

AIR QUALITY EXPERT GROUP

Particulate Matter in the United Kingdom

Summary



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





This is a summary of the second report produced by the Air Quality Expert Group.

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This document is also available on the AQEG website at:

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Published by the Department for the Environment, Food and Rural Affairs.

Printed in April 2005 on material containing 80% post-consumer waste and 20% elemental chlorine-free pulp.

Product code PB10580a ISBN 0-85521-144-X

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When referencing this document, please use the following phrasing:
AQEG (2005) *Particulate Matter in the UK: Summary*. Defra, London.

■ Introduction

The Air Quality Expert Group (AQEG) was set up in 2002, following the publication of the '**Air Quality Strategy for England, Scotland, Wales and Northern Ireland**', which describes the plans drawn up by the Government and Devolved Administrations to protect and improve air quality in the United Kingdom (UK).

AQEG aims to help the UK Government tackle air pollution by examining where pollutants come from and what their **concentrations** are in the UK.

This is a Summary of AQEG's second report, *Particulate Matter in the United Kingdom*. We have included a glossary at the back to explain certain terms (these are shown in **bold** the first time they occur in the document).

■ What is particulate matter?

Airborne particulate matter is made up of a collection of solid and/or liquid materials of various sizes that range from a few **nanometres** in diameter (about the size of a virus) to around 100 **micrometres** (100 μm , about the thickness of a human hair). It consists of both **primary components**, which are released directly from the source into the atmosphere, and **secondary components**, which are formed in the atmosphere by chemical reactions. Particulate matter comes from both human-made and natural sources. It contains a range of chemical compounds and the identity of these compounds provides clues to its origin (see Tables 1 and 2).

Measurements of the concentration of particulate matter in air are made by recording the mass of particulate matter in one cubic metre of air, using the units micrograms per cubic metre, $\mu\text{g m}^{-3}$.



Particulate matter is classified according to its size and this classification is used in concentration measurements. For example, PM_{10} is – to a good approximation – the

concentration of particles that are less than or equal to $10\ \mu\text{m}$ in diameter; similarly $PM_{2.5}$ describes the concentration of particles that are less than or equal to $2.5\ \mu\text{m}$ in diameter.

Table 1. Components of particulate matter.

Primary components	Sources
Sodium chloride	Sea salt.
Elemental carbon	Black carbon (soot) is formed during high temperature combustion of fossil fuels such as coal, natural gas and oil (diesel and petrol) and biomass fuels such as wood chips.
Trace metals	These metals are present at very low concentrations and include lead, cadmium, nickel, chromium, zinc and manganese. They are generated by metallurgical processes, such as steel making, or by impurities found in or additives mixed into fuels used by industry. Metals in particles are also derived from mechanical abrasion processes, e.g. during vehicle motion and break and tyre wear.
Mineral components	These minerals are found in coarse dusts from quarrying, construction and demolition work and from wind-driven dusts. They include aluminium, silicon, iron and calcium.
Secondary components	Sources
Sulphate	Formed by the oxidation of sulphur dioxide (SO_2) in the atmosphere to form sulphuric acid, which can react with ammonia (NH_3) to give ammonium sulphate.
Nitrate	Formed by the oxidation of nitrogen oxides (NO_x – which consists of nitric oxide (nitrogen monoxide, NO) and nitrogen dioxide (NO_2) in the atmosphere to form nitric acid, which can react with NH_3 to give ammonium nitrate. Also present as sodium nitrate.
Water	Some components of the aerosol form of particulate matter, such as ammonium sulphates and ammonium nitrates, take up water from the atmosphere.
Primary and secondary components	Sources
Organic carbon	Primary organic carbon comes from traffic or industrial combustion sources. Secondary organic carbon comes from the oxidation of volatile organic compounds (VOCs). There may be several hundred individual components. Some of these trace organic compounds, such as certain polycyclic aromatic hydrocarbons, are highly toxic.

Note that abbreviations such as SO_2 and NO_x are often used instead of the names of the chemicals in full. We will follow this practice in this Summary.

Table 2. Precursors of secondary particulate matter.

Primary components	Sources
SO ₂	SO ₂ is formed by the combustion of sulphur-containing fuels such as coal. Ship fuels such as heavy fuel oil are also a source. However, SO ₂ emissions from coal-burning power stations have been much reduced by the use of a technology called flue gas desulphurisation and automotive fuels are now low in sulphur.
NO _x	NO _x is formed by the combustion of fuels used in power generation, domestic heating and traffic. See the AQEG report <i>Nitrogen Dioxide in the United Kingdom</i> for more details.
NH ₃	Ammonia (NH ₃) is emitted mainly from agricultural sources, particularly livestock waste.
VOCs	Aromatic compounds such as benzene and toluene are generated by traffic and solvents. Monoterpenes come from vegetation, especially conifers and heathers.

■ Where does it come from?

Primary particles are released into the atmosphere from a number of stationary and mobile sources. The major mobile source is road transport, which produces primary particles when fuels are burned or lubricants used up in the engine, when tyres and brakes wear down and from road dust. The main stationary sources are the burning of fuels for industrial, commercial and domestic purposes. Emissions of dust can also generate high concentrations of particulate matter close to quarries and construction sites. Primary particles can also be produced from natural sources, for example sea spray and dust from the Saharan desert travelling vast distances. Secondary particulate matter is formed from chemical reactions of the gases NH₃, SO₂ and NO_x released into the atmosphere (see Table 1). Secondary particulate matter is also formed from organic compounds by reactions that occur in the atmosphere. These organic compounds are released when fuel is burned or when fuel or solvents evaporate; they are also emitted naturally by vegetation.

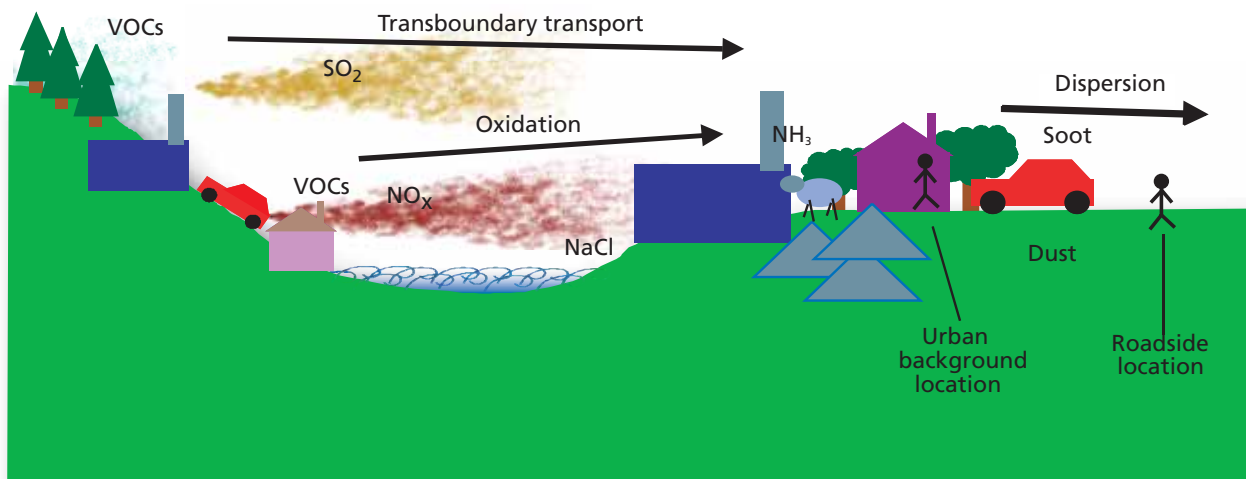
The sources of particulate matter are shown in Figure 1. To the right of the figure are urban background and roadside sites (these terms are defined later in this summary, on page 9) where people live and work. Furthest to the left of the figure are the sources of secondary particulate matter, VOCs, NO_x and SO₂. The formation of secondary particulate matter takes time. During the hours or even days over which this happens, the air containing the pollution can travel long distances and so these gases may have been emitted on mainland Europe. The sources of primary particulate matter are shown in the centre of the figure.

■ What are the health effects of particulate matter?

Particulate matter can affect our health. The available evidence suggests that it is the fine components of PM₁₀, which have a diameter of 2.5 µm or less and are formed by combustion, that are the main cause of the harmful effects of particulate matter. These fine particles consist of carbon, trace



Figure 1. Sources of particulate matter.



metals (such as copper and zinc) and organic compounds. There is less evidence to connect secondary inorganic particulate matter (such as sulphates and nitrates) or larger particles with adverse health effects, although they cannot be ruled out.

Particles cause the most serious health problems among those susceptible groups with pre-existing lung or heart disease and/or the elderly and children. There is evidence that short- and long-term exposure to particulate matter cause **respiratory** and **cardiovascular illness** and even death. It is likely that the most severe effects on health are caused by exposure to particles over long periods of time. However, UK estimates indicate that short-term exposure to the levels of PM₁₀ that we experienced in 2002 led to 6,500 deaths and 6,400 hospital admissions being brought forward that year, although it is not possible to know by what length of time those deaths were brought forward. Work published by the **Committee on Medical Effects of Air Pollution (COMEAP)** in 2001 also indicates that for

each 1 µg m⁻³ decrease in PM_{2.5} over the lifetime of the current population of England and Wales, between 0.2 and 0.5 million years of life will be gained. This is equivalent, on average, to 1.5 – 3.5 days for every individual in England and Wales. The effect is unlikely to be evenly spread across the population, however, and some people will gain much more.

■ Particulate matter and the UK Air Quality Strategy

To protect our health, Defra and the Devolved Administrations have set two **air quality objectives** for PM₁₀ in their Air Quality Strategy:

1. The 24-hourly objective, which is the concentration of PM₁₀ in the air averaged over 24 hours, is designed to make sure that we are not exposed to high concentrations of PM₁₀ for short periods of time. High concentrations can arise during pollution **episodes**, which are short periods of high levels of pollution



that are usually associated with particular weather conditions.

2. The annual objective, which is the concentration of PM_{10} in the air averaged over one year, aims to protect us from being exposed to PM_{10} over a long time period.

The European Union (EU) has also developed legislation to limit our exposure to air pollutants through **limit values** – concentrations not to be exceeded. Table 3 shows the objectives and limit values that need to be achieved by the UK for PM_{10} concentrations. In addition, emissions of particulate matter are controlled by legislation at national and European levels (for example, by limiting engine emissions from road vehicles).

The EU has also proposed stricter limit values to be achieved by 1 January 2010. These involve a reduction of the number of allowed exceedences of the 24-hourly limit

value from 35 to 7 and a decrease in the annual limit value from $40 \mu g m^{-3}$ to $20 \mu g m^{-3}$. These are called **indicative limit values**, because they currently have no legal standing. They will be subject to further assessment and discussion by experts and policy-makers before a decision is made on whether to adopt them. In its Addendum to the Air Quality Strategy, the UK Government and Devolved Administrations adopted these stricter indicative limit values as provisional objectives to be achieved in the UK by 31 December 2010.

The provisional annual objective is slightly stricter still for Scotland and slightly less strict for London. This reflects the lower concentrations in Scotland and the higher values found in London. Although these tighter objectives have no legal standing in England, Wales and Northern Ireland they have been put into regulations in Scotland for the purposes of Local Air Quality Management.



Table 3. EU limit values and the UK Air Quality Strategy objectives for particulate matter (measured as PM₁₀).

Legislation	24-hourly limit values and objectives	Annual limit values and objectives	Achieve by
EU First Daughter Directive (99/30/EC)	50 µg m ⁻³ with up to 35 exceedences a year	40 µg m ⁻³	1 January 2005
UK Air Quality Strategy (2000)	50 µg m ⁻³ with up to 35 exceedences a year	40 µg m ⁻³	31 December 2004

For the 24-hourly objective, an agreed number of exceedences is permitted. This allows for situations, such as Bonfire Night, where it is not possible or practical to expect 24-hourly average concentrations to remain within the agreed limit (see page 14).

■ How are emissions of particulate matter changing?

Figure 2 shows the total **emissions** of primary PM₁₀ in the UK from 1970 to 2001. The fall in total emissions has been dominated by reductions in emissions from domestic heating, energy production and from industrial combustion largely as a result of a decrease in the use of coal as a fuel. The reductions in particulate matter emissions in the UK are similar to or greater than those achieved in mainland Europe. During 1990 to 2001, emissions of primary PM₁₀ in the UK fell by 42% compared with

23% in Germany, 13% in France and 39% in Sweden.

We expect emissions to fall by a further 28% by 2010, mainly from reductions in power station and road transport emissions, but to level off between 2010 and 2020. However, the reduction may not be as great as this if the recent growth in the numbers of diesel cars on the road continues. The Department for Transport now expects that more diesel cars will be sold in the UK than it had previously forecast. Emissions of particulate matter from diesel cars are greater than those from petrol cars.



The air quality models used in the AQEG report to predict future concentrations of particulate matter used the older, lower estimates of the numbers of diesel cars. As a result, it is likely that future emissions will be somewhat higher than originally predicted.

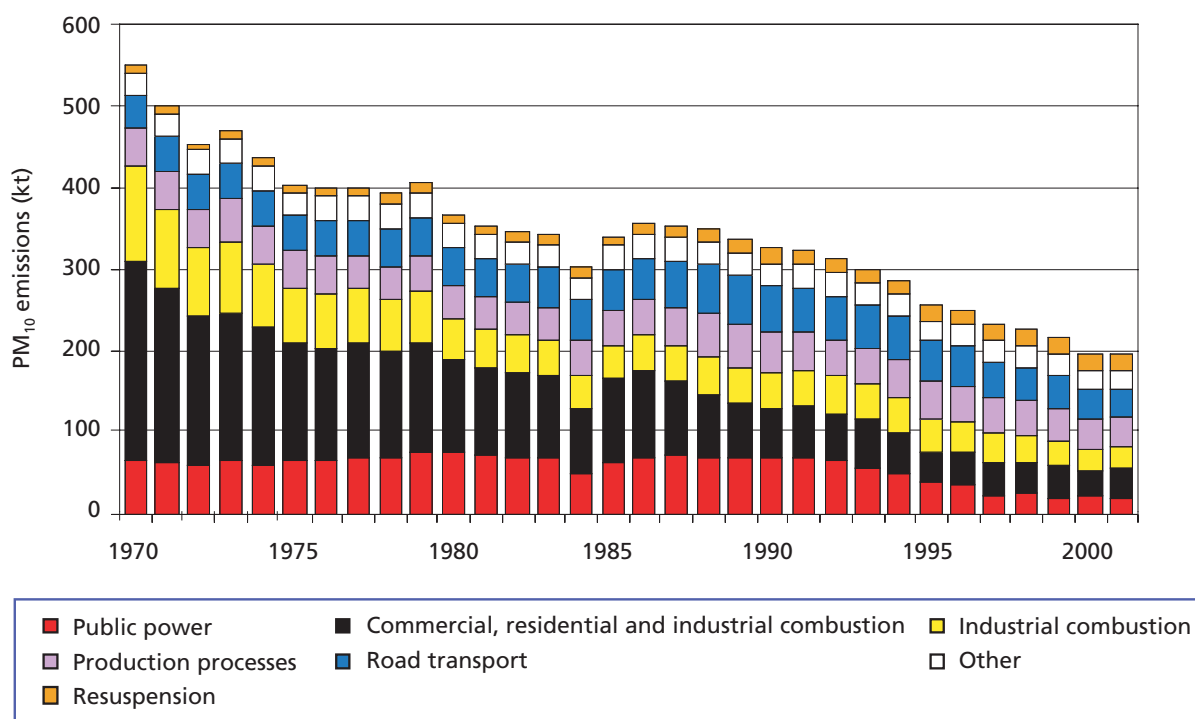
There have also been reductions in the emissions of those pollutants that lead to the formation of secondary particulate matter. Since 1990, SO₂ emissions, which lead to sulphate formation, have fallen by over 83% in the UK. This decrease is attributable to the switch from coal to gas and the use of flue gas desulphurisation at power stations and other industrial plants to trap SO₂ before it reaches the atmosphere. In addition, NO_x emissions, which lead to nitrate formation, have fallen by 39% since 1990 to meet increasingly strict European standards. These reductions in NO_x emissions are

largely due to improvements in engine design and to the fitting of **three-way catalysts** to petrol cars. Reductions in emissions from power stations have also been important.

■ How is particulate matter measured?

The aim of the measurement techniques is to determine the concentration of particulate matter in outdoor air. Since the air quality objectives are framed in terms of the concentration of PM₁₀, it is necessary to exclude particles greater than 10 µm from the analysis. This is achieved by drawing the air through a **size-selective inlet**. Measurements are also made of PM_{2.5} for which a different size-selective inlet is required.

Figure 2. PM₁₀ emissions in **kilotonnes** in the UK by source from 1970 to 2001.



One way of determining particulate matter concentrations is the filter-based gravimetric method. With this method a certain volume of air is drawn through a size-selective inlet and then through a filter. The particulate matter is deposited on the filter, which is then weighed to determine the mass of particulate matter that was in that volume of air.

A widely used alternative method uses the TEOM (Tapered Element Oscillating Microbalance). The filter in a TEOM is mounted on a tapered glass tube that vibrates continually. As particles collect on the filter, the vibration gets slower. The change in vibration can be measured very precisely without stopping sampling, giving a continuous measurement of the amount of particulate matter being collected.

The EU defines the filter-based gravimetric method as its **reference method**.

Other methods, used by member countries to establish compliance with EU limit values, must be related back to this reference method. One disadvantage of the gravimetric method is that it takes about 24 hours to make a measurement, and the results are reported only after several days. In the UK, the TEOM analyser is widely used because it gives results that can be made available immediately to the public. However, this method requires that the air passing into the TEOM analyser is heated and this leads to the loss of **semi-volatile** material such as some organic compounds, ammonium nitrate and water. The filter-based gravimetric method does not use a heated inlet so it is necessary to adjust the data collected from TEOMs using a scaling factor to allow the direct comparison of TEOM measurements with measurements made with the EU's gravimetric reference method and therefore the EU limit values.



■ Particulate matter monitoring networks

Networks of monitoring sites for particulate matter have been established throughout the UK. The majority of sites use a TEOM analyser, but a few use the gravimetric and other methods. Most sites monitor PM_{10} , but a few also measure $PM_{2.5}$. The main networks are:

- national networks, including the Automatic Urban and Rural Network (AURN) – which is funded by Defra and the Devolved Administrations but which also includes some local authority sites, including some from the London Air Quality Network (LAQN);

- regional networks – which consist of the LAQN and other local authority sites; and
- other monitoring sites – which are operated by local authorities and groups such as the Highways Agency and the electricity-generating companies.

Figure 3 shows the locations of the 240 PM_{10} sites that were operational in 2003 in the UK and that were used by AQEG to produce this report. The locations of sites measuring $PM_{2.5}$ are also shown. The monitoring sites are classified into different types depending on their location, for example, kerbside, roadside and urban background. This classification is briefly described in Table 4.

Table 4. Definitions of types of monitoring site.

Type	Definition of site
Kerbside	Sites with sample inlets within one metre of the edge of a busy road.
Roadside	Sites with sample inlets between one metre of the edge of a busy road and the back of the pavement (usually five metres from the roadside).
Urban centre	Sites away from roads in city and town centres (for example, in pedestrian precincts and shopping areas).
Urban background	Sites in urban locations (for example parks and urban residential areas) away from specific emission sources. These locations broadly represent city-wide background concentrations.
Urban industrial	Sites where industrial emissions can make a significant contribution to measured pollution concentrations.
Suburban	Sites typical of residential areas on the outskirts of a town or city.
Rural	Sites in the open country away from roads and industrial and residential areas.
Remote	Sites in the open country in isolated rural areas that only have regional background pollution concentrations for most of the time.

There are also 123 sites nationally that monitor black smoke. Black smoke is dark particulate matter – essentially soot – which is measured from the degree of staining of a filter when a certain volume of air is drawn through it. The main advantage of the black smoke monitoring sites is that some of them have been operating for many years, giving

information on trends in black smoke concentrations over several decades. The method is also a good indicator of a particular source of particulate matter – elemental carbon from stationary and mobile combustion sources. The disadvantage of black smoke measurements is that they cannot be related to the EU

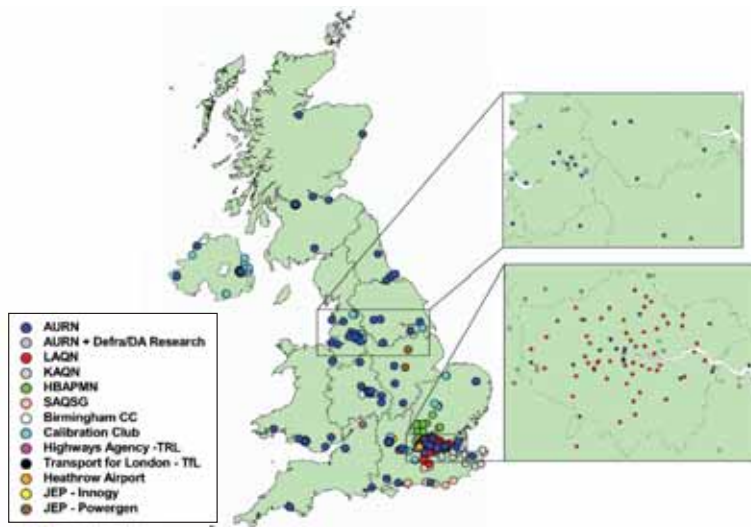
reference method and so have been replaced by measurements of PM_{10} and $PM_{2.5}$ in the monitoring networks.

Finally, if we are to understand the sources of particulate matter, it is essential that we

also measure and assess its composition. To this end, limited measurements are also made of metals, the major ions (such as sulphate, nitrate and chloride), elemental carbon (soot) and organic carbon (carbon in the form of organic compounds).

Figure 3. Location of (a) PM_{10} and (b) $PM_{2.5}$ monitoring sites.

(a)



(b)



AURN, Automatic Urban and Rural Network; DA, Devolved Administrations; LAQN, London Air Quality Network; KAQN, Kent Air Quality Network; HBAPMN, Hertfordshire and Bedfordshire Air Pollution Monitoring Network; SAQSG, Sussex Air Quality Steering Group; Birmingham CC, Birmingham Calibration Club, run by the local authority but with data handling managed by a single company; Calibration Club, run by local authorities but with data handling managed by a single company; Highways Agency – TRL, run by the Highways Agency but with data handling managed by TRL; Transport for London – TRL, run by Transport for London but with data handling managed by TRL; Heathrow, run by Heathrow Airport Ltd.; JEP Innogy and JEP Powergen, run by power generators.



■ What are the concentrations of particulate matter and how are they changing?

It is important to assess whether the reductions that have taken place in the emissions of particulate matter to air are reflected in the concentrations we measure.

The longest continuous particulate matter measurements that have been recorded are those of black smoke. Figure 4 illustrates the substantial reductions in black smoke concentrations achieved in the London Borough of Lambeth between 1961 and 1998; the decrease reflects the substantial decline in coal use. Several severe winter smog events occurred, particularly in London, during the last century. The worst episode was in December 1952. The number of deaths brought forward, in excess of those that would normally have been expected, during the first three weeks of December was between 3,500 and 4,000. Particulate matter was a major contributor to these health effects and also led to very poor visibility conditions, sometimes down to only a metre or so.

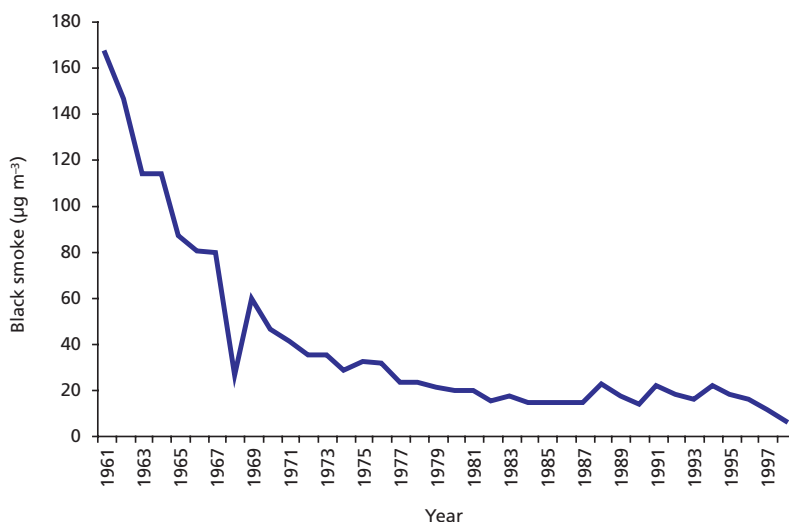
Domestic coal burning was a major contributor to these smogs.

The air quality objectives set by Government in response to EU legislation are given in terms of PM_{10} concentrations.

Measurements of PM_{10} started in 1992 and so have been made over a much shorter time period compared to measurements of black smoke. Figure 5 shows the annual average PM_{10} concentrations recorded at a set of long-running urban background PM_{10} monitoring sites in the UK. The falls in PM_{10} levels recorded at all sites during the 1990s have stopped in recent years and at some sites the concentrations have even increased. The reasons for these changes are unclear but they may have been related to the atmospheric conditions, particularly during 2003, when the weather was unusual – especially over the summer when record-breaking temperatures were recorded.

We need to continue to examine the monitoring data as they become available to see whether the expected reductions in emissions are seen in the concentrations. It is clear, though, that the decreases in emissions of primary particulate matter are not fully reflected in the PM_{10} concentrations recorded by the monitors.

Figure 4. Annual average black smoke concentrations in the London Borough of Lambeth between 1961 and 1998.



A comparison between the different types of monitoring site reveals interesting information which helps us to understand why this is the case. Figure 6 shows the annual mean PM_{10} concentrations recorded at 196 monitoring sites in 2003. These sites include roadside, urban background and rural sites. They use TEOM measurements, and the scaling factor discussed earlier has not been applied. The pink, green and blue lines show the average PM_{10} concentrations recorded across each monitoring site type. Although, as expected, the roadside average

is greater than the urban background average, which in turn is greater than the rural average, the differences are not large. If the same analysis is carried out for another pollutant – NO_x – a much bigger difference is seen. NO_x is emitted exclusively from combustion sources, especially road traffic. It is clear that, compared to NO_x , PM_{10} concentrations are much more evenly distributed across the UK. This observation reflects the wide range of PM_{10} sources and, in particular, the contribution of secondary particulate matter.



Figure 5. Annual mean PM_{10} concentrations (TEOM, not scaled) at long-running urban background monitoring sites in the UK between 1992 and 2003.

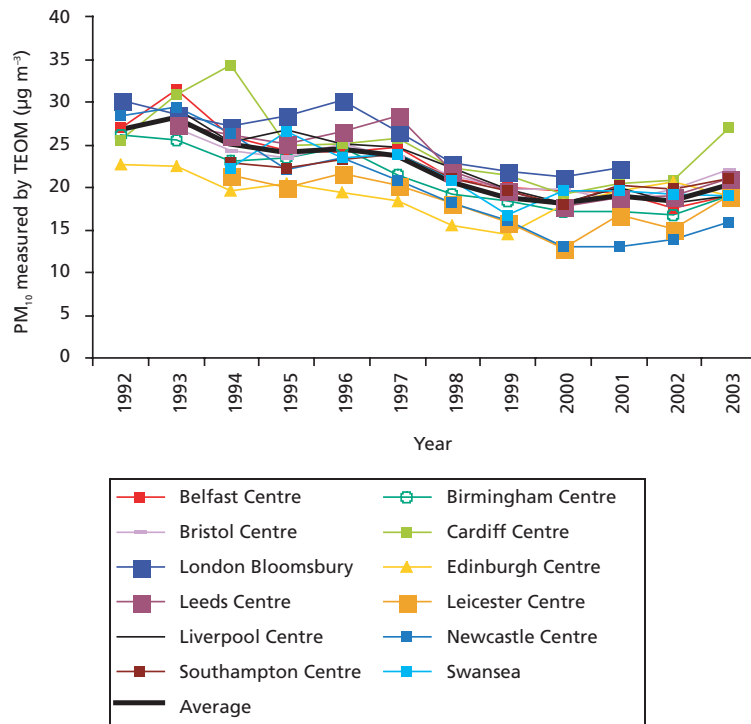
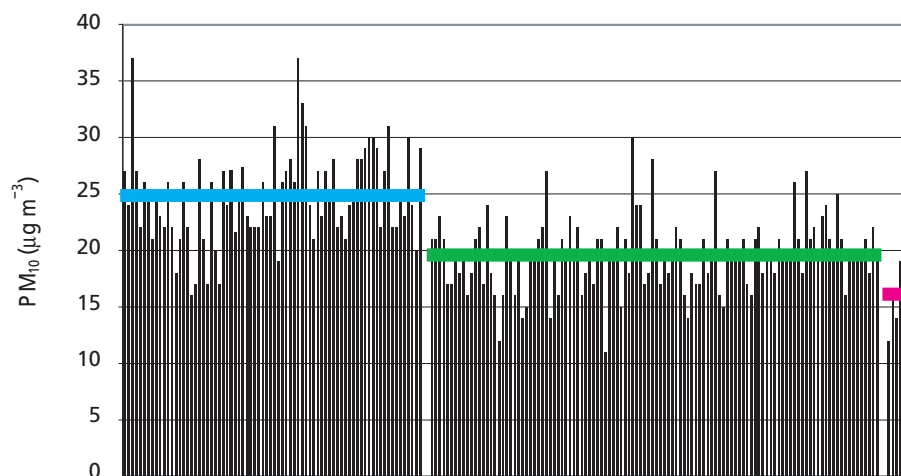


Figure 6. Roadside, urban background and rural annual average PM_{10} concentrations (TEOM, not scaled) at 196 sites in 2003. The horizontal lines show averages across site types: roadside (blue), urban background (green) and rural (pink).



Looking at the way in which PM_{10} concentrations change with time and their relationship to concentrations of other pollutants in air can help us understand what the sources are. For example, the strongest link between PM_{10} and other pollutants generated by traffic, such as NO_x and carbon monoxide, is found at roadside monitoring sites. On Marylebone Road in London, the concentrations of particulate matter recorded during the week are higher than those found on Sundays, despite there being little difference in the overall volume of traffic. A probable explanation for this is that the amount of heavy-duty traffic (such as lorries) is reduced on Sundays. Heavy-duty vehicles emit more particulate matter than other traffic.

The composition of the particles also provides information on their origins, as shown in Table 1. Iron, for example, is representative of road dust, chloride of marine particles and sulphate of secondary particles formed from SO_2 . Measurements of composition are, therefore, essential to identifying the emissions sources of both primary and secondary particulate matter.

■ Are there conditions that can lead to high concentrations of particulate matter?

Pollution episodes are short periods of high levels of pollution, such as when 24-hourly average particulate matter concentrations higher than $50 \mu\text{g m}^{-3}$ are recorded. There are several types of episode.

- In winter, pollution episodes are particularly severe during weather conditions known as inversions. When the ground is cold and there is little wind, emissions become trapped near to the ground and pollutant concentrations

from sources such as traffic and domestic heating can reach high levels.

- Particulate matter concentrations rise on the nights around November 5th, when Bonfire Night is celebrated. The concentrations can be particularly high under inversion conditions but are not so high under windy conditions.
- Summer episodes take place when the weather is hot and sunny and there is little wind. In the presence of sunlight, emissions of VOCs and NO_x lead to the production of high concentrations of secondary particulate matter. A severe episode occurred in August 2003 in Southeastern England during a heatwave that affected much of Europe. These summer smog episodes are also associated with high concentrations of ozone. Secondary particle concentrations can also increase at other times of the year, as happened in Spring 2003.
- Gales can cause between one and five sea salt episodes each year from sea spray. Even sites well inland can experience increased concentrations of particulate matter from this source.
- One or two episodes happen each year when we experience high concentrations of dust, blown from the Sahara desert.
- In September 2002, hourly PM_{10} concentrations over $100 \mu\text{g m}^{-3}$ were observed at several locations in the UK as a result of forest fires in Western Russia.
- Local pollution episodes can occur as a result of, for example, construction works.

By and large, the number of exceedences of a 24-hourly mean of $50 \mu\text{g m}^{-3}$ has declined over the last 10 years, although there were more exceedences in 2003 than in any year since 1997.

■ Do current concentrations exceed the EU limit values?

PM₁₀ results for 2002 and 2003 give a good indication of what concentrations will be like in 2005, when the objectives and limit values are to be achieved. Table 4 shows the number and percentage of sites that exceeded the annual mean and 24-hourly limit values in each year. The percentage exceedences of the stricter indicative limit values for 2010 are also shown in Table 4. The sites are divided into two types: roadside and kerbside – where PM₁₀ concentrations tend to be higher because of traffic-related emissions – and other sites. The results show that there were a large numbers of exceedences during 2002 and 2003 and demonstrate the differences that can occur from one year to the next. The high PM₁₀ concentrations experienced during 2003 were discussed previously on page 14.

■ What are the concentrations in places without monitoring sites?

We use computer **models** to work out the concentrations of PM₁₀ in those parts of the UK where there are no monitoring sites. The types of modelling methods used were outlined in the Summary of AQEG's first report *Nitrogen Dioxide in the United Kingdom*. The models for PM₁₀ are more complicated than those used for NO₂ because of the complex nature of particulate matter and the many components and sources, both primary and secondary, that must be taken into account. The models are built on the data we get from UK particulate matter monitoring sites and also consider how pollutants **disperse** in the air. Figure 7 shows the estimated annual average background concentrations of PM₁₀ during 2002. The map shows that higher concentrations of particulate matter are found in urban areas.

Figure 7. Estimated UK annual average background PM₁₀ concentrations ($\mu\text{g m}^{-3}$) during 2002.

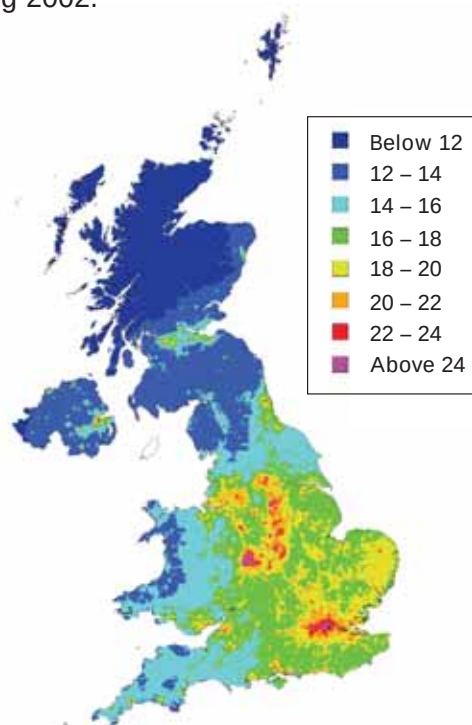


Table 4. Numbers and percentages of roadside and kerbside and other PM₁₀ monitoring sites exceeding the 2005 and 2010 EU limit values in 2002 and 2003.

Site type and year	Total number of sites	Annual limit value 2005 ^a	Annual limit value 2010 ^b	24-hourly limit value 2005 ^c	24-hourly limit value 2010 ^d
Roadside and kerbside (2002)	67	5 (7%)	66 (99%)	18 (27%)	56 (84%)
Other (2002)	108	1 (1%)	87 (81%)	8 (7%)	58 (55%)
Roadside and kerbside (2003)	76	13 (17%)	74 (97%)	45 (59%)	75 (99%)
Other (2003)	111	2 (2%)	100 (90%)	20 (18%)	104 (94%)

^aNumber (and percentage) of sites with an annual mean greater than 40 µg m⁻³. ^bNumber (and percentage) of sites with an annual mean greater than 20 µg m⁻³. ^cNumber (and percentage) of sites with a 24-hourly mean greater than 50 µg m⁻³ for more than 35 days per year. ^dNumber (and percentage) of sites with a 24-hourly mean greater than 50 µg m⁻³ for more than 7 days per year.

■ How are particulate matter concentrations predicted to change in the future?

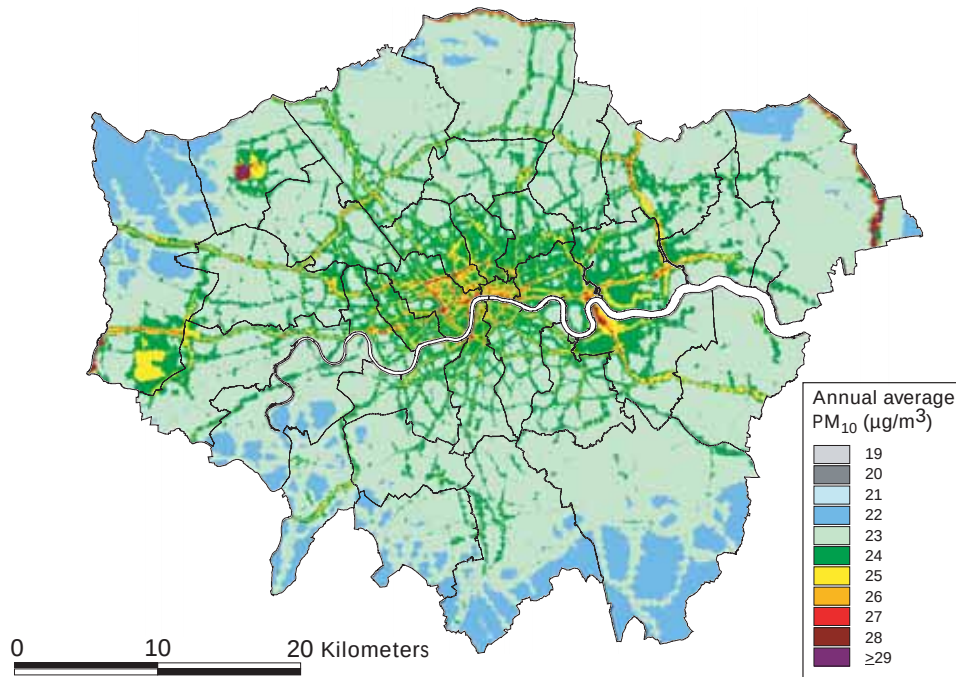
Models are also used to predict future concentrations of pollutants and have to take into account changes in future emissions arising, for example, from the use of

improved technology such as particle traps on diesel vehicles. Figure 8 shows the calculated annual average concentrations of particulate matter in London that were predicted for 2004 and that are predicted for 2010 and shows clearly the reductions in concentrations of this pollutant that are predicted over that period.

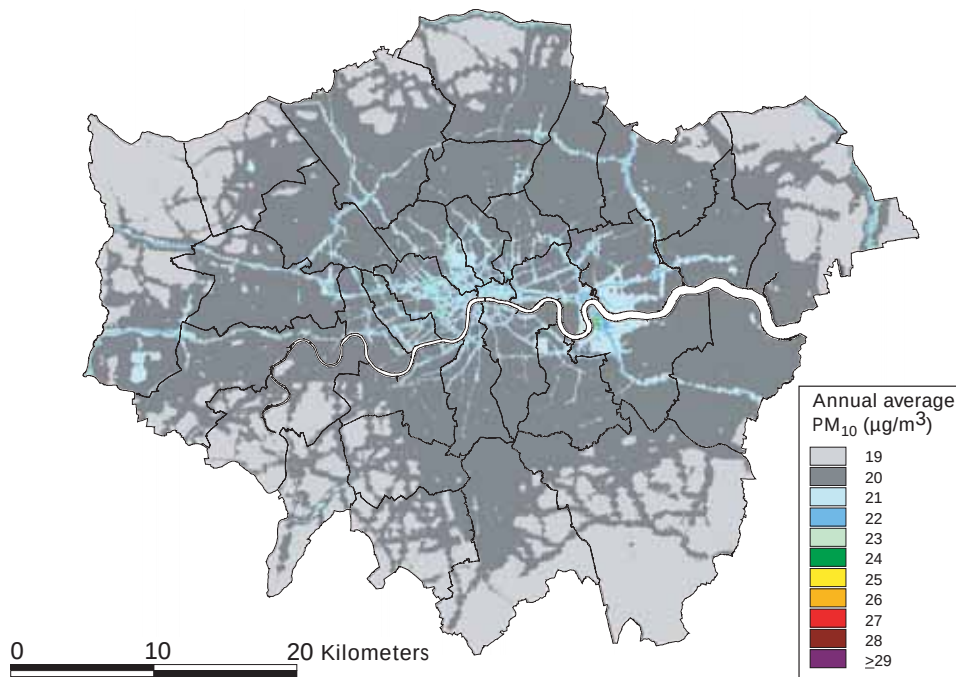


Figure 8. Annual average particulate matter ($\mu\text{g m}^{-3}$) concentrations in London calculated for (a) 2004 and (b) 2010.

(a)



(b)



Analysis of the data from maps of this sort allows us to predict likely future exceedences of the air quality objectives. The results show that the 24-hourly objective was more difficult to achieve than the annual objective in 2004 and that there will be exceedences along major roads, mainly in London. These maps also show that the stricter air quality objectives suggested for 2010 will lead to many more exceedences at roadside and even at urban background locations. However, it is important to remember that these 2010 objectives are provisional and currently have no legal standing in England, Wales and Northern Ireland. In Scotland the 2010 objectives have been put into regulations for the purpose of Local Air Quality Management.

It is difficult to make accurate predictions about future air quality for a number of reasons.

- The number of pollution episodes varies from year to year.
- The complex nature of particulate matter and the large number of possible sources make modelling – and therefore predictions – difficult. AQEG argues

in its report that Defra and the Devolved Administrations should increase the number of monitoring sites at which measurements are made of the composition of particulate matter. This would make it easier for us to work out the origins of the particulate matter, which in turn would improve the accuracy of our models. For example, we do not have a detailed understanding of the contributions that nitrate and sulphate make to regional background concentrations of particulate matter.

- Secondary organic compounds also contribute to regional background levels of particulate matter, especially in summertime. By increasing the number of sites monitoring the composition of particulate matter across the UK, we should be better able to understand how much is secondary particulate matter, how much comes from natural sources such as sea spray and vegetation and how much is from human-made sources such as traffic. Ultimately this information will help the Government to better assess what can be done to further protect human health.





■ The future

It is clear that, although road traffic emissions are a major source of particulate matter near to roads, the regional contribution to particulate matter is substantial. Controlling background particulate matter must, therefore, be a central part of any UK strategy to control exposure to particulate matter. In addition, because there is no known safe level for exposure to particulate matter, it is not appropriate to rely solely on the use of air quality objectives. They focus attention on 'hotspots' – places where the pollutant concentration is high, for example close to busy roads, but where relatively few people tend to live.

To maximise the benefits of our controls on particulate matter, we must aim to reduce exposure more widely. AQEG recommends that forms of regulation be considered that are based on reducing the average exposure to particulate matter experienced by the UK population, which would complement the 24-hourly and annual objectives.

Particulate matter has many sources and shows links to several different pollutants. Traffic contributions lead to high concentrations of both particulate matter and NO_2 near to roads. During summer pollution episodes, regional background concentrations of ozone and of particulate matter can both be high because they are produced in the atmosphere by related chemical reactions. The sources of these secondary pollutants are widespread and include mainland Europe. The effects of pollutants are not only limited to health effects. Acid deposition originates from the emissions of NO_x , NH_3 and SO_2 , which also form secondary particulate matter. Particulate matter and ozone also influence climate change.

There is a tendency to treat pollutants, their effects and their control independently, which neglects these relationships. AQEG recommends a more flexible and holistic approach, which will deliver more cost-effective solutions to air quality management, including the improvement of particulate matter air quality.

■ Glossary

Air quality objective	<i>Standards</i> are concentrations of pollutants in the air that have been set to achieve a certain level of air quality. <i>Objectives</i> are the policy target dates by which the standards should be achieved, either without exception or with a permitted number of exceedences in a year.
Air Quality Strategy	Report published by the UK Government describing plans to improve and protect air quality in the UK. A copy can be found at: http://www.defra.gov.uk/environment/airquality/strategy/index/htm .
Background concentration	Refers to the concentration of a pollutant in the atmosphere in a region away from pollutant sources.
Cardiovascular illness	Disease relating to or involving the heart and the blood vessels.
Committee on Medical Effects of Air Pollution (COMEAP)	An Advisory Committee of independent experts that provides advice to Government Departments and Agencies on all matters concerning the potential toxicity and effects upon health of air pollutants.
Concentration	The amount of a pollutant in a given volume of air.
Dispersion	The process by which a pollutant spreads from its source in the absence of a wind.
Emission	Direct release of a pollutant into the atmosphere.
Episode	Short period of high concentrations of pollution.
Exceedence	A period of time when the concentration of a pollutant is higher than the air quality objective.
Indicative limit value	A concentration not to be exceeded after a certain date that may become legally binding if adopted in legislation.
Kilotonne	One-thousand tonnes.
Limit value	A concentration not to be exceeded that becomes legally binding after a certain date.
Microgram (µg)	One-millionth of a gram.
Micrometre (µm)	One-millionth of a metre.
Model	In this document, the term refers to a mathematical way of converting knowledge of air pollutant emissions into concentrations in the atmosphere.

$\mu\text{g m}^{-3}$	Micrograms of a substance in each cubic metre of air. A unit for describing the concentration of air pollutants in the atmosphere. A concentration of $1 \mu\text{g m}^{-3}$ means that one cubic metre of air contains one microgram of pollutant.
Nanometre (nm)	One-billionth (one thousand millionth) of a metre.
Ozone	Toxic unstable gas made up of three oxygen atoms; the chemical formula is O_3 . At ground level ozone is formed by sunlight-driven chemical reactions of NO_x with VOCs.
Particulate filter	Device for reducing emissions of particulate matter from diesel vehicles.
Primary pollutant	A pollutant that is released straight into the atmosphere (contrast with secondary pollutant).
Reference method	The method that the EU uses to define its air quality limit values. If member countries use another method for monitoring, they need to demonstrate that their method gives the same results as the reference method.
Respiratory illness	Disease relating to or involving the lungs and breathing.
Sample inlet	The point, usually at the end of a sampling tube, from which air is taken in to be measured by an air pollution monitoring instrument.
Secondary pollutant	A pollutant that is formed in the atmosphere by chemical reactions (contrast with primary pollutant).
Semi-volatile compounds	Compounds such as ammonium nitrate that will evaporate on mild heating. Volatile compounds evaporate at even lower temperatures.
Size-selective inlet	A sample inlet that ensures that only particles of a diameter equal to or less than a specified value are passed to the monitoring instrument.
Three-way catalyst	Device fitted to the exhaust of petrol cars to reduce emissions of carbon monoxide, NO_x and VOCs.
VOCs (volatile organic compounds)	Chemicals containing carbon that are gases, such as ethane, or that easily evaporate at room temperature, such as benzene. VOCs are released into the atmosphere from the burning of fossil fuels and from other sources. Some VOCs, such as isoprene, are emitted by vegetation.

Further information

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