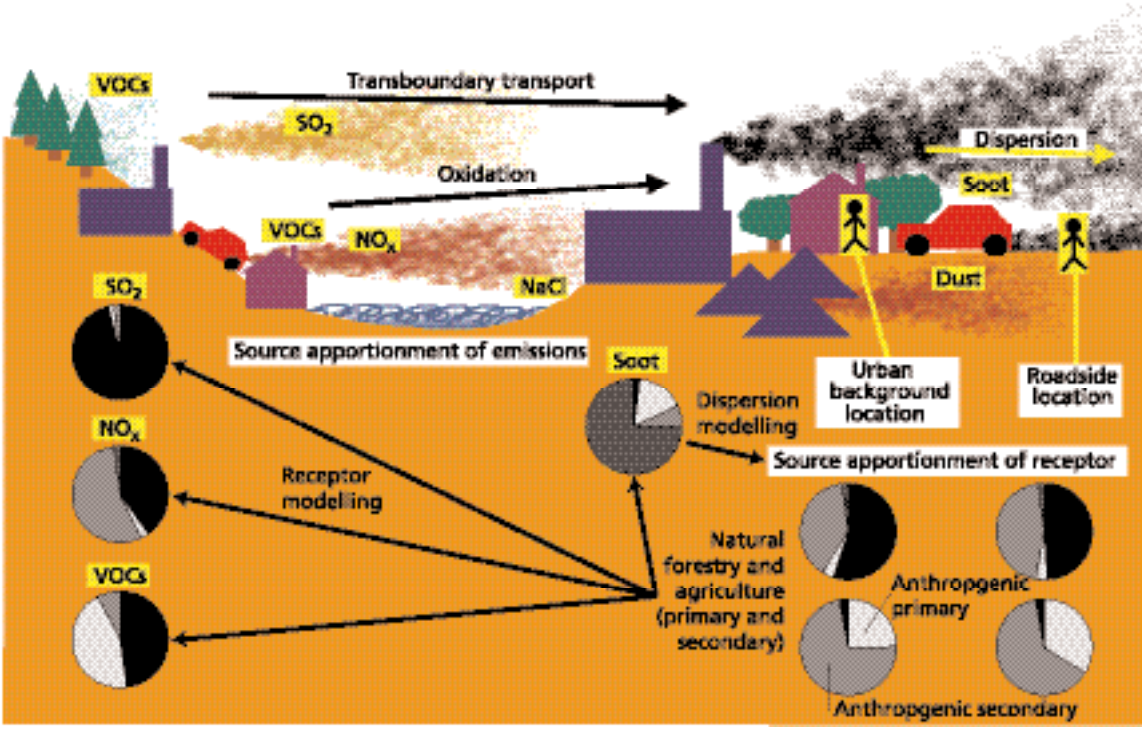
Discussion

9.1 Introduction

877. This chapter provides a direct response to the questions set for AQEG by Defra and the Devolved Administrations (see Chapter 1). It draws extensively upon the emissions, measurement and modelling data described in detail within previous chapters.

878. An important recurring theme throughout Chapters 2–8 of this report is source apportionment, which was introduced in Section 2.5. PM has many different sources, and it is important to identify these correctly. Figure 9.1 illustrates approximate PM_{10} source apportionment by source location, source type and particle type, summarising the main conclusions of Chapters 4, 6 and 8. The sources of PM and precursor gaseous emissions are shown to the left side of the figure. Dispersion, pollutant transport and transformation occurs from left to right across to receptors on the right hand side.

Figure 9.1 Summary of PM_{10} source apportionment and methods of assessment used in this report (see text for detailed explanation).



879. On the far left of Figure 9.1, farthest upwind of the receptors, are the gaseous precursors of secondary PM that were described in Figure 4.7. The colours of the pie slices correspond to the colours of the major source types shown on the diagram: industrial (blue); transport (red); domestic and commercial (purple); and natural (green).

880. At the centre of Figure 9.1 are the sources of primary PM that were described and quantified in detail throughout Chapter 4. These are most significant closer to the receptors than the gaseous secondary PM precursor emissions sources. The pie chart indicates a typical source apportionment of combustion-related emissions for a major UK city. Note that sea salt and fugitive dust are additional local sources of primary PM, partly natural and partly anthropogenic, that are not included in this pie.

881. The right-hand half of Figure 9.1 shows how the emissions, dispersion, pollutant transport and transformation processes add up to produce the current annual average source apportionment of concentration at two types of receptor in a typical UK city, an urban background and a roadside location. The precise contribution of each source depends on the location of the receptor relative to the source and relative to local topography. For local sources of primary PM, changes of a few kilometres in the location of an urban background receptor (Sections 6.2.1 and 6.2.2) or a few metres for a roadside one (Section 6.2.4) can cause the source apportionment to change. For secondary PM, changes of a few hundred kilometres will produce a difference of similar magnitude (Section 6.2.6). The source apportionment shown is typical of a large city in Southeast England; for Scottish, Welsh, Northern Irish and Northern English cities, the secondary contribution is smaller because they are further from mainland Europe. Smaller cities have similar source apportionment, except the contribution of local primary emissions to urban background concentrations tends to be smaller and similar source apportionment can be found in the suburbs of larger cities.

882. The coloured receptor source apportionment pie charts in Figure 9.1 have the same key as the emissions pie charts, indicating typical contributions of industrial, transport, domestic and commercial and natural source types. These include the contribution of these source types to gaseous precursors of secondary PM and fugitive and sea salt primary emissions, in addition to primary combustion-related emissions.

883. The monochrome receptor source apportionment pie charts in Figure 9.1 indicate approximate contributions of anthropogenic primary (including fugitive dusts and road surface emissions), anthropogenic secondary and natural particle types to the total annual average PM_{10} (based on Table 8.6(b)). Note that 'natural' includes sea salt and secondary PM from biogenic emissions of VOCs.

884. The arrows on Figure 9.1 linking the various parts of the diagram indicate processes that occur in the atmosphere as well as modelling and data analysis methods used in this report. The arrows from left to right representing dispersion, pollutant transport and transformation reflect processes that are parameterised in the emissions-based models that were described in Chapter 8 (see paragraphs 748 and 749 and also Sections 2.5.2, 8.2.2.2, 8.2.3 and 8.2.4.2.). The arrows from right to left indicate how source apportionment can be deduced from measurements as discussed in Section 2.5.1 (described in more detail in Sections 8.2.1 and 8.2.2.1.).

9.2 Answers to questions

885. The level of confidence with which AQEG has been able to provide answers to the questions posed in Chapter 1 varies. For PM, difficulties arise for several reasons. Firstly, the level of scientific uncertainty in our understanding of the underlying

processes contains some gaps. Secondly, as a consequence of these gaps, some of our quantitative calculations and estimates lack precision. Thirdly, some properties of PM make this an inherently difficult pollutant to assess in accordance with the requirements of current policy. This sometimes causes inconsistency between the results of different models or between models and the analysis of measurements. The recommendations for future research set out in Chapter 10 have been devised with the aim of resolving some of these problems.

9.3 Are the current assessment methods (emissions inventories, measurements and modelling) fit for purpose? How could they be improved?

9.3.1 Answer

886 The methods of assessment are considered fit for purpose in terms of characterising current annual mean PM concentrations at urban background and rural locations and the approximate magnitude and distribution of concentrations at roadside locations. The methods of assessment become progressively more uncertain when used to quantify precise areas of exceedence, future concentrations and exceedences of the daily mean limit values.

9.3.1.1 Emissions inventories

887 Emissions of primary combustion PM, and emissions that form secondary inorganic particles (NO_x, SO_x and NH_3) are well established. Emissions from other sources, mostly particles in the coarse fraction, are either very uncertain (for example, from quarrying and agriculture) or poorly understood (for example, non-exhaust vehicle emissions). The latter adds significantly to the difficulty of predicting roadside concentrations.

888 Emissions from intermittent and natural sources (such as forest fires) are not well defined, but may contribute to exceedences of the daily mean limit value.

889 For all source categories, emissions inventories for future years (for example, 2010) have a greater degree of uncertainty attached to them compared to the current year.

890 The PM_{coarse} component, between 2.5 and 10 µm, makes a large but ill-defined contribution to total PM_{10} concentrations, and further work to better quantify this component is required. In particular, the contribution from non-exhaust road traffic emissions needs to be better quantified. Specific recommendations are provided in Chapter 10.

9.3.1.2 Measurements

891 There is an extensive network of PM_{10} monitoring in the UK that provides invaluable information on current concentrations and trends. The networks are principally founded on the TEOM analyser, which produces continuous hourly data that are valuable in analysing patterns of exposure and source apportionment. However, the elevated temperature of the TEOM inlet causes inevitable losses of semi-volatile species and makes direct comparison with the European reference sampler extremely difficult. To enable comparison of measured concentrations with the UK objectives and EU limit values, TEOM data are currently adjusted by

applying offset and scaling factors, which impedes any accurate assessment of compliance with the objectives and limit values, particularly in future years. However, despite these problems, AQEG does not consider the use of gravimetric techniques (such as the reference sampler) to be a viable alternative, as these methods introduce other problems.

892. There are several ways in which the current monitoring networks could be improved: with the addition of more rural PM_{10} sites, additional monitoring of $PM_{2.5}$ concentrations and further monitoring of the chemical composition of PM. Specific recommendations are provided in Chapter 10.

9.3.1.3 Modelling

893. The modelling of particulate concentrations is inherently more complex than for other common pollutants. This is because of the need to combine the contributions from different sources, for example, long-range transport of secondary PM, primary contributions from urban sources and very local contributions from individual roads. A substantial 'residual' contribution is also included in many models, but is poorly understood. Models perform reasonably well for current years, but the complexity of PM and the manner in which source contributions may change adds to the difficulty of predicting future concentrations.

894. In general terms, the models are better at predicting the annual mean concentration rather than the number of daily exceedences in a given year and are better at predicting the changes associated with a prescribed change in emissions rather than the absolute PM concentration.

895. Further work is required to improve and refine the models and to check their accuracy with respect to the different components and source apportionment. Specific recommendations are provided in Chapter 10.

9.3.2 Rationale

9.3.2.1 Emissions inventories

9.3.2.1.1 Uncertainty of annual emissions inventories

896. The analysis carried out for the NAEI gives an overall uncertainty for the annual rate of UK emissions of PM_{10} of –20% to +50% at the 95% CI. However, uncertainties in emission estimates for particular sources and in particular locations at particular times, will be considerably higher, for example, in the case of emissions near a roadside or near sources of mechanically generated PM. This partly reflects the level of detail required to understand and quantify localised emissions due to their transient nature (for example, vehicle exhaust emissions) or the amount of local activity (for example, level of construction activity), which may be poorly understood.

897. Emissions of the finer particle size fractions ($PM_{2.5}$ and smaller) are more difficult to quantify and are less certain than estimates for PM_{10} emissions. Although there are increasing data from research on the particle size distribution of emissions from vehicle exhausts, there are very few data for other combustion and non-combustion sources.

9.3.2.1.2 Local and episodic emissions

898. The limit values and objectives place an emphasis on PM concentrations at 'hotspots', such as busy roads, and there is, therefore, a need to characterise emissions at such locations. This is dependent on traffic data, which introduces additional assumptions and uncertainties; it is also difficult to allow for the 'stop-start' flows in congested conditions and at junctions. Coupled with uncertainties regarding the non-exhaust component of vehicle emissions, in particular the resuspension of road dusts by traffic, the quantification of local emissions at critical urban locations causes significant difficulties.

899. Ambient concentrations of PM are also affected by short-term emissions, for example, construction/demolition activities, road works and bonfire night, and exceedences of the daily mean limit values may be directly associated with such events. Emissions inventories are unable to describe the temporal variation in emissions from these source types, as many are unique or random in occurrence and some are influenced by external factors such as meteorology. Many of these processes are not amenable to inclusion in emissions inventories.

9.3.2.1.3 Improvements to the annual emissions inventories

900. An analysis carried out by the NAEI found that the major contributors to uncertainty at a national level are emissions from a number of sectors, including quarrying and construction, domestic combustion of solid fuels and gas, tyre and brake wear, coal-fired power stations, Part B industrial processes and agricultural livestock housing.

901. The NAEI has recently carried out a review of a number of these sources. Emission factors for tyre and brake wear have recently been revised leading to an overall increase in national emissions. Current estimates of emissions from the domestic combustion of gas have been revised downwards, but there remains a lack of robust data. The review also suggested changes to the activity data and to emission factors for the quarrying and construction sectors that would lower the current national PM estimates. However, it remains difficult to accurately quantify emissions from any of these sectors and uncertainties remain high.

9.3.2.1.4 Emissions in future years

902. The prediction of concentrations in future years depends heavily on accurate forecasting of changes in emissions of both primary PM and secondary precursors in the UK and Europe. This requires assumptions to be made as to how individual sectors will evolve, which becomes increasingly uncertain as forecasts are projected further into the future.

903. For road transport, emissions projections are based on the expected implementation of new vehicle emissions standards. They also depend on factors affecting the make-up of the vehicle fleet, particularly the mix of petrol and diesel cars. A study by the NAEI has demonstrated the importance of assumptions made regarding the proportion of diesel cars. The current assumption that 30% of all new cars sold will be diesel by 2010 now appears to be an underestimate because current sales are rapidly increasing towards this level. The impact of increasing diesel car sales to 42% by 2010 would be to increase urban PM exhaust emissions from road transport by 10% above levels previously forecast for 2015.

904. Emission projections for the power generation, industry and domestic sectors are based upon energy and economic growth forecasts. The accuracy of emissions projections will depend upon the implications of energy policies and how they are implemented as well as the uptake rates and effectiveness of new technologies. Where these are linked to legislative requirements, they can be predicted with some certainty, but general improvements are more uncertain.

9.3.2.2 Measurements

905 Because of the complex nature and composition of airborne PM, the method that is selected for the collection and determination of particle mass significantly influences the result. The requirements for PM_{10} monitoring are very much dependant upon the eventual use of the data. For reporting against the limit values, as set out in the First Daughter Directive, it is a requirement that the European reference sampler or equivalent is used. The current UK approach of adjusting measured TEOM concentrations using an internal adjustment offset and a further scaling factor of 1.3 is unlikely to prove satisfactory beyond the immediate term. However, restructuring of the networks based on the reference sampler is not considered to be a viable alternative, as this approach does not provide the required time resolution of data and is also subject to both positive and negative artefacts, depending upon environmental conditions.

906. A programme of work to evaluate new instrumentation for the automatic monitoring of PM_{10} concentrations is currently under way and, depending upon the outcome of this work, the existing networks may need to be modified or replaced. It is noted that if the reference method were changed so that only the non-volatile component of the particle mass were measured, this would greatly improve the consistency and practicality of measurements for regulatory purposes. These measurements of 'core particulate' mass could then be supplemented at representative sites by specific monitoring techniques to determine the volatile species.

907. A detailed analysis of the TEOM adjustments and their implications is given in Annex 6. This discusses how removal of the internal offset would lead to the need for a larger 'default scaling factor' and provides illustrations of how such changes could alter estimated compliance or non-compliance. Removal of the internal offset would also affect the empirically modelled concentrations. For sensitivity analysis with respect to compliance with the limit values (discussed in Section 9.4), the implied differences are of the order of 1 μg m^{-3} in the typical examples given.

9.3.2.2.1 Relationships between episode days and annual means

908. The application of a uniform scaling factor to daily TEOM concentrations significantly affects the estimated number of days above the daily mean limit value. In practice the volatile fraction lost will vary from day to day and it is highly unlikely that a single factor could account for this. This also has significant implications for modelling results where the number of days >50 μg m^{-3} is estimated from a relationship with the annual mean. Such assumptions critically influence the number of predicted exceedences of the daily mean limit value.

9.3.2.2.2 Spatial representation

909. Roadside concentrations can vary both spatially and temporally within a street. For this reason a statistical picture from fixed long-term sites is important both in establishing the extent of exceedence and trends, and it is recommended that

greater attention is given to the pairing of background and roadside sites to improve definition of roadside increments.

910. A particular deficiency in the existing national network is the paucity of rural sites: currently, measurements of PM_{10} are being carried out at only four rural locations. More rural sites would help to clarify the urban enhancement, enabling checks of consistency with current source apportionment and modelling estimates. They would also improve the definition of background concentrations for non-urban AQMAs. Specific recommendations are set out in Chapter 10.

9.3.2.2.3 Measurements of $PM_{2.5}$

911. Monitoring of both $PM_{2.5}$ and PM_{10} is currently carried out at only a small number of sites. Generally, the data indicate a close correlation between the two metrics and provide important information on the PM_{coarse} fraction. If, however, the limit values were revised to include $PM_{2.5}$ this would require either:

- considerable expenditure in more direct measurements of this size range – this would be both costly and difficult to implement at all sites due to space limitations;
- reliance on derived correlations – but there would be only extremely limited historic data from which to establish such relationships; or
- reconfiguration of the existing PM_{10} network towards $PM_{2.5}$ – this would result in the loss of valuable trend data in PM_{10}.

912. Irrespective of whether new limit values are set for $PM_{2.5}$, AQEG recommend more co-located hourly measurements of $PM_{2.5}$ and PM_{10} at selected sites to characterise the relative contributions at roadside, urban background and rural sites. In conjunction with other measurements this would help to clarify the PM_{coarse} fraction and its spatial and temporal variation. Specific recommendations are provided in Chapter 10.

9.3.2.2.4 Chemical composition and source apportionment

913. It is important to develop a better understanding of the different source contributions to PM concentrations, including the primary and secondary components and long-range versus local contributions. The UK Acid Deposition Networks provide data on sodium, ammonium and particulate nitrate (together with gaseous HNO_3) based upon daily or monthly sampling, but these are rural networks that do not indicate whether there is significant enhancement of nitrate in major cities. In addition, both particulate nitrate and sulphate make a substantial contribution to the regional background levels upon which urban and roadside increments are superimposed. There is a requirement to more fully understand the particulate nitrate and sulphate concentrations, particularly during PM episodes, and to obtain measurement data that can be used to validate the regional model assessments and support source apportionment studies.

914. Particulate iron is a valuable indicator of the non-exhaust road traffic emission component of PM_{10} emissions. As discussed in earlier chapters, non-exhaust traffic emissions may become of even greater importance in future years, and a more accurate quantification of this source is needed.

915. AQEG recommends expansion of the networks to include paired urban background/rural monitoring of continuous nitrate and sulphate and paired roadside/urban background monitoring for continuous elemental and organic carbon measurements. It is also recommended that existing networks are modified and extended to include additional daily measurements of iron. Specific recommendations are provided in Chapter 10.

9.3.2.3 Modelling

916. The manner in which different models account for the different source contributions is key to understanding their performance and how improvements may be provided in the future.

9.3.2.3.1 Secondary inorganic component

917. The Netcen, ADMS and ERG models incorporate a simple treatment of the secondary inorganic component, based on measurements. They are all thus highly empirical and do not address the effect of reducing UK precursor emissions directly, but use scaling factors to project into the future using different assumptions. Recent calculations based on the Eulerian EMEP model for current scenarios within the CAFE programme indicate somewhat greater reductions in secondary inorganic aerosol up to 2010, which suggests that assumptions made in the UK may be on the conservative side.

9.3.2.3.2 Primary PM

918. The contribution of primary particles is accounted for either directly from dispersion of the emissions, or empirically from regression analysis against the measurements. Annex 7 (Table A7.1) provides an illustration of source apportionment calculations for both PM_{10} and $PM_{2.5}$ based upon calculations using the ADMS model for selected sites in London.

919. The results show that predicted exceedences at roadside locations are highly dependent on the increment due to road traffic. However, this is variable, depending upon characteristics of the local road and the traffic including street canyon effects, vehicle speeds, traffic densities, street layout and traffic control schemes. Research funded by EPSRC is in progress (DAPPLE[1]) to gain a better understanding of dispersion and concentrations within urban streets. Uncertainties of at least a factor of 2 in the prediction of the roadside increment for annual mean concentrations are likely at some locations.

920. Empirical estimates of roadside increments are an alternative to deterministic modelling, but are hampered by the paucity of paired roadside and background sites.

9.3.2.3.3 Residual component

921. The residual component accounts for particulate emissions, largely within the PM_{coarse} fraction, that are not well-characterised or are not included in emissions inventories, such as wind-blown dust and sea salt. This component is poorly understood within models. Some models simply add a constant background (both in space and time) based on measurements. Other models explicitly account for the rural background contribution from rural monitoring data (although these

[1] DAPPLE (Dispersion of Air Pollution and Penetration into the Local Environment) is a 4-year consortium project. See www.dapple.org.uk for details.

data are very limited) with a constant urban coarse component then added. Despite these uncertainties, the residual component represents a substantial fraction of the whole. There is good reason to believe that a part of this component is associated with the suspension of road dust by traffic, hence contributing a significant increment to roadside emissions, which importantly is not expected to reduce in the future. Different assumptions regarding both the scale and spatial representation of this residual component would have a very significant impact upon estimated exceedences in future years.

9.3.2.3.4 Air pollution episodes and daily limit values and objectives

922. It is also a requirement for models to consider exceedences of the daily mean limit values and objectives, which is considerably more challenging. Such episodes are highly correlated with meteorology and are thus subject to large interannual variation. Even more sophisticated models are challenged in representing the dispersion and chemical and physical characteristics of particle behaviour in such episodic conditions.

923. The Netcen, ADMS and ERG models take a simplified but different approach to assessing the number of daily exceedences. These approaches include the derivation of a surrogate annual mean concentration based on regression analysis with daily mean exceedences or direct modelling of the individual days based on the predicted primary PM component superimposed on the secondary PM derived from rural measurement and a constant 'residual' component. Each approach is subject to additional uncertainty over and above that associated with predictions of the annual mean concentration. For example, the models are unable to directly predict high nitrate episodes (likely to be of increasing importance) or deal with episodes due to more local natural or intermittent sources that are not adequately represented in emission inventories. Validation (see Table 8.2) suggests that the approaches used provide useful predictions of the number of exceedences of 50 μg m^{-3} for comparison with the 2005 limit value (daily mean to be exceeded no more than 35 times), but with increasing underestimates/uncertainty for the higher percentiles required by the indicative Stage II limit value (no more than 7 exceedences). In the latter case the lack of consideration of local intermittent sources, including coarse particle sources, and limitations of model dispersion in extreme conditions becomes more important.

9.3.2.3.5 Links between modelling and measurements

924. The model predictions considered in this report have been 'calibrated' to match the measurements, either by adjustment of parameters (for example, urban boundary layers) or by application of multiplying factors (derived from regression analysis) to particular components of the particulate concentration. Such procedures could lead to an underestimation, or more critically an overestimation of the reduction in PM concentrations associated with a reduction of the corresponding emissions. For example, if the model does not accurately represent traffic-related non-exhaust emissions, calibration of the model against current monitoring data may result in an underprediction of PM concentrations in future years. Uncertainties of the order of 1–2 μg m^{-3} in projected annual mean concentrations might easily be expected to occur.

9.3.2.3.6 *Interannual variation and extrapolation of trends*

925. There are additional difficulties with future predictions of PM concentrations. Interannual variability introduces difficulties for establishing trends and extrapolating into the future; in particular, 2003 was an unusual year, with very high temperatures and episodes of significantly elevated nitrate concentrations during the spring. Concentrations during 2003 were typically higher than those measured during 2002, despite a likely slight decrease in manmade primary emissions and secondary particulate precursor emissions. It is difficult to judge how exceptional this year was or how the potential effects of climate change could affect future pollution episodes and overall concentrations. As a result, the model results presented in this chapter for comparison with limit values relate to more average years of meteorology.

9.3.2.3.7 *Other uncertainties when assessing exceedence of limits*

926. The modelling results reported later in this chapter are concerned with local areas of exceedence along major roads and wider areas of exceedence at urban background locations. As discussed by Colvile *et al*. (2002), a small perturbation in a relatively smooth concentration field of the order of 10% (or 1–2 μg m^{-3}, well within the range of uncertainty) can make a large difference to the concentration isopleths, moving them by possibly several kilometres and causing the appearance and disappearance of 'blob-shaped' areas of exceedence. Similarly, different assumptions about the residual component and its spatial variability could also make a significant difference. As a result, predicted areas of exceedence are highly sensitive to uncertainties and assumptions.

927. The trend towards higher percentiles to tighten legislation on air quality is welcomed as a means of protecting the public from infrequent exposure to higher concentrations, but causes difficulties with respect to the capabilities of current assessment methods that effectively ignore a number of local and intermittent sources. The implications of moving from 35 days exceedence of the daily mean limit value to only 7 days exceedence (as proposed in the indicative Stage II limit values) needs to be carefully considered, bearing in mind the limitations of the available analysis tools. Current modelling technology used in the 2002/2003 analysis conducted for the AQS Addendum considered Stage II limit values as objectives across the UK: Scotland put the Stage II limit values into regulation for the purpose of LAQM.

9.4 Are there sources missing from (a) UK emissions inventories and (b) other European inventories?

9.4.1 Answer

928. The NAEI is a comprehensive database of emissions for the UK. A number of potential sources of PM emissions are not included in the NAEI because there are insufficient data available, but these are not considered to be significant and it is estimated that their inclusion would only increase the UK estimate of PM_{10} emissions by no more than a few percent.

929. In addition, there are also many important natural sources of particles – including sea salt, forest fires and wind-blown dust – that contribute significantly to ambient PM concentrations, but which are not included in the NAEI. These sources are difficult to quantify and are not amenable to inclusion within national

inventories. Although estimates of PM emissions from both non-exhaust road traffic emissions and construction activities are included in the NAEI at a national level, it is extremely difficult to derive representative emission rates at a local level. Nationally, these sources make only a small contribution to total PM emissions, but at a local level (close to major roads or construction and demolition sites), they may be extremely important.

930. A detailed analysis of European emissions has recently been carried out by the CAFE Working Group on Particulate Matter. This report has drawn extensively upon the conclusions of the Working Group and no further analysis has been undertaken.

9.4.2 Rationale

931. A recent study has identified a number of potential sources of PM emissions that have been omitted from the NAEI (see Chapter 4). Although their impact at a national level is not considered important, they could be significant at particular times at a local level, contributing to exceedences of the daily mean limit values. In some cases, insufficient data are currently available to allow quantification of these sources, but in other cases emissions estimates will be included in future revisions to the NAEI.

932. Many natural sources of particles are random in origin and cannot be accurately quantified in terms of their magnitude or temporal characteristics, and they are best described through ambient measurements and source apportionment studies. Nonetheless, it is recognised that such sources can make significant contributions to particle concentrations particularly during 'episode' conditions, for example, impacts of sea salt aerosol and Saharan dust, which are described in Chapter 6.

933. Emissions associated with non-exhaust road traffic sources are included in the NAEI, but are poorly understood. At a national level this is unlikely to be an important source, but at a local level it may be extremely important, perhaps more so than exhaust emissions. Studies indicate that HGVs are more important in terms of non-exhaust road traffic emissions than smaller vehicles, such as cars, but as the rate of resuspension is governed by many local factors, such as the road surface condition and meteorological conditions, it is currently difficult to derive emission rates that can be included in inventories in the normal manner.

934. Emissions estimates from construction activities are also included in the NAEI, but again are poorly understood. At a local level, emissions may be very significant, particularly if the activities are scheduled over a long time period. However, as emissions are governed by a wide range of local factors, such as the size and nature of the works, the meteorological conditions and the application of abatement measures, it is again extremely difficult to derive emission rates in the normal manner.

9.5 Is the UK likely to achieve, with current abatement measures and technologies (a) the Stage I and indicative Stage II annual and daily mean PM_{10} limit values in the First Air Quality Directive and (b) 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?

9.5.1 Answer

935. For the air quality objectives and Stage I limit values to be met by 2004/2005, the daily mean target will be more difficult to attain than the annual mean, and there will almost certainly be some exceedences along major roads, mainly in London. It is difficult to be more precise due to the interannual variability in the measurements and uncertainties in the modelling. There are also areas affected by non-traffic sources, which have been identified by local authorities as part of their duties under LAQM, where additional exceedences may occur.

936. With respect to the indicative Stage II limit values, based on current measures and policies there will be many urban background and roadside locations where these targets will not be achieved. These exceedences are more extreme in London and remain even if the less stringent provisional objectives for 2010 are considered. Although exceedences of the Stage I annual mean limit value are very small in Scotland, a much wider area of exceedence of the 2010 objective is predicted.

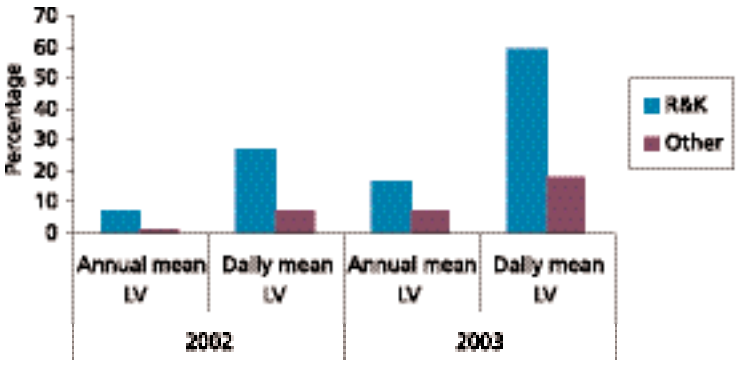
937. There are a number of different sources contributing to the predicted exceedences in both 2004 and 2010, and it is not possible to single out any specific sector. A more detailed analysis of source apportionment is provided in Section 9.7.

9.5.2 Rationale

938. For the Stage I limit values and air quality objectives to be met by 2004/2005, it is expected that there will be little change from current measured concentrations. Figure 9.2 shows a summary of the measured PM_{10} concentrations in 2002 and 2003 compared with the Stage I annual mean and daily mean limit values (a more detailed description of the results is provided in Annex 7, Tables A7.2 and A7.3).

939. Annual mean PM_{10} concentrations in 2002 and 2003 were below 40 µg m^{-3} at the majority of monitoring sites, with exceedences largely confined to roadside and kerbside sites in London. The daily mean limit value was more widely exceeded, particularly at roadside and kerbside sites. There were more exceedences in 2003 than in 2002.

Figure 9.2 Percentage of UK PM_{10} monitoring sites in 2002 and 2003 exceeding the Stage I annual and daily mean limit values. (R&K, roadside and kerbside sites; other, all other site classifications. Data collected using TEOM analysers have been adjusted using a 1.3 scaling factor.)



940. Corresponding estimates of predicted exceedences in 2004/2005 have been derived using the Netcen, ADMS and ERG models. Table 9.1 describes the results for London and the UK, indicating areas of exceedence at both roadside and urban background locations. The results are broadly consistent with the measured results for 2002, with a small number of exceedences of the annual mean limit value and a much greater number of exceedences of the daily mean limit value. As expected, exceedences are predominantly located along major roads. These modelling results are based on average meteorology; in a year with more extreme meteorology such as 2003, the number of exceedences may be significantly higher.

9.5.2.1 AQMAs and exceedences away from roads

941. As part of their duties under the system of LAQM, local authorities are required to carry out regular reviews and assessments of air quality in their areas and to identify locations where one or more of the air quality objectives is unlikely to be met by the relevant due date. Where such an exceedence is identified, the authority must designate an AQMA and prepare an action plan setting out measures in pursuit of meeting the objectives.

942. Of the 433 local authorities in England, Scotland, Wales and Northern Ireland, a total of 57 have designated AQMAs for PM_{10}, largely associated with road traffic emissions. However, AQMAs have also been designated in other areas, associated with fugitive dust sources from industrial processes and materials/waste handling activities, and it is anticipated that additional AQMAs associated with domestic solid fuel combustion will be designated in Northern Ireland. Action plans will be required for each of these areas; further work is underway to integrate as far as possible the local and national assessments.

9.5.2.2 Achievement of Stage II limit values and provisional air quality objectives

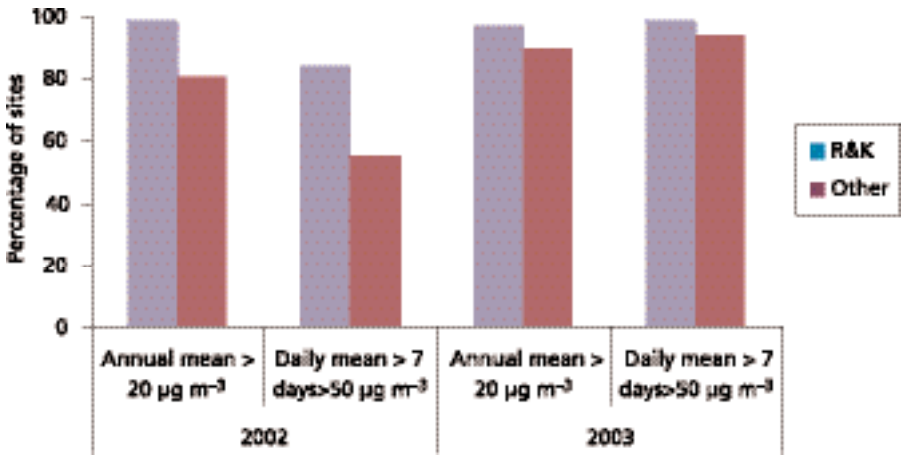
943. Figure 9.3 shows a summary of the measured PM_{10} concentrations in 2002 and 2003 compared with the Stage II annual mean and daily mean limit values (a more detailed description of the results is provided in Tables A7.2 and A7.3 in Annex 7). For both 2002 and 2003, the measured annual mean PM_{10} concentration widely exceeded 20 μg m^{-3} at both roadside and kerbside and background sites. The daily limit value (no more than 7 days >50 μg m^{-3}) is exceeded at a smaller number of sites in 2002, but at a greater number in 2003.

Table 9.1 Modelled exceedences of objectives for 2004/2005.

Statistic	Model	Area	Road length (km)	Base case	Base case -2 µg m^{-3}	Base case + 2 µg m^{-3}
Annual mean >40 µg m^{-3}	NETCEN	UK	16037	9	—	—
	NETCEN	Greater London	1786	9	2	19
	ADMS	Greater London	3651	0	0	0
	ERG	Greater London	4814	5	3	9
Daily limit more than 35 days >50 µg m^{-3}	NETCEN	UK	16037	269	106	589
	NETCEN	Greater London	1786	119	60	236
	ADMS	Greater London	3651	0.48	0	3
	ERG	Greater London	4814	81	71	91
Annual mean >40 µg m^{-3}	NETCEN	UK	242349	0	0	0
	NETCEN	Greater London	1624	0	0	0
	ADMS	Greater London	1574	0	0	0
	ERG	Greater London	1858	0	0	0
Daily limit more than 35 days >50 µg m^{-3}	NETCEN	Greater London	1624	1	0	3
	ADMS	Greater London	1574	0.14	0.03	0.43

NB: Base case ±2 µg m^{-3} indicates the likely range of exceedence.

Figure 9.3 Measured PM_{10} concentrations in 2002 and 2003 compared with the indicative Stage II annual and daily mean limit values, showing the percentage of sites exceeding the proposed limit value in each year. (R&K = Roadside and kerbside sites; Other = all other site classifications. Data collected using TEOM analysers have been adjusted using a 1.3 scaling factor.)



9.5.2.3 *Site-specific projections*

944. An analysis of predicted annual mean PM_{10} concentrations in 2010 based on a combination of observed measurements and site-specific modelling has been described in Chapter 8. These predictions show that although PM_{10}

concentrations closely approach the indicative Stage II annual mean limit value, exceedences still occur. To a large extent, these exceedences are driven by the change from a steeply declining trend in measured PM_{10} concentrations (over the period 1992 to 2000) to a levelling off in recent years.

945. The observed trends are complex, showing considerable year-to-year variation that is determined largely by meteorology and, in particular, by variation in the contribution from secondary particles and other long range transport, such as Saharan dust events. This leads to years with relatively high concentrations (1996, 1997 and 2003) and relatively low concentrations (1998 and 1999). The preliminary monitoring results for the first part of 2004 are in much closer agreement with projections from previous years, suggesting that the upward measured trend to 2003 may be reversed with the long-term trend gently downwards in line with PM_{10} emissions reduction.

946. It is considered likely that the reversal of trends in recent years reflects some influence of changing weather patterns that has masked the influence of decreasing PM emissions. This could be some form of climate drift, in which case it may be a permanent feature of the future PM climate of the UK or it may just reflect year-on-year variability. Regardless, it is considered unlikely that the indicative Stage II limit values will be met by 2010.

947. There are a number of assumptions inherent in the site-specific model itself but it is considered a reasonably reliable tool for estimating future annual mean PM_{10} concentrations, as it has shown good agreement with past trends. There are, however, two important limitations.

- The assumption of a constant residual particle contribution when levels may be increasing.

- The difficulties resolving the apparent differences between roadside and kerbside increments and emission inventories in terms of either locally resuspended coarse material or the underestimation of fine particle emissions due to the emission of semi-volatile organic compounds from diesel fuels or lubricants. The site-specific projections for roadside sites could be systematically optimistic as they do not include an explicitly increasing contribution from resuspended dusts due to increased traffic movements.

9.5.2.4 GIS-based modelling results

948. Exceedences of the indicative Stage II limit values in 2010 have also been derived using the Netcen, ADMS and ERG models. The results are described in Table 9.2 (and in more detail in Chapter 8) and show a reasonable consistency with the measurement and trend data discussed above. There are substantial exceedences of the annual mean limit value at roadsides and within the surrounding urban areas. The daily mean limit value appears less restricting, but this does not allow for episodic exceedences due to other intermittent sources.

Table 9.2 Exceedences of air quality objectives in 2010. (a) Length of road (km) exceeding different objectives in 2010. (b) Area (km^2) exceeding different objectives.

(a) Road length

Statistic	Model	Area	Road length modelled (km^2)	Base case	Base case –2 µg m^{-3}	Base case + 2 µg m^{-3}
Annual mean >20 µg m^{-3}	NETCEN	UK	16037	6096	3135	10040
	NETCEN	Greater London	1786	1730	1300	1781
	ADMS	Greater London	3651	1626	146	3651
	ERG	Greater London	4814	1742	247	4007
Annual mean >23 µg m^{-3} (Greater London)	NETCEN	Greater London	1786	914	—	—
	ERG	Greater London	4814	247	86	866
Annual mean >18 µg m^{-3} (Scotland)	NETCEN	Scotland	1348	211	—	—
Daily limit more than 7 days >50 µg m^{-3}	ADMS	Greater London	3651	0	0	0.4
	ERG	Greater London	4814	263	146	1049
Daily limit more than 10 days >50 µg m^{-3}	ADMS	Greater London	3651	0	0	0
	ERG	Greater London	4814	2.5	1.7	3.9

(b) Area

Statistic	Model	Area	Area modelled (km^2)	Base case	Base case –2 µg m^{-3}	Base case + 2 µg m^{-3}
Annual mean >20 µg m^{-3}	NETCEN	UK	242349	2648	634	12278
	NETCEN	Greater London	1624	778	113	1528
	ADMS	Greater London	1574	1175	21	1574
	ERG	Greater London	1858	39	12	374
Annual mean >23 µg m^{-3} (Greater London)	NETCEN	Greater London	1624	40	—	—
	ERG	Greater London	1858	7	3	21

Statistic	Model	Area	Area modelled (km^2)	Base case	Base case –2 µg m^{-3}	Base case + 2 µg m^{-3}
Annual mean >18 µg m^{-3} (Scotland)	NETCEN	Scotland	77535	42	—	—
Daily limit more than 7 days >50 µg m^{-3}	ADMS ERG	Greater London Greater London	1574	0.0011	0.0003	0.003
Daily limit more than 10 days >50 µg m^{-3}	ADMS ERG	Greater London Greater London	1574	0	0	0

Note: Base case ±2 µg m^{-3} indicates the likely range of predicted exceedence.

949. The small number of predicted exceedences in Scotland increases if the more stringent annual mean objective (18 µg m^{-3}) is assumed. Relaxation of the annual mean objective in London from 20 µg m^{-3} to 23 µg m^{-3} substantially reduces, but does not eliminate, exceedences. The extent of predicted exceedences in London varies considerably when a ±2 µg m^{-3} perturbation is applied, and ranges from very little, or almost all, of London being in exceedence (a more detailed explanation is provided in Annex 8). In practice there is likely to be considerable spatial variability in the residual component, maybe enhancing the importance of roads. Until better information is available it is not possible to resolve this, but it is an important limitation in assessing the precise areas of exceedence in future years.

9.6 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? If not, why not? What levels of $PM_{2.5}$ are likely to be achieved by current measures and policies?

9.6.1 Answer

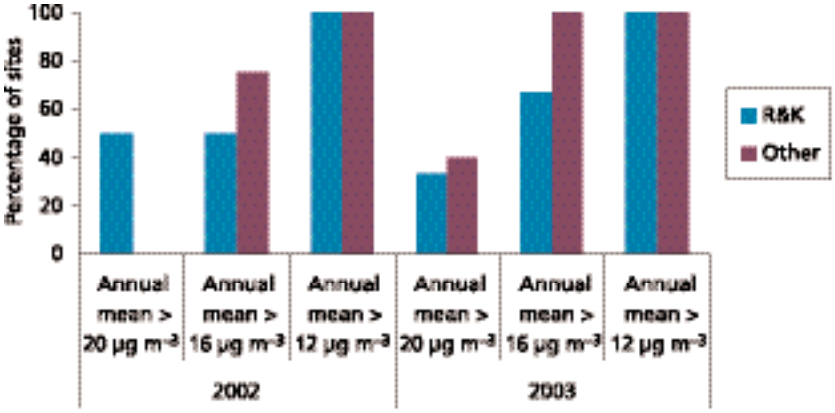
950. The CAFE Position Paper does not set firm targets for $PM_{2.5}$, but suggests that the attainment date would not be before 2010 and recommends a limit value based on annual means within the range 12–20 µg m^{-3}. Assuming a business as usual scenario, it is predicted that exceedences would be restricted to a small number of busy roads, predominantly within London at the upper end of this range (20 µg m^{-3}). At the lower end (12 µg m^{-3}) exceedences would be widespread across the UK, including both roadside and urban background locations.

951. There are a number of different sources contributing to the predicted exceedences in 2010, and it is not possible to single out any specific factor. A more detailed analysis of source apportionment is provided in Section 9.7.

9.6.2 Rationale

952. Figure 9.4 shows a summary of measured $PM_{2.5}$ concentrations in 2002 and 2003 compared with annual mean targets of 12, 16 and 20 µg m^{-3} (a more detailed description of the results is provided in Annex 7, Tables A7.4 and A7.5). There are currently few exceedences of 20 µg m^{-3}, but a considerably greater number if the limit value was reduced to 16 µg m^{-3}. If a 12 µg m^{-3} limit value was assumed, there would be non-compliance at all sites.

Figure 9.4 Measured $PM_{2.5}$ concentrations (gravimetric measurements only) in 2002 and 2003 compared with the CAFE proposed annual and daily mean limit values: percentages of sites exceeding the proposed limit value in each year are shown. (R&K, Roadside and kerbside sites; Other, all other site classifications.)



953. Predicted concentrations of $PM_{2.5}$ in 2010 have also been based on modelling studies, albeit with additional uncertainties compared with PM_{10}. Table 9.3 provides modelling estimates for exceedence of different annual mean limit values for the roads and regional areas considered in the Netcen model, for both 2002 and 2010. Corresponding estimates from the ADMS model for London in 2004 and 2010 are also included for comparison; these appear generally more optimistic for 2010 despite lower assumed reductions in the secondary inorganic component.

954. For 2010, if an annual mean limit value of 20 µg m^{-3} was assumed, then exceedences would be limited to a small number of road links, predominantly within London. As the assumed limit value is decreased, then exceedences occur at roads outside of London and then within wider urban areas. If a limit value of 12 µg m^{-3} was imposed, it is predicted that exceedences would occur along over 70% of roads in the UK and at about 25% of the urban areas.

9.7 What are the practical maximum feasible reductions of PM_{10} and $PM_{2.5}$ concentrations at (a) hotspots and (b) urban background, for example central London locations?

9.7.1 Answer

955. Unless and until mass closure can be achieved between PM components and PM_{10} and $PM_{2.5}$ mass, quantitative answers are compromised by uncertainty in our basic understanding. If the major manmade contributions to PM_{10} and $PM_{2.5}$ levels

Table 9.3 Predicted exceedences of proposed annual mean $PM_{2.5}$ concentrations by (a) road length and (b) area in 2002 and 2010 (Netcen model) and 2004 and 2010 (ADMS model).

	>12 µg m^{-3}			>14 µg m^{-3}			>16 µg m^{-3}			>18 µg m^{-3}			>20 µg m^{-3}		
	2002	**2004**	**2010**	**2002**	**2004**	**2010**	**2002**	**2004**	**2010**	**2002**	**2004**	**2010**	**2002**	**2004**	**2010**
(a) Road lengths (km)															
Region (km length)															
London (1,786)	1786	—	1782	1781	—	1638	1547	—	358	678	—	187	245	—	19
ADMS (3,651)	—	*3651*	*815*	—	*3247*	*84*	—	*698*	*7*	—	*186*	*0*	—	*67*	*0*
Rest of England (10,911)	9695	—	6861	6273	—	1371	2223	—	420	729	—	49	236	—	2
Scotland (1,348)	264	—	27	46	—	0	3	—	0	0	—	0	0	—	0
Wales (982)	362	—	61	58	—	7	16	—	0	7	—	0	0	—	0
Northern Ireland (1.010)	318	—	65	154	—	1	38	—	0	4	—	0	0	—	0
TOTAL (16,037)	**12325**	**—**	**8795**	**8312**	**—**	**2963**	**3828**	**—**	**778**	**1418**	**—**	**236**	**481**	**—**	**21**
(b) Area (km^2)															
Region (area in km^2)															
London (1,624)	1624	—	1531	1332	—	146	111	—	9	13	—	0	0	—	0
ADMS (1,574)	—	*1574*	*410*	—	*1555*	*10*	—	*139*	*1*	—	*21*	*0*	—	*6*	*0*
Rest of England (128,765)	54866	—	12660	4167	—	489	292	—	52	27	—	1	0	—	0
Scotland (77,535)	26	—	4	2	—	0	0	—	—	0	—	0	0	—	0
Wales (20,745)	212	—	53	12	—	1	0	—	0	0	—	0	0	—	0
Northern Ireland (13,680)	52	—	1	2	—	0	0	—	0	0	—	0	0	—	0
TOTAL (242,349)	**56780**	**—**	**14249**	**5615**	**—**	**636**	**403**	**—**	**61**	**40**	**—**	**1**	**0**	**—**	**0**

could be reduced to insignificant levels by foreseeable emissions controls, this would still leave natural sources and a proportion of manmade sources that are difficult or impossible to control (such as non-exhaust road traffic emissions). We estimate that these might account for up to 10 μg m^{-3} PM_{10} and 5 μg m^{-3} $PM_{2.5}$ in urban background locations. The uncertainties are such that it is difficult to estimate corresponding levels for hotspots close to roads.

956. Although it is not possible to directly answer what reductions are feasible, it is possible to consider what level of reduction would be required. An analysis of the emissions reduction required relative to baseline projected emissions at selected locations is provided in Table 9.4 below.

Table 9.4 Reductions in concentration and emissions required to meet objectives at selected sites.

Location and objective	Reductions required
Marylebone Road 2005 objective of ≤35 days >50μg m^{-3}	31% all primary and secondary; or 40% all primary; or 62% traffic emissions.
Marylebone Road 2010 objective of 23μg m^{-3} annual mean	46% all primary and secondary; or 61% all primary; or 100% all traffic emissions.
Bury roadside 2010 objective of 20μg m^{-3} annual mean	23% all primary and secondary; or 34% all primary; or 84% traffic emissions.
Glasgow kerbside 2010 objective of 18μg m^{-3} annual mean	38% all primary and secondary; or 49% all primary; or 83% traffic emissions.

9.8 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?

9.8.1 Answer

957. Modelled PM_{10} concentrations for the current year show that the traffic contribution dominates at roadside locations, but makes a relatively small contribution at urban background and suburban sites. For all sites, there is also a stationary source contribution and a substantial contribution from the regional background, including the secondary PM component. The 'residual' component also makes a very significant contribution to the total. By 2010, the traffic component is estimated to fall to about 50–75% of its current contribution, with the secondary component then dominating at non-roadside sites. However, the residual component is assumed to remain unchanged by 2010, and represents 50% or more of the total PM_{10} concentration at non-roadside locations.

958. For $PM_{2.5}$, a broadly similar pattern emerges for both the current and future years, although the residual component is much lower than that assumed for PM_{10}.

9.8.2 Rationale

959. Figure 9.5 describes calculations from the APEG source apportionment model for two sites in London (the Marylebone Road kerbside site and the London North Kensington urban background site). Comparisons are made between 2002 and 2010, for both PM_{10} and $PM_{2.5}$. The calculations are based on measurements carried out using the Partisol gravimetric sampler in order to take account of the volatile component.

960. At the Marylebone Road site, the traffic contribution strongly dominates PM_{10} concentrations in 2002, but declines by about 50% by 2010, by which time the residual component makes the greatest contribution. A very similar pattern is observed for $PM_{2.5}$.

961. At the London North Kensington background site the traffic contribution is significantly lower, with the secondary and residual components contributing equally to PM_{10} concentrations in 2002 and 2010. The distribution for $PM_{2.5}$ concentrations is very different, with the secondary component making the largest contributions in both 2002 and 2010.

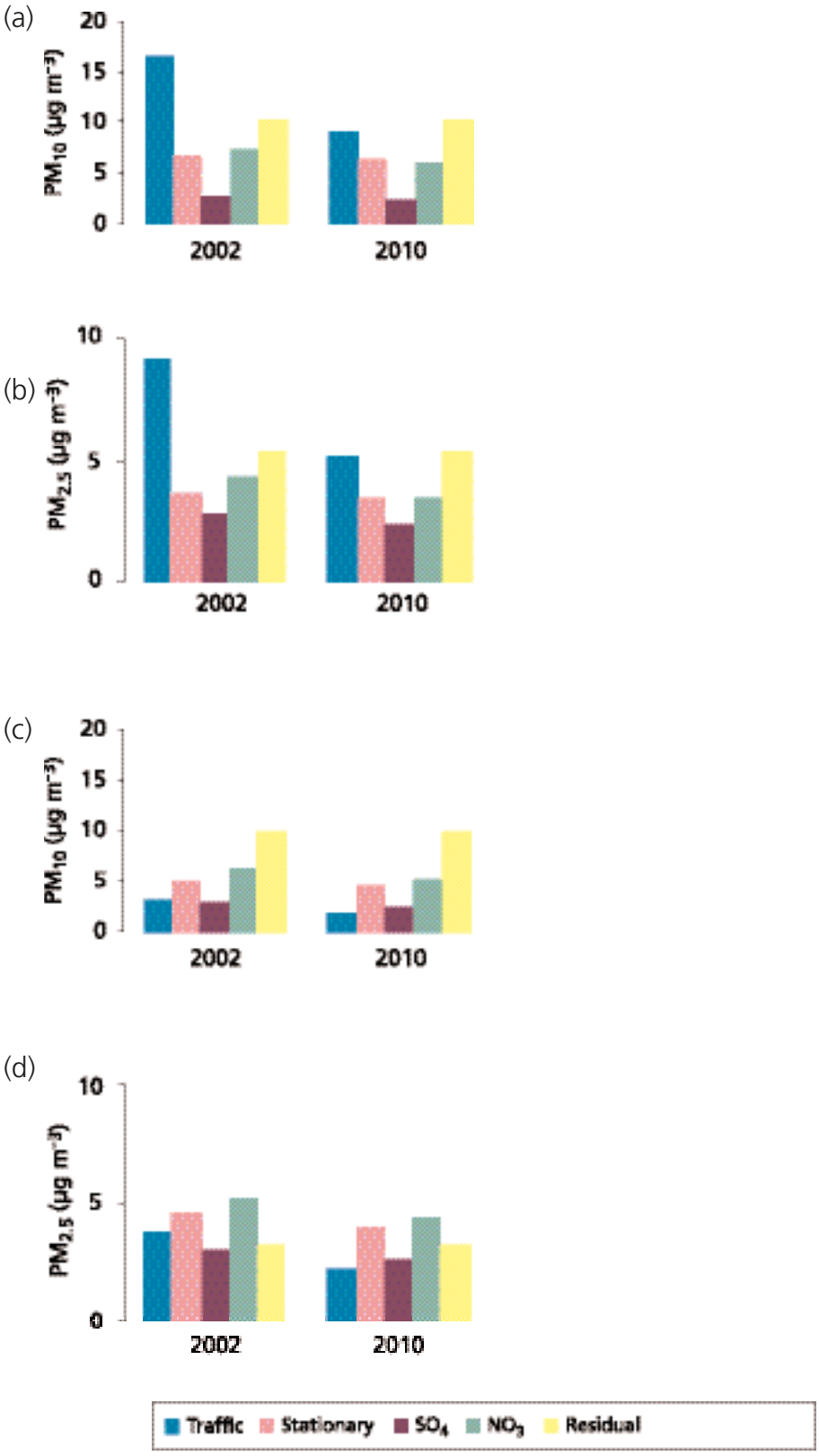
9.9 What are the potential sources of abatement and types of measures to reduce particle concentrations at (a) hotspots, such as near busy roads, (b) at urban background, central London and (c) across the whole country? What role can local/national/EU-wide measures play in meeting targets? These measures should be defined as technical (for example, vehicle standards); non-technical (for example, traffic management systems); and international (for example, controlling European/hemispheric emissions). Are there alternatives to emissions reduction?

9.9.1 Answer

962. There are a wide range of abatement measures beyond 'business as usual' that have the potential to reduce primary, secondary precursor and PM_{coarse} emissions. For the control of primary emissions, these include technical measures (such as the fitting of particulate traps on new diesel vehicles, retrofit of FGD to power stations, a switch from domestic coal to gas combustion and so on) and non-technical measures (such as the introduction of LEZs). Technical measures can be generally expected to be of benefit at the local and regional levels as well as nationally and may even be specifically targeted at hotspots.

963. A significant proportion of the precursor emissions are associated with long-range transport and are hence dependent upon action in Europe and beyond. The results of a European-wide assessment of emissions have been considered by the CAFE Working Group on Particulate Matter, which concluded that a large

Figure 9.5 Source apportionment during 2002 and 2010 based on APEG receptor model for (a) Marylebone Road PM_{10}, (b) Marylebone Road $PM_{2.5}$, (c) London North Kensington PM_{10} and (d) London North Kensington $PM_{2.5}$. All results based on Partisol measurement data.



potential exists for reducing PM precursor emissions in Europe. At a national level, various initiatives to control NO_x emissions (for example, for new diesel vehicles) may also have a significant impact on reducing precursors, but only a small impact on PM concentrations at a local level.

964. Measures for controlling PM_{coarse} emissions are specifically targeted at the local level and could include the sweeping or watering of road surfaces for example.

965. Alternatives to emission reduction include measures to reduce traffic volumes, such as incentives to use public transport or congestion charging schemes.

9.9.2 Rationale

966. The NAEI is currently investigating the emission reduction benefits of a number of transport and non-transport scenarios beyond the 'business as usual' case. Table 9.5 lists some of the measures being assessed, and additional measures considered by the CAFE Working Group on Particulate Matter. The table describes the reduction in emissions from the source being targeted (if it is a technical measure) and, where it has been quantified, the overall percentage reduction in UK PM_{10} emissions. The table also shows where the reductions in emissions will generally occur (for example, in urban areas or at specific points). It should be noted that the measures shown in the table are illustrative only.

967. The NAEI has assessed a number of scenarios relating to the setting of more stringent standards on emissions from road vehicles. The EC is considering tighter Euro V standards for cars and light duty vehicles and Euro VI standards on heavy-duty vehicles, which are likely to be introduced between 2010 and 2013. These might effectively mandate the fitting of particulate traps on all new diesel vehicles, which could lead to a significant reduction in urban exhaust emissions of PM_{10} from traffic in 2015. Other schemes being considered include incentives for using water-diesel emulsion.

968. Non-technical transport measures are also being assessed within the NAEI, for example, increasing the scrappage rate to accelerate the removal of higher emitting pre-Euro I and Euro I cars. Other measures being examined include various road charging schemes and LEZs, which could be targeted to control emissions at local hotspots.

969. The CAFE Position Paper on Particulate Matter considered several non-technical measures for reducing PM emissions from traffic. For example, non-exhaust road traffic emissions could potentially be reduced by vacuum sweeping and water spraying of road surfaces and so on. These measures could be targeted at hotspots and could prove beneficial at controlling PM emissions in and around construction and mineral extraction sites. The CAFE Position Paper also lists a number of traffic management measures, green travel plans and modal transport policies with potential at reducing local emissions, some of which are currently being picked up in local authority action plans to help improve air quality.

970. Among other modes of transport, emissions of PM, NO_x and SO_2 may benefit from the reduction of the sulphur content of gas oil used to power diesel trains and fuel oil used for shipping. Reducing the sulphur content of fuels may itself lead to reductions in PM emissions, but will also enable opportunities for

Table 9.5 Illustrative beyond 'business as usual' abatement measures for primary PM emissions.

Measure	Percentage reduction in PM_{10} at source	Effect on PM[a] size fractions	PM components affected	Percentage reduction in UK PM_{10} emissions	Where reductions will mainly occur	Note
Particulate traps on all new diesel vehicles – by 2010 for light duty vehicles, 2013 for heavy duty vehicles	90%	Reductions in fine PM; smaller reductions on ultrafines	Solid carbon, maybe less effective on low volatile organics	45% in 2015 for all urban road transport exhaust emissions; 4.7% in 2015 for all UK emissions	Urban and rural areas	A
Uptake of water-diesel emulsion – all buses and 10% HGVs running on water-diesel emulsion from 2006	25%	Reductions in fine PM; effect on ultrafines unknown	Not known	1.1% in 2010 for all urban road transport exhaust emissions; 0.1% in 2010 for all UK emissions	Mainly urban areas	A
Increase car scrappage rate by 10% from 2006	Not a technology-based measure	Reductions in fine PM	Solid carbon and volatile organic fractions	1.8% in 2010 for all urban road transport exhaust emissions; 0.2% in 2010 for all UK emissions	Urban and rural areas	A
LEZ – restricting access to Euro III+ heavy duty vehicles and 10-year age limit on vans and taxis by 2010	Not a technology-based measure	Reductions in fine PM	Solid carbon and volatile organic fractions	23% reduction in exhaust PM_{10} emissions if scheme applied to London in 2010	London. Scheme could be applied to other conurbations	B
Washing of roads (vacuum sweeping, water flushing)	Not quantified	Reductions in coarse PM	Inorganic material, solid carbon	Not assessed	Urban areas	C

Measure	Percentage reduction in PM_{10} at source	Effect on PM size fractions	PM components affected	Percentage reduction in UK PM_{10} emissions	Where reductions will mainly occur	Note
Local traffic management schemes	Not quantified; depends on scheme	Reductions in coarse and fine PM	Solid carbon and volatile organic fractions and inorganic material	Not assessed; depends on scheme	Urban areas	
Domestic combustion – 100% switch from coal to gas completed by 2010	99.8%	Reductions in coarse and fine PM	Metals, inorganic material, solid carbon	2.5% in 2010	Urban areas	A
Low cost filters on small industry processes – 30% uptake by 2010	99.5%	Reductions in coarse and fine PM	Depends on process, but expect effect on metals, inorganic material, solid carbon	1.1% in 2010	Industrial areas	A
Sinter plant fabric filter on iron and steel plants – 100% by 2010	80%	Reductions in coarse and fine PM	Metals, inorganic material, some carbon	1.8% in 2010	Point sources in industrial areas	A
FGD on coal-fired power stations – all remaining plants fitted by 2010	90%	Reductions in coarse and fine PM	Metals, inorganic material, some carbon	4.4% in 2010	Point sources	A, D
Spraying water at construction sites	20%	Reductions in coarse PM	Minerals	Not assessed	Construction areas	C

A: Based on assessment of illustrative measures by the NAEI. B: From Watkiss *et al*. (2003). C: Taken from CAFE Draft Second Position Paper on Particulate Matter, 2003. D: Business as usual case assumes seven power stations (54% of generating capacity) will already be fitted with FGD by 2010. Beyond business as usual assumes remaining 12 power stations fitted with FGD. These figures are based on projections from the 2001 NAEI using data from the Pollution Inventory on power station emissions in 2001.

implementation of after-treatment technologies like exhaust gas recirculation and selective catalytic reduction (AQEG, 2004).

971. In terms of stationary source emissions, important abatement measures include further retrofitting of FGD and electrostatic precipitators to UK combustion plant and improved filter technologies to smaller industrial processes. Fuel switching from coal to gas would also bring benefits within both the industrial and domestic sectors. In the latter case, measures could be focussed upon urban hotspot regions.

972. The National Emissions Ceilings Directive is currently under review with proposals expected in 2006. Potential 'add-on' measures for additional abatement of SO_2, NO_x and NH_3 have been assembled for each Member State, including fuel switching and energy conservation schemes. An additional contribution to precursor emissions comes from shipping, which now contributes about 10% of the secondary sulphate and nitrate background concentrations across the UK; additional control measures, such as the reduction in the sulphur content of fuels, are also being considered.

973. Controlling precursor emissions leads to fairly uniform reductions of secondary particles over large areas, as opposed to targeted reductions in urban areas. Correspondingly, local action to reduce precursor emissions has little effect on local PM concentrations.

974. A summary of illustrative 'beyond business as usual' measures for the UK reduction of PM precursor emissions is provided in Table 9.4. The table describes the impact upon NO_x or SO_2 reduction at source and the overall impact upon UK emissions. At a European level, the CAFE Position Paper discusses a number of abatement measures, including studies by the UK Interdepartmental Group on Costs and Benefits (IGCB), which investigated the effects of possible measures to further reduce PM_{10} levels in the UK. Although based on an older set of UK emission projections than the current NAEI projections, the IGCB study concluded that overall, transport measures appeared less cost-effective than many potential industrial measures in terms of reducing background PM_{10} concentrations. However, targeted transport measures were more effective at reducing roadside concentrations than industry measures. These conclusions may need to be reassessed on the basis of more recent baseline emission projections for road transport and industry and domestic sources in the UK.

975. The CAFE Position Paper also covers the results of a European-wide assessment of emissions carried out by IIASA and summarises the emission reduction potentials of a number of PM emission abatement options included in the study. In its initial study, IIASA concluded that a large potential exists for reducing PM precursor emissions in Europe, but that results for the reduction potential of primary PM sources and measures are somewhat conflicting. A further assessment of abatement measures to reduce PM is currently underway by IIASA.

976. Alternative measures to emissions reduction include various schemes to reduce traffic volumes, which would be particularly valuable in urban areas. Such measures include incentives to use public transport, park-and-ride schemes, LEZs and designation of car-free areas. Financial measures to restrict private car use include higher taxation, increased parking fees and congestion charging. The latter is of particular interest following its introduction in London during 2003, and a summary of the effects is provided in Annex 9.

Table 9.6 Illustrative beyond business as usual abatement for PM precursor emissions.

Measure	Pollutant	Percentage reduction at source	Percentage reduction in UK emissions	Note
50% reduction in NO_x limits for new diesel vehicles from 2010 (light duty vehicles) and 2013 (heavy duty vehicles) plus tougher durability requirements on petrol vehicles	NO_x	50%	26% in UK road transport emissions in 2015; 7% in all UK emissions in 2015	A
Uptake of hybrid cars in vehicle fleet – reaching 10% of car sales by 2010	NO_x	~70%	0.8% in UK road transport emissions in 2010; 0.2% in all UK emissions in 2010	A
Uptake of water-diesel emulsion – all buses and 10% HGVs running on water-diesel emulsion from 2006	NO_x	14%	1.5% in UK road transport emissions in 2010; 0.5% in all UK emissions in 2010	A
Increase car scrappage rate by 10% from 2006	NO_x	Not a technology-based measure	2% in UK road transport emissions in 2010; 0.6% in all UK emissions in 2010	A
Selective catalytic reduction fitted to iron and steel plants (100%), power stations (100%) and refineries (80%) by 2010	NO_x	60–85%	7% in 2010	A
Domestic combustion – 100% switch from coal to gas completed by 2010	SO_2	100%	0.9% in 2010	A
Selective non-catalytic reduction fitted to cement kilns, Selective catalytic reduction on iron and steel plants – 100% by 2010	NO_x	60%	3.1% in 2010	A
FGD on coal-fired power stations – all remaining plants fitted by 2010	SO_2	90%	32% in 2010	A, B

A: Based on assessment of illustrative measures by the NAEI. B: 'Business as usual' case assumes seven power stations (54% of generating capacity) will already be fitted with FGD by 2010. Beyond business as usual assumes remaining 12 power stations fitted with FGD. These figures are based on projections from the 2001 NAEI using data from the Pollution Inventory on power station emissions in 2001.

9.10 A number of recent studies (that is, the WHO report) have highlighted the health effects of certain components of PM (fines, ultrafines, particle number, metals and elemental/organic carbon). Where further abatement techniques are known, how might they specifically affect reduction of the different PM metrics (for example PM_{10}, $PM_{2.5}$, PM_1 and particle numbers) and chemical components?

9.10.1 Answer

977. Current limit values have focused attention on reducing particle mass and specifically PM_{10}. The relative effectiveness of measures in reducing finer fractions or specific chemical components depend both on the source type and particle characteristic and the type of abatement technique employed. Measures aimed at reducing coarser particles, such as mineral dust from roads, quarrying or construction sites, will have little effect on reducing $PM_{2.5}$ or finer fractions, whereas measures to control primary particle emissions from combustion sources should be very effective in reducing fine particles. Measures that reduce activity levels, such as traffic control measures, reduce all components of the corresponding particles equally. Secondary inorganic particles are mainly in the $PM_{2.5}$ range except for a proportion of the nitrate attached to coarser particles, and measures to reduce precursor emissions are correspondingly effective across all size ranges.

978. There are currently insufficient measurement data to determine the precise impacts of PM_{10} control measures upon ultrafines and chemical components.

9.10.2 Rationale

979. Table 9.5 describes in qualitative terms the likely impact of the different beyond business as usual measures upon the different PM size fractions and chemical components, where these are known. Principal measures targeted at reducing PM emissions from traffic, such as particulate traps and the uptake of water-diesel emulsion, should be effective in reducing fine fraction ($PM_{2.5}$ and PM_1) and ultrafine emissions but this is by no means certain and cannot be currently quantified. In terms of industrial emissions, measurement data on smaller PM size fractions are even less plentiful, but improvements in technology, such as the use of bag filters, are expected to be beneficial in terms of controlling ultrafines.

980. Chapter 6 describes in detail the mechanism of ultrafine particle formation at Marylebone Road. Measures that reduce fine-fraction particle emissions may also reduce the effectiveness of the condensation sink, favouring instead the growth of fresh ultrafines, although there is no evidence to support this theory at present.

9.11 Ultrafines – what have we learned from the measured data, including source apportionment? Are the observed trends real? What fraction of ultrafine particles volatilise?

9.11.1 Answer

981. The ultrafine fraction contributes little to overall mass but dominates the particle number count. From measured data, it is clear that traffic is a major source of ultrafine particles, but there is also widespread formation by photochemical processes in the atmosphere. Time series of measurements in the UK are insufficient at present to comment on long-term trends. Current evidence suggests that volatilisation is not a significant process.

9.11.2 Rationale

982. Measurement programmes for both size-fractionated and total particle number concentrations have shown that road traffic is a major source of ultrafine particles. A substantial proportion of these particles is formed during dilution of the exhaust gas with ambient air, rather than being emitted directly from the exhaust. The formation process is significantly dependent on meteorology, with lower temperatures favouring the formation of high concentrations of particles at the lower end of the size range. Particle number concentrations are significantly higher at Marylebone Road (a kerbside site) than at the urban background sites, which show a reasonable consistency between one city and another.

983. There is clear evidence at the Harwell (rural) site for the formation of new particles, through the process of homogenous nucleation. Such processes are widespread in the atmosphere and are favoured by the low pre-existing particle concentrations at rural sites. While the formation processes are photochemically driven, the precise chemistry of particle formation is currently not well understood.

984. The subsequent fate of ultrafine particles will depend upon processes of dilution, coagulation and deposition, which are not yet fully understood.

9.12 Source apportionment 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 between 2.5 and 10 µm accounted for?

9.12.1 Answer

985. The models used within the UK have both common themes and major differences in the manner in which they operate. In general terms, the models account for the PM_{coarse} fraction by the addition of a constant background. There is good

reason to believe that part of this component is associated with non-exhaust traffic emissions (resuspension of road dust). Such an assumption in modelling leads to a different distribution of PM_{10} concentrations at roadside sites, with significant implications for where the limit values may be exceeded.

986. In terms of annual mean concentrations for the current year, the models show a broadly similar performance at monitoring sites. In terms of source apportionment, the ADMS model shows a greater traffic contribution at roadside sites and a greater secondary and a lower stationary source contribution at all sites for both PM_{10} and $PM_{2.5}$.

987. An overview of models used within Europe for the prediction of PM concentrations was provided by the CAFE Working Group on Particulate Matter, and no further analysis has been carried out within this report.

9.12.2 Rationale

988. The models that are routinely used in the UK for predictions at the national level are based either upon semi-empirical methods (relying upon monitored data and local dispersion calculations) or based primarily on dispersion modelling. An intercomparison of these models shows a broadly similar performance for the prediction of annual mean PM_{10} concentrations at monitoring sites, but an intercomparison of calculated concentrations on individual road segments in London shows a wide scatter between the ADMS and ERG models. This reflects the different manner in which the models account for individual source components and, in particular, the different treatment of the background. No such intercomparison has been carried out for $PM_{2.5}$.

989. Treatment of the PM_{coarse} fraction is handled in a slightly different manner by each of the UK models, including the derivation of 'roadside specific' adjustment factors or the derivation of a PM_{coarse} component based on regression analysis with NO_x. Although these approaches have a sound base, it is currently not clear how successful they are in taking full account of non-exhaust road traffic emissions. As this is believed to be a significant component of PM_{coarse} emissions, the current models may underestimate the importance of road traffic to predicted PM_{10} concentrations.

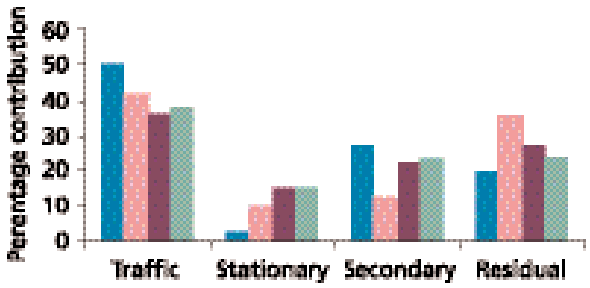
990. Site-specific source apportionment studies have been carried out using the Netcen and ADMS models for London. The detailed results are provided in Chapter 8, with an intercomparison of the model performance summarised in Figure 9.6 for Marylebone Road. Several important conclusions may be drawn.

- The Netcen model shows significantly different results, depending upon which measurement method was used to collect the data. This may be directly attributed to the loss of the volatile species by the TEOM analyser.

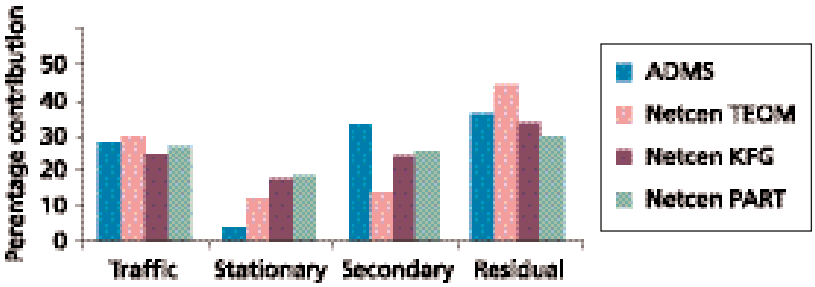
- The ADMS model shows a higher traffic contribution, much greater secondary and much lower stationary source contribution.

Figure 9.6 Comparison of source apportionment at Marylebone Road site based on Netcen (NAEI) and ADMS (LAEI) models for (a) 2002 and (b) 2010. (Netcen model results shown for three measurement methods: TEOM, KFG and Partisol.)

(a) 2002



(b) 2010



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

9.13.1 Answer

991. The downward trends in measured PM_{10}, sulphur and black smoke since 1992 are complicated by interannual variations. Across the UK, PM_{10} concentrations declined steadily throughout the 1990s, broadly in line with declining PM_{10} and precursor emissions. This downward trend appears to have flattened off, or even become an increase, in more recent years. The influence upon these trends of the significant regional pollution episodes in 2003, due to meterological conditions, is not yet clear.

992. Particulate sulphate concentrations are also declining, albeit at a lower rate than SO_2 emissions. This may point to increasing oxidising capacity of the atmosphere as NO_x emissions decline.

993. Black smoke concentrations have declined in line with emissions across most of the UK with the exception of London where diesel traffic emissions make a significant contribution.

9.13.2 Rationale

994. There are 12 long-running monitoring sites across the UK that allow an analysis of PM_{10} trends from 1992 onwards. For all of these sites, there are statistically significant downward trends in PM_{10} concentrations up to 2003. Average PM_{10} concentrations are declining at about –4.4% per annum, which is close to the –5% per annum decrease in PM_{10} emissions described within the emissions inventory.

995. This trend in PM_{10} concentrations has not remained constant, and there is evidence to suggest that it may have reversed over the period 2000 to 2003. Although PM_{10} emissions have continued to decline at about –5% per annum over the period 1997 to 2003, this has not been the case for urban PM_{10} concentrations, which have slowed to about –2% per annum, with some sites in London exhibiting trends much smaller than this or close to zero.

996. At some urban sites there is evidence of increasing PM_{10} concentrations over the period 2000 to 2003, although this may have been strongly influenced by large-scale regional pollution episodes during 2003. However, although 2003 stood out as a significantly different year for about one-third of the monitoring sites, this difference was not apparent at other monitoring locations and there is no clear spatial distribution.

997. The UK network sites show a significant downward trend in particulate sulphate concentrations over the period 1990 to 2002, in the range of –4.3 to –9.3% per annum. This is somewhat smaller than the decline in UK SO_2 emissions over the same period, suggesting that an increasing fraction of the emitted SO_2 is being oxidised. A potential mechanism for this may be declining NO_x emissions and hence an increased photochemical oxidation rate for SO_2 to sulphate aerosol.

998. There is a large network of black smoke monitoring sites across the UK. Over the period 1990 to 2002, average concentrations declined at a rate of about –5% per annum. Over the same period, black smoke emissions are estimated to have declined at –6.8% per annum. A more detailed analysis of the trend data on a region-by-region basis demonstrates that significant downward trends have been observed in locations where domestic coal burning has been phased out. Within London, some of the smallest downward trends in the UK have been identified. This is partly due to the much earlier phase-out of domestic coal burning and the increasing contribution from road traffic, in particular diesel vehicles.

9.14 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?

9.14.1 Answer

999. Strategies based solely on limit values tend to focus attention on reducing concentrations in localised areas or 'hotspots' where exceedences are measured or predicted. However, such localised areas are unlikely to be associated with large population exposure. For pollutants such as PM, where there is no evidence of a

threshold concentration below which health effects do not occur, a strategy based on reducing exposure to the largest population would seem to offer improved benefits to public health. AQEG recommends such an exposure reduction strategy.

9.14.2 Rationale

1000. Air quality control is currently based upon the use of limit values that are defined in the Air Quality Daughter Directives. Limit values have proved to be an extremely useful mechanism over the past 20 years or so; they provide a simple, uniform measure of progress in improving air quality as well as providing a driver for emissions controls and helping raise public awareness. There are, however, emerging limitations with this approach.

1001. The limit values for human health apply to all locations within a Member State, and this inevitably leads policy makers towards the improvement of conditions in areas of very poor air quality, that is hotspots, where the limit values are exceeded. For PM, these hotspots will include major roads, particularly within urban centres in the majority of European cities. If there are no exceedences of the limit values, then the Member State will not be required to develop any policy measures to further reduce exposure to PM, even though health benefits would be achieved.

1002. However, it is widely recognised that in the case of PM, there is no threshold concentration below which there are no health effects. It may be concluded that any reduction in exposure would be associated with an improvement to health, even if levels are below the limit value. In terms of maximising health benefits to the general population, such an approach is expected to be far more effective. For example, reducing the exposure of 10 million people by 0.1 $\mu g/m^3$ is ten-times more effective than reducing the exposure of 1,000 people (at hotspots) by 10 $\mu g/m^3$.

1003. A system of reducing long-term population-weighted exposure would provide a useful supplement to limit values. This could be based on reducing concentrations measured principally in urban background locations, where people are most exposed.