Department
for Environment
Food & Rural Affairs

Assessing progress towards WHO guideline levels of $PM_{2.5}$ in the UK

July 2019

This publication is available at www.gov.uk/government/publications

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Executive summary

Air quality in the UK has improved considerably in recent decades – for example, annual average $PM_{2.5}$ concentrations at background and roadside locations fell by 23 and 26% respectively between 2010 and 2018[1]. Much progress has been made in reducing emissions to air and subsequently the air we breathe now is cleaner than it has been for many generations.

However, air pollution is still the largest environmental risk to public health and contributes to shortening and reducing the quality of life for thousands. Fine particulate matter ($PM_{2.5}$) is widely understood to be the pollutant that is the most damaging to health, which is why we have already outlined bold action in our Clean Air Strategy[2] and why we are considering how we can go further to reduce health impacts.

What is particulate matter?

Particulate matter (PM) can be anything in the air that isn't a gas and can include both man-made and naturally occurring materials. PM can find itself in the air as a result of all types of human activities as well as natural processes. For example, PM is directly emitted from industry, vehicles or homes, but is also generated through physical processes such as brake and tyre wear from the vehicles we use, or simply lifted into the air as a result of human activity or wind patterns. PM is commonly separated into two size fractions $PM_{2.5}$ and PM_{10}. $PM_{2.5}$ relates to the smaller particles with a size limit of 2.5 microns in diameter and is the most damaging to health.

Alongside 'primary PM' (emissions of PM to the air arising from activities such as burning coal and wood), 'secondary PM' is formed from pollutant gases (precursor gases) combining in the atmosphere. A key source of secondary PM is ammonia released from agriculture. Controlling emissions of primary $PM_{2.5}$ and precursor gases is a key challenge to reduce $PM_{2.5}$ levels and is the focus of the Clean Air Strategy that was published in January 2019. However, $PM_{2.5}$ can travel large distances and subsequently around a third of $PM_{2.5}$ in the UK is from non-UK sources, disproportionately affecting the south eastern areas of England, including London, so it is important that we work with our neighbours to reduce the impacts of $PM_{2.5}$.

Although large industrial processes and agriculture can be significant sources of PM or precursor gases, it is often the things we make everyday decisions to use that make the greatest contributions, such as how we choose to travel and how we heat our homes.

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1 https://www.gov.uk/government/statistics/air-quality-statistics

2 https://www.gov.uk/government/publications/clean-air-strategy-2019

Understanding the processes behind PM emissions, its formation, and movement in the atmosphere is complex. This presents a significant scientific challenge to accurately assessing levels of PM in the atmosphere, particularly in future years. As $PM_{2.5}$ is not a single substance but comprises a complex mixture of materials and chemical species, from a large diversity of sources and activities, it means there is a significant element of uncertainty in our analysis and it could be a long time before we fully understand all aspects of its formation and behaviour in the atmosphere, as well as the mechanisms of how it affects our health. However, evidence available to us suggests there is a compelling case to act now, despite these complexities and uncertainties.

Health impacts of PM

There is now a large body of evidence linking air pollution to health impacts at levels still found in the UK. Associations are particularly strong for long term exposure to $PM_{2.5}$. These particles are known to enter the blood stream and are carried into many organs in the body and are linked to a range of health impacts including respiratory and cardiovascular illness, such as aggravation of asthma and respiratory symptoms. This in turn has been linked to an increase in hospital admissions as well as mortality from cardiovascular and respiratory diseases and lung cancer.

Given the health impacts associated with $PM_{2.5}$ there is a compelling case to reduce the contributions from man-made sources to reduce public exposure as far as practically possible.

The World Health Organization (WHO) recognises the harm that air pollution can do. Current estimates by the WHO indicate that world-wide ambient (outdoor) air pollution is responsible for some 4.2 million deaths per year[3] globally. The WHO publish Air Quality Guidelines[4] to support the setting of air quality standards worldwide by considering the body of evidence for key pollutants: particulate matter ($PM_{2.5}$ and PM_{10}), ozone, nitrogen dioxide (NO_2) and sulphur dioxide (SO_2). These guidelines represent recommended maximum levels for pollution in ambient air that countries should aim to achieve and are set purely on an understanding of the human health impacts. In setting these guidelines, the WHO do not consider the practicalities of policy development and implementation, including issues of costs and proportionality. Rather, the guidelines are intended to inform the process of setting standards alongside policy discussions.

The UK already has legally binding ambient air quality standards for these pollutants, as well as for a range of other pollutants such as carbon monoxide and benzene. Latest

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[3] https://www.who.int/airpollution/en/

[4] http://www.euro.who.int/en/health-topics/environment-and-health/air-quality/publications/pre2009/air-quality-guidelines.-global-update-2005.-particulate-matter,-ozone,-nitrogen-dioxide-and-sulfur-dioxide

evidence shows that the UK meets legal limits for all pollutants with the exception of NO_2. To keep this exceedance as short as possible, in July 2017 we published *The UK Plan for Tackling Roadside Nitrogen Dioxide Concentrations* supported by a £3.5bn investment into air quality and cleaner transport.

The Government's Clean Air Strategy (CAS) committed to the setting of a new ambitious, long term target to reduce the population's exposure to $PM_{2.5}$ and also committed to reducing the number of people affected by levels of $PM_{2.5}$ that exceed WHO guidelines.

The UK is the first country in the world to commit to a target that takes the WHO guideline levels for $PM_{2.5}$ into consideration. To support this ambition, Government commissioned analysis to consider how far the ambitious action set out in the CAS would take us towards the guideline level and to begin to consider what additional action would be needed in order to achieve it. This initial phase of work focussed on assessing current commitments and did not attempt to establish what date WHO guidelines might be achieved.

Our approach

In order to consider what level of action will be needed to achieve the WHO guideline annual mean level of $PM_{2.5}$ of 10µg/m^3 in the UK, we are carrying out analyses in 3 phases:

1. Estimating how $PM_{2.5}$ concentrations are likely to be reduced across the UK by meeting our national emissions reduction commitments for all five key pollutants by 2030.

2. Using the latest microsimulation modelling to update estimates of the reduction in cases of disease and resulting public health benefits to be achieved:

    a. As a result of achieving the 2030 emissions reduction commitments; and

    b. The further benefits and disease reductions to be realised as a result of achieving further reductions in $PM_{2.5}$ concentration to achieve these levels across all the UK.

3. Identifying, following detailed analysis, the further options for measures beyond the CAS and their costs to achieve WHO guideline levels in areas of the UK identified in the first analysis as not meeting the WHO guideline limits under current commitments as well as reflecting climate change policies, technological innovation and behaviour change.

This publication comprises two reports that were commissioned under the first phase to explore how close $PM_{2.5}$ levels get to the WHO guideline levels in the UK by 2030, as a result of the actions set out in the CAS. This date reflects current commitments to meet our national emission reduction commitments – a key focus of the CAS.

The first report (Annex 1) is the output of work undertaken by Imperial College London on behalf of Defra using the United Kingdom Integrated Assessment Model (UKIAM). This model works by establishing relationships between emissions and concentrations and uses these relationships to evaluate how future emissions scenarios may impact $PM_{2.5}$ concentrations in future years. A second report (Annex 2) was commissioned by Defra from King's College London to replicate the main scenarios explored in Annex 1, but to apply the scenarios to more sophisticated modelling. This type of modelling simulates atmospheric processes (such as complex chemistry, physics and meteorology) rather than being based on established relationships, in order to calculate air quality concentrations under specific emissions reduction scenarios. Running both assessments, we are able to compare and validate the key findings.

These reports were reviewed by Defra's Air Quality Expert Group (AQEG)[5] in order to ensure independent scientific expert scrutiny of the analysis undertaken. The group have provided their expert views on the key findings which we are also publishing (see Annex 3).

AQEG's review illustrated the scientific challenges inherent in such modelling studies – in this case, their review highlighted the challenge of predicting concentrations of $PM_{2.5}$ due to the significant elements of uncertainty associated with current understanding of specific emissions sources, understanding about future emissions as well as uncertainties in how the models work in predicting levels of $PM_{2.5}$ now and in the future.

Such uncertainties illustrate how complex the challenge of assessing $PM_{2.5}$ levels in future years is. AQEG have made a range of recommendations that will be used to inform the next phase of work but although we hope to address some of these uncertainties, many are inherent to the challenge of predicting future concentrations in this manner and will therefore remain, regardless of how much additional modelling is undertaken. It is therefore important to recognise the limitations of the evidence presented and to not take the findings out of context. For example – maps of model outputs are good at providing a geographical representation of a model output but they tell you little about the range of possible outcomes. For this purpose, tables are presented in the reports that aim to provide a more realistic range of possible results, but again cannot capture the full range of uncertainties inherent in the scenarios.

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[5] https://uk-air.defra.gov.uk/library/aqeg/

Key findings

The key findings of this work show that:

- actions set out in the Clean Air Strategy take us a substantive way towards achieving the WHO guideline level for $PM_{2.5}$ across the country. However, this evidence shows that there will be localised areas, in particular in central London, where higher levels are likely to persist

- not all benefits are delivered through UK emission reductions; part of the benefit will be dependent on EU Member States meeting their own emission reduction commitments, due to transboundary transport of PM

- in all cases, population exposure to $PM_{2.5}$ will be substantially lower in 2030, relative to now

More specifically, the central scenario that delivers a minimum reduction to meet 2030 emissions reduction commitments will deliver:

- an estimated health benefit of ~ £6.8 billion per year based on newly published damage costs[6] (nb: this does not include NHS and social care costs)

- a reduction in population exceedance of WHO guideline levels of $PM_{2.5}$ of 95% (based on calculation of the population's accumulated exceedance of WHO) compared to 2016

- a reduction in the number of people living in locations that exceed WHO guideline levels of $PM_{2.5}$ of over 80% compared to 2016

- a reduction in the average exposure of populations living in areas above WHO guideline levels of 1-2 $\mu g/m^3$ compared to 2016

Scenarios that deliver greater emissions abatement are also included in the Imperial College report (Annex 1) and demonstrate how further action can deliver additional benefits.

It should be recognised that these analyses have a number of key uncertainties and constraints. In particular, the analyses do not take into account the potential impact of technological innovation, climate change policies or behaviour change in future years.

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[6] https://www.gov.uk/guidance/air-quality-economic-analysis

It is important to develop the scientific modelling of this nature to incorporate a wider range of measures as well as to ensure the modelling is underpinned by appropriately robust assumptions. However, modelling of this sort alone will never provide a definitive evidence base as it should always be evaluated alongside a wider suite of evidence that considers economic analysis and the practical deliverability of measures.

This modelling has demonstrated significant progress is likely to be made but also identified that additional measures will be needed and highlighted where the modelling approach needs further development. It is clear that further modelling, beyond 2030, will introduce an additional level of uncertainty and many of the additional measures that will potentially be needed are currently difficult to quantify (i.e. behaviour change). It is therefore important to have realistic expectations of the level of further clarity that can be achieved by additional modelling and to accept that there will always be a degree of inherent uncertainty that cannot be overcome.

In light of this, there are a number of next steps that are important in advancing this work that are outlined below.

Conclusion and next steps

This analysis demonstrates that measures in the Clean Air Strategy, alongside action by EU Member States, are likely to take us a substantial way towards achieving the WHO guideline level for annual mean $PM_{2.5}$, including an anticipated 95% reduction in the population exceedance of WHO guideline levels of $PM_{2.5}$ in 2030 compared to 2016. It also helps us understand where further action is needed.

It is important to recognise that the analysis is limited in scope to a sub-set of available policy measures. Therefore, at present, irrespective of cost, we do not know the measures it would take to meet the WHO guideline levels for everyone in the UK by 2030.

However, the analysis does not yet take into account important wider policy measures such as behaviour change, technological innovation and our commitment to deliver net zero GHG emissions, nor does it take into account benefits beyond 2030 from government policies which have already been agreed to, such as the Road to Zero strategy. It also does not include some factors that could have negative impacts on future achievability such as climate change and urban density trends. We must also recognise the natural irreducible contributions and imported contributions from other countries, over which the government has limited control.

On the basis of scientific modelling, which has not considered full economic viability and practical deliverability, we believe that, whilst challenging, it would be technically feasible to meet the WHO guideline level for $PM_{2.5}$ across the UK in the future. Substantive further analysis is needed to understand what would be an appropriate timescale and means, and we will work with a broad range of experts, factoring in economic, social and technological feasibility to do this.

This will be achieved through the following steps:

Health benefits

- Public Health England will continue to build on work they have previously undertaken to explore the burden on health services related to future scenarios of air pollution

- PHE will progress work to evaluate the expected benefits of implementing the actions in the CAS as well as explore the potential benefits of achieving WHO guideline levels across the UK

Modelling development

There are a number of expert recommendations made by AQEG that we are already taking forward and which will help underpin the evidence and provide a stronger base on which experts can provide further advice.

- we will improve our modelling to address some of the key recommendations from AQEG in order to provide a stronger and more robust evidence base

- we will undertake further analysis to consider how far additional actions could take us, as well as the implications for air quality of a net-zero Greenhouse Gas (GHG) emissions target

Expert advice

- We have demonstrated through this work the importance of expert opinion in helping to evaluate this complex piece of analysis. We are committed to acting on the expert recommendations in order to ensure we are able to take this work forward in the most efficient and cost effective way

- we will continue to seek expert advice to inform development of our modelling. We will draw on broader expertise to consider additional measures available to us, to support economic assessment, and to consider opportunities for deriving co-benefits from a wider policy landscape

- we will publish updates to the analyses as this work is completed