AIR QUALITY EXPERT GROUP

Particulate Matter in the United Kingdom




Prepared for:
Department for Environment, Food and Rural Affairs;
Scottish Executive; Welsh Assembly Government; and
Department of the Environment in Northern Ireland

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Terms of reference

The Air Quality Expert Group was set-up in 2001 to provide independent scientific advice on air quality, in particular the air pollutants contained in the Air Quality Strategy (AQS) for England, Scotland, Wales and Northern Ireland and those covered by the EU Directive on ambient air quality assessment and management (the Air Quality Framework Directive). AQEG replaces the Airborne Particles Expert Group, who published their report on Source apportionment of airborne particulate matter in the UK in January 1999.

AQEG reports to the Secretary of State for Environment, Food and Rural Affairs, Scottish Ministers, the National Assembly for Wales and the Department of the Environment in Northern Ireland (the Government and Devolved Administrations). AQEG is an advisory non-departmental public body in England, Wales and Northern Ireland. In terms of the Scotland Act 1998, the Group is a jointly established body.

AQEG's main functions are:

- to give advice to ministers on levels, sources and characteristics of air pollutants in the UK;
- to assess the extent of exceedences of Air Quality Strategy objectives and proposed objectives, EU limit values and proposed or possible objectives and limit values, where monitoring data are not available;
- to analyse trends in pollutant concentrations;
- to assess current and future ambient concentrations of air pollutants in the UK; and
- to suggest potential priority areas for future research aimed at providing a better understanding of the issues that need to be addressed in setting air quality objectives.

The Group will not give approval for products or equipment.

Further information on AQEG can be found on the Group's website at:
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Information on these pages includes the dates, agendas, and minutes of meetings as they become available, a list of the members, the Register of Interests and draft and final reports as they become available.

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Executive summary

When commissioning this report, Defra and the Devolved Administrations asked the Air Quality Expert Group (AQEG) a number of questions that are shown, in abbreviated form, in Figure 1. AQEG's answers to these questions, together with a rationale for each answer, are provided in Chapter 9. This executive summary provides a less detailed overview of the report and does not attempt to answer the questions explicitly.

Figure 1. Questions on particulate matter set by Defra and the Devolved Administrations for AQEG.

- Are the current assessment methods fit for purpose? How could they be improved?
- Are there sources missing from UK other European emissions inventories?
- Is the UK likely to achieve, with current abatement measures and technologies, the European Union limit values and the Air Quality Strategy objectives for PM_{10}? If not, why not? What levels of PM_{10} are likely to be achieved by current measures and policies?
- Will the UK be able to meet the range of targets for $PM_{2.5}$ as proposed in the draft CAFE Position Paper on Particulate Matter?
- What are the practical maximum feasible reductions of PM_{10} and $PM_{2.5}$ concentrations at hotspots and urban background, for example central London locations.
- Where and what are the main source contributors to current and future concentrations of PM_{10} and $PM_{2.5}$? What are the contributions of different sources to forecast exceedences of the EU limit values and UK objectives?
- What are the potential sources of abatement and types of measures to reduce particle concentrations at hotspots, at urban background, central London and across the whole country? What role can local/national/EU-wide measures play in meeting targets? Are there alternatives to emissions reduction?
- A number of recent studies have highlighted the health effects of certain components of particulate matter. Where further abatement techniques are known, how might they specifically affect reduction of the different particulate matter metrics and chemical components?
- What have we learned from the measured data on ultrafines, including source apportionment? Are the observed trends real? What fraction of ultrafine particles volatilise?
- How does the UK source apportionment for PM_{10}, $PM_{2.5}$ and other metrics compare with other modelling in Europe? Is road traffic more important than current models show? How is the coarser fraction accounted for?

- Can we explain the trends in measured PM_{10}, sulphur and black smoke since 1992?

- What are the differences between strategies that address hotspots of exceedence and those that aim to reduce population exposure? Should policy evaluation consider impacts on population exposure as well as concentrations at specific locations?

Properties of particulate matter

Atmospheric particulate matter consists of solid or liquid matter in sizes that range from a few nanometres (nm) in diameter to around 100 micrometres (100 µm). Its chemical composition includes sulphates, nitrates, ammonium, sodium chloride, elemental and organic carbon and a range of minerals. It contains both primary components, emitted directly into the atmosphere, and secondary components formed in the atmosphere by chemical reactions. The metric generally employed for particles in the UK is PM_{10}, which, to a good approximation, describes the mass of particles with a size of less than 10 µm diameter; similarly $PM_{2.5}$ describes the mass of particles with a size of less than 2.5 µm diameter. An older, but still useful, metric measures the blackness of particulate matter and is termed black smoke.

The balance of evidence currently available suggests that it is combustion-derived components of which PM_{10} that are primarily responsible for the harmful effects on human health. These components are comprised predominantly of fine (less than 2.5 µm) and ultrafine (less than 100 nm) carbon-containing particles and may be enriched with trace metals or specific organic compounds. There is generally less evidence to connect secondary inorganic particulate matter and coarse particles with adverse health effects. However the latter, in particular, cannot be ruled out since certain sources of these particles may be enriched with components of putative high risk (for example, soluble trace metals). The coarse fraction also contains biological material such as pollen and may be proportionally enriched with endotoxin, both of which factors can lead to adverse health effects.

Objectives and limit values for concentrations of particulate matter

The Air Quality Strategy objectives for particulate matter are based on the health effects, which can result from both short-term and long-term exposure, and are linked mainly to respiratory and cardiovascular effects. The European Union limit value for PM_{10} that came into force on 1 January 2005 is 50 µg m^{-3} per 24-h period, with up to 35 exceedences per year allowed. The annual limit value that also came into force on 1 January 2005 is 40 µg m^{-3}. The European Union has proposed an indicative limit value that should be met by 1 January 2010. It is also 50 µg m^{-3} per 24-h period, but the number of allowed exceedences is reduced to seven per year and the annual limit value is halved to 20 µg m^{-3}.The Air Quality Strategy adopted the 2005 values as objectives and the 2010 values as provisional objectives but modified them to make the annual objective more stringent (18 µg m^{-3}) in Scotland and less stringent (23 µg m^{-3}) in London. The 2010 limit values will be reviewed by the EC in the light of further experience and information and currently have no legal standing.

Sources of particulate matter and trends in emissions

Particulate matter derives from both human-made and natural sources. Road transport gives rise to primary particles from engine emissions, from tyre and brake wear and from other non-exhaust traffic emissions. Other primary sources include stationary combustion processes (industrial, commercial and domestic), quarrying, construction and non-road mobile sources; natural sources include sea spray and Saharan dust. Secondary particulate matter is formed from emissions of ammonia (NH_3), sulphur dioxide (SO_2) and nitrogen oxides as well as emissions of organic compounds both from combustion sources and vegetation.

There have been substantial reductions in emissions in recent decades. Primary UK PM_{10} emissions fell from 570 kt in 1970 to 200 kt in 2000. A further fall of 28% is expected between 2000 and 2010 and predicted reductions in UK emissions of secondary precursors over this period range from 52% (SO_2) to 10% (NH_3). It is clear, however, that reductions will level off and total UK PM_{10} emissions are expected to change little between 2010 and 2020 with current measures. The Department for Transport now expects greater market penetration of diesel cars in the UK than it had previously forecast and had been assumed in the earlier versions of the National Atmospheric Emissions Inventory used in the air quality models that are discussed in this report. This will lead to slightly higher PM_{10} emissions than were originally predicted.

Monitoring of particulate matter

UK monitoring networks primarily use the tapered element oscillating microbalance (TEOM) analyser. This provides real-time data with a short time resolution that is essential for the delivery of up-to-date public information. The TEOM uses a heated inlet, which leads to losses of semi-volatile compounds. The European reference method uses an unheated, filter-based gravimetric method. This method provides 24-h concentrations some days after the measurement. The differences in sampling lead to some inconsistency in results. Currently, as an interim measure, TEOM values are scaled by a factor of 1.3 to account for the losses of semi-volatile components. This is not ideal, as the real factor is highly variable from day to day and place to place. It would therefore be advantageous to identify a continuous method of quantifying the semi-volatile components.

The Clean Air for Europe (CAFE) programme is currently considering the introduction of targets for $PM_{2.5}$. Only a small number of sites (15) in the UK have co-located monitoring of PM_{10} and $PM_{2.5}$. Although current evidence in this report indicates a strong correlation between daily PM_{10} and $PM_{2.5}$ concentrations, AQEG views this number as inadequate and recommends an increase in the number of sites measuring both.

Current measured concentrations and composition of particulate matter

The report collates measurements from 240 monitoring sites, including kerbside, roadside, urban background/centre, industrial and rural/remote locations. Data from these sites and from other measurements have been used to assess sources, distributions and concentrations of particulate matter in the UK. Annual mean PM_{10} concentrations are highest at roadside sites and lowest at rural sites, demonstrating the importance of road traffic as a source. There is evidence that the contribution of heavy duty vehicles is much greater than that of light duty vehicles. The concentration gradient between roadside, urban background and rural concentrations is much less pronounced than is found for nitrogen oxides and indicates a greater regional background contribution to PM_{10}. This regional background contribution is a substantial fraction of the total even in London. There is a considerable variability, from month to month, in the number of exceedences of 24-h average concentrations of 50 $\mu g\ m^{-3}$. This demonstrates episodicity in concentrations derived from a range of sources that contribute to PM_{10}. Episodes of high secondary particulate matter also result from air masses arriving in the UK from European sources during anticyclones. Other episodic sources include sea salt, Saharan dust and biomass burning. Locally elevated particulate matter concentrations can result from construction activities, local roads, industries and domestic premises burning solid fuel.

Observed and predicted trends in concentrations of particulate matter

Monitoring sites that have long enough records to establish trends show downward trends in PM_{10} concentrations, but the steep decline observed over the period 1992–1999 has given way to a flattening out or even a slight increase over the period 2000–2003. It is unclear to what extent this change in behaviour arises from year-to-year variations in the weather. Black smoke records provide an 80-year record in London and show a decrease of a factor of about 50 over this period, largely as a result of the phase-out of coal burning. Measurements in London, though, show evidence of a slower decline in black smoke concentration over the last 10 years, related to emissions from diesel road traffic. Declines have also been seen in rural PM_{10} measurements that can be related, in part, to reduced emissions of SO_2 and hence of production of secondary particulate sulphate. The overall reductions show, however, that other sources – primary or secondary – must also contribute to rural concentrations.

Attainability of the Air Quality Strategy's objectives

Models incorporating assessments of future source strengths are used to predict future concentrations of particulate matter and likely exceedences of limit values and objectives in 2005 and 2010 as well as to develop mitigation policies. The models routinely used for national and local policy support in the UK include empirical components, based on monitoring data, and dispersion calculations. The diverse sources of particulate matter make predictions difficult and problems are encountered with: (i) the coarse fraction, which has a large range of sources, including road dust; (ii) the background concentrations and their dependence on both primary and secondary sources; and (iii) the increment in concentrations occurring at the road side. Calculations show the annual mean limit value set for 2005 being met nearly everywhere, but with some exceedences of the limit of 35 days with 24-hour averages above 50 $\mu g\ m^{-3}$, especially in London. However, substantial exceedences both of the more stringent indicative annual mean limit values and of the smaller number of days above 50 $\mu g\ m^{-3}$ suggested for 2010 are likely throughout the UK. It is clear, given the substantial background particulate matter concentrations and the extent of the exceedences, that the additional reductions required by 2010 to meet the Stage 2 indicative limit values cannot be met by control of primary emissions alone.

Local air quality management is able to identify local hotspots that are not necessarily identified through national studies. Air Quality Management Areas (AQMAs) have been established by 63 local authorities where exceedences of the 2005 limit values for PM_{10} are likely. The majority of these are for traffic sources, but there are also AQMAs for industrial, commercial and domestic sources of PM_{10}. The Action Plans being developed will help to ensure that concentrations are driven down in these areas, but will probably make only a marginal contribution to the wider reduction in particulate matter concentrations because of the substantial background contribution. The exception to this might be in London and other major conurbations, where many local authorities are working together to develop larger scale plans, for example, the low emission zone initiative being developed in London.

Enhancement of policy assessment and improvement of air quality

The modelling of particulate matter concentrations is inherently more complex than for other common pollutants because of the need to combine the contributions from different sources, for example, long-range transport of secondary particulate matter, primary contributions from urban sources and very local contributions from individual roads. Models perform reasonably well for current years, but the complexity of particulate matter and the manner in which source contributions may change adds to the uncertainty in predicting future concentrations. Further work is required to improve and refine the models and to check their accuracy with respect to the different components and their sources. It is still not possible to relate all the observed PM_{10} mass to specific sources or to be certain about the relative contributions of different types of source, some of which remain obscure. Targeted imporvements in the monitoring network, including enhanced monitoring of chemical components of the particulate mass, would help to clarify these questions and uncertainties. These improvements should include the deployment of monitors for particulate sulphate, nitrate, elemental and organic carbon and iron. It is also recommended that further rural PM_{10} and $PM_{2.5}$ monitoring is undertaken to assess the background levels of particulate matter and hence determine the urban increment and to aid the understanding of particulate matter episodes. Co-location of particulate sulphate monitors with existing rural ozone, particulate nitrate, PM_{10} and $PM_{2.5}$ measurements would contribute substantially to our understanding of the link between elevated regional particulate matter concentrations and the concentrations of individual components.

It is clear that while road traffic emissions are a major source of particulate matter near to roads, the regional background contribution, both rural and urban, is still dominant and must form a central component of mitigation strategies. AQEG recommends that consideration be given to additional forms of regulation to reduce mean population exposure, complementing concentration-based limit values, which tend to focus attention on local hotspots. The regional contribution and the links between the concentrations of different pollutants demonstrate the need for a more holistic approach to urban air quality management and its coupling to the control of acid rain, eutrophication and ground-level ozone.