approach is dependent on modelling of concentrations. A '**Population-weighted Mean Concentration'** (PWMC)[8] metric, unlike Accumulated Exceedance, can be used to calculate, approximately[9], the health impact of a pollutant such as $PM_{2.5}$. This metric is also reliant on a model calculation. A '**Deprivation-indexed Population-weighted Mean Concentration'** (DPWMC) is a refinement of the PWMC metric to weight the concentration/population product using health and/or deprivation data for each modelled grid square. For example, the income deprivation indicator from the Welsh Index of Multiple

[7] Accumulated exceedance = Σ population x Max (0; C-T), where the sum is over all grid squares in the country.

[8] PWMC is defined as $\Sigma P_i C_i / \Sigma P_i$ where P_i and C_i are the population and concentration in grid square I and the sum is over all grid squares.

[9] The calculation would be approximate since the PWMC metric averages PiCi over the whole area before calculating health impacts whereas if the health impact is calculated in each grid square and then summed, the total will in general give a higher impact than the PWMC.

Deprivation (WIMD) could be taken as a proxy for the multiple deprivation index score[10] in each grid square to allow calculation of a DPWMC[11].

The CAAP suggest that a suitable candidate for reporting a limit value is the 'Annual Mean Concentration Target' (AMCT) based on fixed monitoring at suitable locations in sufficient numbers, using suitable monitoring devices and taking account of measurement uncertainty. For testing compliance against limit values, assessment should be carried out for individual calendar years with no averaging over multiple years.

3.2. Exposure Reduction target

It should be noted here that in this context the term 'exposure' does not refer to the true exposure of people as they move in their daily lives through a range of outdoor and indoor micro-environments. It simply refers to the assumption that some form of outdoor monitored or modelled concentrations is a surrogate for this true exposure. The question then becomes how best to formulate such a target in the 'twin-track' approach combined with a standard or limit as discussed in the previous section.

A '**Population Exposure Reduction'** approach is an option which sets a requirement for a reduction in concentration over a given time frame. This is the approach which has been incorporated in England for the Pollution Exposure Reduction Target (PERT) based on measurements.

A **'Primary Emission Reduction'** approach would calculate direct active emissions of $PM_{2.5}$. Such an approach is currently in legislation for $PM_{2.5}$ emission reduction such as in the National Emission Ceilings Regulations, 2018.

Other metrics have been suggested, including 'Population (number of people) living in locations above a concentration', 'Area above a concentration' and 'Population weighted mean exceedance' (PWME). If modelling were to be used as a supplementary method to estimate $PM_{2.5}$ concentrations at locations where there are no monitors present, then a number of potential metrics could be used. An **'Average Exposure Indicator'**[12] can be defined as the *average* $PM_{2.5}$ concentration measured in a geographic zone at locations representative of exposure. These representative locations have typically been urban background monitors.

It would be best to focus the exposure reduction target using only measurements made away from any direct influence of local sources. The CAAP note previous considerations by AQEG around metrics, their calculation and assessment. Recommendations included that the PERT should be expressed as a population-weighted mean concentration. Population weighting for the PERT can be most effectively accomplished by calculating the average across monitoring stations that are strategically located in proportion to population distribution. This approach ensures that the data collected more accurately represent the exposure levels experienced by the majority of people in a given area. If interim targets were set, these could include population weighted mean concentrations and mean exceedance, reductions in UK emissions and

[10] Brunt et al., A pragmatic public health-driven approach to enhance local air quality management risk assessment in Wales, UK (2019), Environmental Science & Policy, 96:18-26

[11] DPWMC index as ΣDiPiCi/ΣPi where Di is the deprivation index in grid square i

[12] The approach set out in EU Directive 2024/2881

reductions in PM component concentrations where measured[13]. Therefore, the use of longer-term averaging, for example smoothing out variation over a 3-year period and calculating a rolling mean, would provide a better estimate of the metric for comparison against a baseline.

As with an AMCT, a PERT should also not attempt to account for varying levels of population susceptibility.

Again, as with an AMCT, if modelling were to be used as a supplementary method to estimate exposure reduction at locations where there are no monitors present, then it will be important to ensure the locations reflect those for which the target was set. For example, if an AMCT was set for suburban areas, i.e. it was not set based on the concentrations near to a roadside, then it would not be appropriate to consider modelling of concentrations at near roadside locations in comparison to the target.

The CAAP suggest that the most suitable exposure reduction target for consideration is the Population Exposure Reduction Target (PERT) based on fixed monitoring at suitable locations and with a sufficient numbers of monitoring points for a robust assessment.

3.3. Considerations in setting a target and achieving compliance

As noted above, it is the CAAP's view that legal compliance should be assessed through monitoring and supported by modelling to provide supplementary understanding where necessary. Currently, for air quality assessment, Wales is divided into two zones and two agglomerations for the purposes of reporting air pollution monitoring. These defined areas permit assessments to be carried out separately allowing account of local source impacts and environmental conditions. This system could continue to be used for assessment of new $PM_{2.5}$ targets and legal compliance which will allow comparison with current and previous data. As noted by AQEG however, there is no compelling reason to change the current EU reporting zones for regional exposure reduction metrics[13].

Measurement-based compliance reporting would have multiple benefits and disadvantages. Regularly tracking and monitoring of progress towards established targets would be the most effective way to measure advancement, despite not being a legal requirement. However, this method may face challenges in accurately predicting whether future compliance deadlines will be met. It would not however easily be used to estimate health and economic impacts if required in the future. For assessment of compliance through monitoring however, data capture criteria need to be set to minimize uncertainty. For example, a monitor should be operational for at least 90% of the period over which concentrations are assessed. Ideally, management of missing data from monitoring stations should avoid complicated manipulation of data. Furthermore, for reference instruments, natural measurement fluctuations that occur during monitoring also lead to uncertainties, hence a level permitted of +/- 25%. As air quality improves and pollutant concentrations decrease in the future, the AQEG points out that the measurement uncertainty between various technologies and the reference method is likely to increase. Consequently, the

[13] https://uk-air.defra.gov.uk/assets/documents/reports/cat09/2205061255_Air_Quality_Targets_Technical_Workshop.pdf

equivalence or comparability of these different measurement technologies may become less reliable under such lower-concentration scenarios.[14]

As stated, monitoring of $PM_{2.5}$ concentrations using appropriate equipment is more robust than deriving exposure metrics that solely rely on models for their calculation due to the requirement of a Reference Method. One disadvantage of a measurement-only approach is that defining a reasonably credible surrogate for all exposure e.g. an urban, or indeed a national population would require a substantial increase in monitoring in Wales and the locations would need to be selected carefully to represent proportionally the distribution of the population exposure across Wales. The location of monitors may be open to legal challenge if not considered representative of exposure in relation to a target set. Thus, ensuring any target set can be achieved when accounting for strategic and spatial planning is important. Any measurement-based compliance reporting will also need to be representative of locations where new exposure may be introduced e.g. new residential development or newly established emission sources.

Increasing the scale of monitoring to support targets has been proposed in the draft Clean Air Plan for Wales[15], although any enhancement is unlikely to be able to detect small-scale local variations (or peaks) in concentrations. This potential disadvantage could be mitigated to some extent by including some of the even higher concentration 'hot spots' in an expanded monitoring network.

The placement of new monitoring sites would need to ensure that an appropriate and representative cross-section of environments is covered, for example, residential areas near sources of $PM_{2.5}$. Road transport (including non-exhaust emissions), domestic and commercial combustion (particularly wood burning) and industry are significant local contributors to annual mean concentrations. Non-exhaust road traffic and domestic combustion are sectors in which authorities currently have limited significant regulatory powers or ability to control. Also, a PM2.5 target may prove difficult to achieve in some 'hot spot' areas around large industrial plants where a liaison with Natural Resources Wales would be required to achieve compliance. Locations, such as near to road junctions, are generally where road traffic is congested and $PM_{2.5}$ concentrations are highest, often combined with relevant exposure (e.g. residential properties). Exempting these from compliance may miss opportunities for meaningful benefit, including for example, when considering active travel, such as cycling (omitting cycle carriageways is potentially increasing the health burden on the economy). It is debatable whether monitoring near to $PM_{2.5}$ roadside sources is of benefit to calculation of the PERT but could be included when assessing compliance with a Limit Value[12]

As stated, population weighting for the PERT can be calculated using the average across monitoring stations that are strategically located in proportion to population distribution. It is also likely that exposure reduction targets will focus on background measurements. The most socioeconomically disadvantaged areas tend to have the highest pollutant concentrations. This, together with such populations being the most susceptible to $PM_{2.5}$ (due to high prevalence rates

---

[14] https://uk-air.defra.gov.uk/assets/documents/reports/cat09/2205061255_Measurement_Uncertainty_for_PM2.5_in_the_Context_of_the_UK_National_Network.pdf

[15] https://www.gov.wales/sites/default/files/publications/2020-08/clean-air-plan-for-wales-healthy-air-healthy-wales.pdf

of chronic illness) can lead to disproportionate health burdens. A study of England showed that there were modest socioeconomic differentials in $PM_{2.5}$ concentrations but comparatively large differentials in associated mortality burdens due to the very strong socioeconomic gradients in underlying mortality rates[16]. In Wales, air pollution concentrations were also reported to be highest in most deprived areas[17]. Considered simultaneously, air pollution added to already strong deprivation-health associations; interactions between air pollution and deprivation were found to modify and strengthen associations with all-cause and respiratory disease mortality, especially in most deprived areas and where health needs are greatest.

Ricardo have previously provided Welsh Government with an assessment of monitoring options to underpin $PM_{2.5}$ targets and establish new monitoring sites across Wales, supplemented by additional rural sites. This technical advice was based on a detailed analysis of population density, exposure gradients, and spatial representativeness. The report proposed that a minimum of an additional eleven monitors would be required across Wales. Following discussion, CAAP Members concluded that the technical advice was both proportionate and fit for purpose to cover Wales spatially. In determining the number of monitoring sites required for England, AQEG used an approach to account for measurement error in the PERT compliance reporting network. This method assumed that the cumulative error across the network depends on the average error of an annual mean measurement at a single site and the square root of the number of such measurements. The CAAP has also been asked to review this approach, which remains ongoing, and consider its implications for determining the number of monitors required in Wales.

A relatively substantial proportion of $PM_{2.5}$ concentrations in Wales also derive from transboundary sources that cannot be controlled by the Welsh Government because they originate from outside Wales (other countries, international shipping etc) or are from natural sources (such as sea salt or volcanic eruptions). Accounting for and quantifying the contribution from transboundary $PM_{2.5}$ that may increase in the future is difficult through monitoring and the uncertainty introduces risk when setting target concentrations and compliance dates. Natural source components of $PM_{2.5}$ (such as sea salt) are difficult or impossible to control but may account for substantial contributions to a monitored pollutant sample. Whereas modelling can be used to try to elucidate the different sources of $PM_{2.5}$, subtracting transboundary of natural contributions is non-trivial. Modelling could be used to determine air trajectory paths at the fixed monitoring sites. In this way, easterly sites could provide an estimate of incoming trans-boundary pollution and westerly sites could provide background estimates, assuming prevailing westerly winds. The models used to derive air mass trajectories are generally subject to smaller uncertainties than atmospheric chemistry models. If used, 5-day back trajectories are not necessary, but 1-day would be sufficient and are more reliable.

Panel members agreed that if Welsh Government were going to consider subtracting of natural sources of PM2.5 for compliance, then, in addition to acknowledgement of the concerns expressed above, there would need to be a robust method of assessment and

[16] Milojevic et al., Socioeconomic and urban-rural differentials in exposure to air pollution and mortality burden in England (2017), Environmental Health, 16:104

[17] Brunt et al., Air pollution, deprivation and health: understanding relationships to add value to local air quality management policy and practice in Wales, UK (2017), Journal of Public Health, 39:485-497

justification for subtracting, with the possibility of revisiting the issue if new evidence or methods became available.

Finally, modelling could help in assessing compliance by allowing ongoing review of strategic planning and the impact on complying with any targets set. Modelling can also be updated annually (or at a set interval) to incorporate the latest emission factors and projections leading to a more ‘realistic’ scenario of the future compared to basing a target exclusively on modelling carried out with the current model version and available input datasets on emissions. Purely model based metrics for compliance reporting could, however, pose potential legal problems in that there are no well-defined standard modelling methods, models are inherently uncertain and change with time, and the legislation could be vulnerable to challenge from alternative calculations by other organisations. However, although not a legislative requirement, modelling does provide advantages such as use of a metric like the PWMC to directly give an approximate estimate of the total health impact of a pollutant such as $PM_{2.5}$. However, potential changes in particle composition and toxicology over time and uncertainties in modelling lead to uncertainty in estimation of health impacts. Projecting future compliance with targets, as well as the current trajectory towards target compliance through modelling, could though be carried out at any stage.

In summary, the CAAP advise that, in the process of target setting, Welsh Government consider the causes and effects of uncertainties that could arise through monitoring and supplementary modelling and possible implications in achieving future compliance.