Air Pollution in the UK: 2008

A report prepared by
AEA for Defra and the
Devolved Administrations

Front cover image

Playing ‘noughts and crosses’ in the sky above Harwell, Oxfordshire (March 2009) © Jon Bower, Apexphotos 2009

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A report prepared for the Department for Environment, Food and Rural Affairs, the Welsh Assembly Government, the Scottish Government and the Department of Environment in Northern Ireland

This year's report has been compiled and written by Jon Bower, Alison Loader, Rachel Yardley, Jaume Targa, Geoff Broughton, John Stedman, Keith Vincent, Andrew Kent, Andy Cook, Marios Valiantis, Andy Glynn, Paul Willis, Ken Stevenson and many others within AEA; however, the data here presented represent the end-product of the efforts of many persons and organisations in the private sector, local and central government. Thanks to you all!

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Winter sunrise above Didcot power station cooling towers, Oxfordshire

Executive Summary

This is the latest in a long-running series of annual reports summarising measurements from national air pollution monitoring networks operated on behalf of Defra (the Department for Environment, Food and Rural Affairs) and the Devolved Administrations of Scotland, Wales and Northern Ireland. It includes data and analyses from the calendar year (January to December) of 2008. The pollutants we summarise and analyse are:

- Benzene
- 1,3-butadiene
- Carbon Monoxide (CO)
- Nitrogen oxides (NO_x = NO and NO_2)
- PM_{10} and $PM_{2.5}$ particles
- Sulphur dioxide (SO_2)
- Ozone (O_3)
- Acid deposition (reviewed in Section 7 for the first time in this report series)

Because of their potential impacts on human health, welfare and natural environments, ambient concentrations of these pollutants are measured continuously at a wide range of urban, roadside, industrial and rural locations throughout the UK.

The measurements we report here were made primarily in the UK's national automatic air monitoring networks, comprising 127 stations during 2008. These networks serve a wide range of policy, regulatory, scientific research and public health objectives.

In this report, we:

1. ***Consider continuing UK and European efforts to tackle air pollution.*** These both progressed significantly during 2008.
2. ***Describe current UK air monitoring networks, their objectives and methodologies.*** Continuing changes to these programmes are reviewed.
3. ***Summarise the UK's Air Quality Objectives*** and examine how and where these were exceeded during the year.
4. ***Investigate how pollution levels vary across the country***, examining important national-scale patterns of pollution both during this and previous years.
5. ***Examine major periods of elevated pollution*** (so called pollution 'episodes') that occurred during 2008. This year, we examine an interesting particle episode caused by long-range transport of Saharan dust, together with periods of elevated photochemical pollution during the summer months.
6. ***Assess long-term trends*** in order to identify how pollution levels in the atmosphere have changed over time.
7. ***Look back at the history and major achievements of monitoring in the UK*** We review over 30 years of monitoring acid deposition, highlighting long-term changes in levels of a range of pollutants that can damage our ecosystems.
8. ***Consider how UK pollution levels compare with other parts of Europe and the World*** Extending our innovative analyses from last year, we seek to place the UK's pollution issues in a broader European and global context, as well as answering the question: just how bad is air quality here in the UK?
9. ***Identify published, web and media sources for information*** on UK air quality. In particular, we provide details of major new web features & resources.

The report, together with the UK Air Quality websites at www.airquality.co.uk, www.scottishairquality.co.uk, www.welshairquality.co.uk and www.airqualityni.co.uk provides the most comprehensive and complete analytical picture of air pollution during 2008. Together with previous reports in this series, it may be accessed online at: www.airquality.co.uk/annualreport/index.php.

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1 Introduction

A quick outline of what's in this report…

The quality of the air that we breathe can have important effects on our health and quality of life. It can also have major impacts on ecosystems and climate change. Measuring and understanding air pollution provides a sound scientific basis for its management and control. Considerable effort is therefore devoted in the UK to the systematic measurement of levels of air pollution nationwide. This effort started in earnest following the infamous coal-burning smogs of the 1950s and 60s, but has expanded massively in scope, coverage and sophistication since then.

Air quality monitoring, together with the information derived from it, should not be seen as an end in itself; rather, it offers us the best way of understanding our pollution problems, so that they can be tackled effectively at local, national and international level. Some of the very latest actions being taken on a number of fronts in the UK and Europe are described in further detail in this report.

The broad objectives of monitoring air pollution in the UK are:

- To provide a sound scientific basis for the development of cost-effective control policies and solutions under i) the UK Air Quality Strategy and ii) Local Air Quality Management (LAQM) system
- To assess how far air quality standards, limit values and objectives are being met
- To evaluate potential impacts on population health and welfare
- To determine the impact of air pollution on ecosystems and our natural environment
- To provide the public with open, reliable and up-to-date information on air pollution
- To fulfil statutory air quality reporting requirements, particularly those established within Europe

Figure1.1. An acid deposition bulk precipitation collector at Wardlow Hay Cop, Derbyshire. We review acid rain monitoring in Section 7

This report aims to provide a simple guide, written as far as possible in non-technical language, to what the latest measurements tell us about air pollution in the UK. It comprises three parts. The **first part** is primarily descriptive. In it, we'll:

- Summarise ongoing UK and European policy efforts and initiatives to tackle air pollution *(Section 2)*.
- Review where and how air pollution is measured in this country, examining monitoring networks, site locations and measurement techniques, as well as recent changes to UK measurement programmes *(Section 3)*.
- Examine key episodes - major periods of elevated pollution - that occurred in 2008. We give particular prominence this year to a particle episode caused by long-range transport, as well as reviewing the frequency of photochemical smog episodes over recent years *(Section 4).*
- Investigate - through a series of detailed maps and analyses - how pollution levels vary across the UK, and how these patterns are changing over time *(Section 5).*
- Assess long-term pollution trends in order to see whether pollution levels are declining over time. (*Section 6).*
- Look back at over 30 years of sampler-based monitoring of acid rain; we see how this monitoring has revealed long-term changes in acidifying pollutants which have - in the past - damaged UK and European ecosystem damage *(Section 7)*
- Examine how air quality in the UK compares with that in other parts of the Europe *(Section 8).*
- Provide information on where and how to find out more about air pollution emissions, levels and effects in the UK. We introduce important new map-based air quality information resources on the web, as well as how emerging new technologies are set to transform the visualisation and reporting of air pollution levels in the future (*Section 9).*

The **second part** of the report, from Sections 10 to 18, is primarily statistical; this provides a detailed pollutant and site-specific specific summary of measurements made in the UK automatic and hydrocarbon monitoring networks during 2008. Each section offers:

- Information on measurement and calibration techniques, instruments utilised, estimated accuracy and precision
- A summary of relevant UK objectives
- A map of the measurement sites
- A detailed statistical summary of all the measurements made during the year
- Matching information on exceedences of UK Air Quality Objectives
- Graphs showing variations in pollutant concentrations throughout the year at typical urban, rural and other site types
- Analyses showing typical variations in pollutant concentrations during the day
- Long-term trends in annual average measured concentrations.

In the **third part** of the report, a comprehensive a series of Appendices provides:

- Background information on the air pollutants measured in the national networks, their sources and effects
- Detailed maps showing the location of automatic monitoring stations in different parts of the UK
- More information on the various air monitoring networks and their objectives
- A summary and analysis of UK monitoring locations showing statistically significant trends in pollution levels over time
- A full listing of current UK, European and World Health Organisation Air Quality Standards, Objectives, Limit Values and Guidelines for the major air pollutants
- An explanation of some of the terminology used in this report, together with a discussion of measurement accuracy, trend calculation and the mathematical methods used to calculate measurement statistics.

Air Pollution in the UK: 2008

Part 1

In this part of the report, we describe the reasons for monitoring air quality and examine how the UK networks have evolved over the years to meet our changing needs and objectives.

We review recent air pollution episodes and assess variations in pollution levels across the country. We also examine long-term trends, in order to see if pollution is getting worse over time.

We then review the long-term history of acid deposition monitoring in the UK and assess our current pollution levels in a broader European and global context.

Finally, we provide details of how to obtain more information about our air quality, particularly from the World Wide Web.

2 UK & International Policy

What actually drives all the monitoring we do…

To understand why and how we measure air pollution in the UK, it's first necessary to consider the broader policy and regulatory background to the monitoring, both at national and international level. There are also increasingly important local pressures and objectives to air monitoring.

Over the past twenty years, air pollution has become an increasingly important focus of interest for UK, European and international policy makers. This has been prompted by evidence from scientists, medics and researchers that air pollution poses significant risks to our health and our natural environment.

In recognition of this, the European Union's Sixth Environment Action Programme[B1] includes Environment and Health as one of the four main areas where new effort is targetted, with air pollution identified as one of the priority issues to be tackled. The need to protect human health and welfare is also a central feature of the UK's Air Quality Strategy, discussed later in this section.

And what does it all mean for climate change?

Another factor in the increased attention paid to air pollution is growing evidence of its close relationship to broader global issues. Our atmosphere is a complex, dynamic and fragile system, in which global warming, climate change, ecosystem impacts and stratospheric ozone depletion are all intimately inter-linked with air pollution.

This report focuses primarily on gases and particles that are known to have harmful effects on human health or cause damage to our ecosystems. However, air pollutants such as carbon dioxide and fine particulate matter can also have an effect on atmospheric temperatures and have the potential to contribute to climate change.

These important issues are addressed in detail in a recent report from the UK Air Quality Expert Group.[B2] It concluded that:

- Air pollutants - such as particulate matter and ozone - influence climate change. Control of the gases that lead to the formation of particulate matter and ozone can therefore affect both air quality and climate change.
- Hot summers like the 2003 heat wave are likely to become the norm by 2040, leading to increased summer smogs, unless emissions affecting ozone concentrations are substantially reduced. Episodes of winter smog, by contrast, are likely to be less prevalent.
- It is essential that the inter-linkages between emissions of air quality and climate change pollutants are recognised in assessments of the impacts of policies and developments for industry, transport and housing
- Most measures that lead to a reduction in demand or an improvement in the efficiency of an activity or product, benefit both air quality and climate change. Such measures should be actively promoted.
- Local, National and European policies must recognise the interactions between air quality and climate change pollutants in developing measures to reduce them.

So, the pollutants analysed in this report do not only have the potential to affect local and regional conditions; they can also have profound impacts on our world.

2.1 European background

2.1.1 Aspirations and instruments

European Environmental Directives place a duty on each EU Member State to institute policies to protect and improve its environment and the health of its citizens; the majority of the UK's specific air quality standards and related requirements come from Directives. European Community action is designed to:

- Protect the environment and
- Reduce exposure to air pollution
- Whilst ensuring sustainable development and
- Promoting better regulation

These goals will be achieved by:

- Introducing innovative legislation.
- Enhanced international cooperation aimed at reducing cross-border pollution and the better integration of air pollution and climate change policies.
- More effective liaison with national, regional authorities and Non-Governmental Organisations (NGOs).
- Making better use of the research undertaken in its own or Member States' institutes and universities.
- Sharing environmental information.

A series of Air Quality Directives and Decisions over the last twelve years has:

- Assessed the ambient air quality in Member States on the basis of common methods and criteria.
- Generated information on ambient air quality in order to help combat air pollution and nuisance and to monitor long-term trends and improvements resulting from national and Community measures.
- Ensured that such information on ambient air quality has been made available to the public.
- Maintained air quality where it is good and improved it in other cases.
- Promoted increased cooperation between the Member States in reducing air pollution.

A new Directive (2008/50/EC of the European Parliament and of the Council of 21st May 2008, on ambient air quality and cleaner air for Europe[B3]) was adopted in June 2008. From mid-2010, this will streamline the European Union's air quality legislation by replacing with a single, integrated instrument the five previous Air Quality Directives:

- Directive 96/62/EC on Ambient Air Quality Assessment and Management, 'The Framework Directive' [B4,] which established a framework under which the EU agreed air quality limit values for pollutants specified in a series of 'Daughter Directives'.
- The First Daughter Directive (1999/30/EC) [B5], which set limit values for sulphur dioxide (SO_2), oxides of nitrogen, particulate matter as PM_{10}, and lead.
- The Second Daughter Directive (2000/69/EC) [B6], which set limit values for carbon monoxide (CO) and benzene.
- The Third Daughter Directive (or EC Ozone Directive, 2002/3/EC) [B7], which set target values for protection of human health and vegetation.
- Council Decision 97/101/EC [B8], which established a reciprocal exchange of air quality monitoring information and data, between the Member States.

Directive (2004/107/EC) [B9] – The Fourth Daughter Directive, which covers polycyclic aromatic hydrocarbons (PAH) and the metallic elements cadmium, arsenic, nickel and mercury, may be merged with the Ambient Air Quality Directive in the future.

Directive 2008/50/EC retains all the existing air quality standards, and also introduces Limit Values for $PM_{2.5}$ particulate matter, together with an exposure-reduction target, in the light of clear scientific evidence that fine particles are hazardous to health. This new Directive provides greater clarity on where to assess air quality, so that the focus is on areas where members of the public could be exposed.

A list of current Limit and Target Values for air pollutants covered by the new Directive is provided in Appendix 5. Further detailed information on the major sources and impacts of these pollutants is provided in Appendix 1.

2.1.2 Time extension notification for the UK

The new Council Directive 2008/50/EC on Ambient Air Quality and Cleaner Air for Europe sets limit values for ambient pollutants. In April 2009, the UK notified Europe of the need for a time extension for the application of the PM_{10} Limit Value, applicable in eight out of the 43 UK zones and agglomerations. The UK will delay the application of the limit value in these areas until 2011.

The UK notification to the European Commission was subject to public consultation earlier in the year[B10]. It sets out how, on the basis of current and future plans, we will achieve compliance across the UK by 2011.

In compliance with the legislation, the UK reports both monitoring and modelled data. The national model uses 2005 as a base year, and is fully validated by monitoring data. The reason for the time extension notification is based, in part, on evidence which emerged in 2008; this showed that the gravimetric sampler used to validate the 2005 model was reading higher levels of PM_{10} than other particle analysers, even when co-located [B11].

It is expected that a UK request for a similar time extension notification for NO_2 will be submitted later in 2009.

2.1.3 The Convention on Long Range Transboundary Air Pollution

The Geneva Convention on Long-range Transboundary Air Pollution [B12] (LRTAP) was signed by 34 Governments and the European Community (EC) in 1979, and today it has 52 signatories. The cooperation of these signatories has supported the development of international laws and has created a comprehensive framework for managing transboundary air pollution and thereby reducing its impacts on human health and the natural environment.

The Convention's signatories abide by several written Protocols on the control and reduction of different transboundary pollutants, and are obliged to submit an annual emissions inventory and accompanying report to the Centre on Emissions Inventories and Projections (CEIP).

2.1.4 Sharing environmental information

The Community continues to build on the 'three pillars' of the UNECE's Åarhus Convention[B13] (1998) guaranteeing full and open access to information, public participation and justice in environmental matters. New environmental directives have

requirements that Member States report information to the European Commission, share information with one another, and make it available to the public.

Examples of this international data sharing include:

- The European Environment Information and Observation Network (EIONET), a collaborative network that provides the information that is used for:
    1. Making decisions for improving the state of environment in Europe and
    2. Improving the effectiveness of EU policies.
- The European Pollutant Emission Register (EPER), recently succeeded by the European Pollutant Release and Transfer Register (E-PRTR). National governments of all EC Member States are required to maintain inventories of emission data from specified industrial sources and to report emissions from individual facilities to the European Commission.

Directive 2008/50/EC specifies the detailed requirements for the Member States and the Commission to collect, exchange, and disseminate air quality information. A new feature is the embodiment of the requirements of Directive 2007/2/EC[B14] (the INSPIRE Directive) that Member States:

1. Adopt procedures for data provision, assessment and reporting electronically
2. Use the Internet as the main means of its dissemination.

The INSPIRE Directive forms the legal framework for collecting, public viewing, reporting and analysis of environmental data, through the Shared Environment Information System (SEIS). This will provide an access point on environmental information for a multitude of users, including the general public, for regulatory reporting and commercial service providers. It will consist of a network of local, national and EU nodes to allow sharing of all publicly funded spatial data (Figure 2.1).

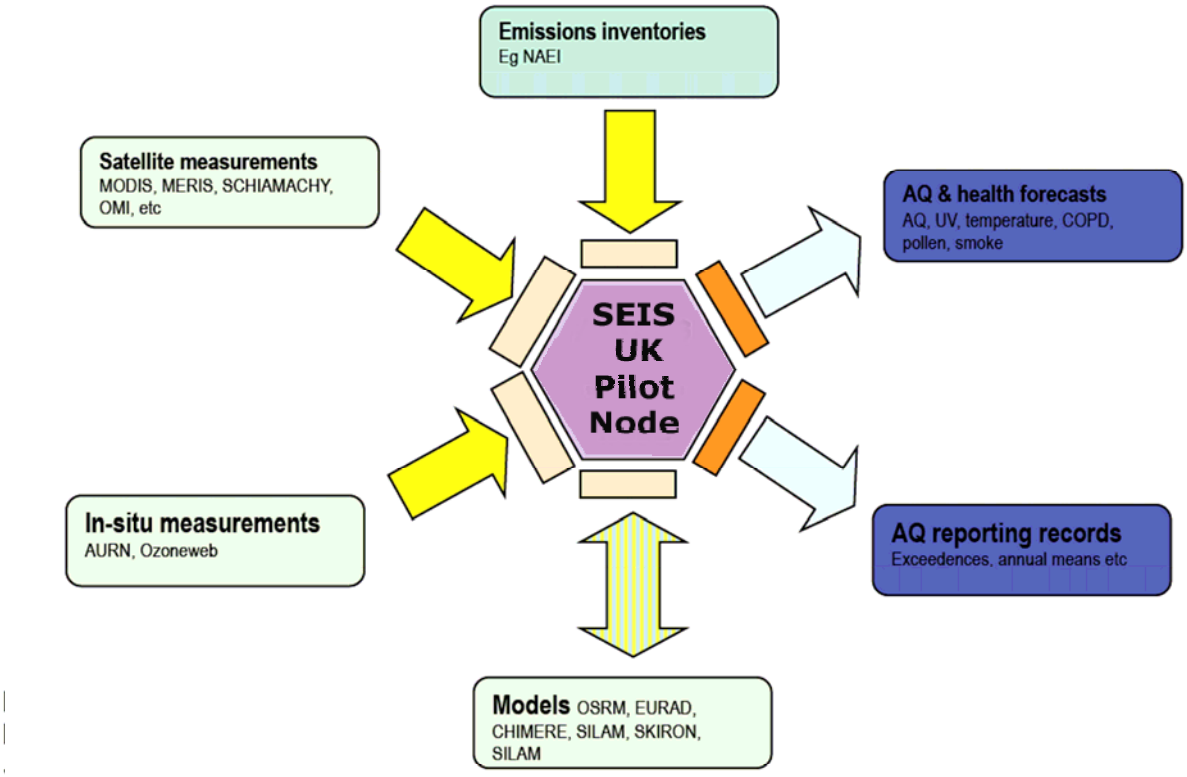


Figure 2.1 What a SEIS national hub for the UK might eventually look like

The SEIS principle will gradually eliminate paper-based reporting and revolutionize the management of all EU and national environmental data. It is expected that the SEIS will be incorporated into national law in 2009, with implementation milestones scheduled over the next eight years. The UK will be required to develop a national hub to draw together the various databases and sources of environmental data. For air quality data, this will include emissions inventories, forecasting systems, models, ambient measurements and satellite data.

INSPIRE requires that Member States within Europe should:

- Build infrastructures and network services for spatial information, made compatible by common Implementing Rules (IR) and Community Measures, that allow data exchange at EC and trans-boundary level.
- Store data at the most appropriate level, but also ensure that data collected at one level of public authority must be available to all others.
- Ensure that access rules do not unduly restrict data use, whilst permitting charges for Rights Managed (RM) data and protecting Intellectual Property (IP).
- Ensure that the directive applies to all spatial data held electronically by or on behalf of public authorities and, subject to certain conditions, spatial data held by other natural or legal persons should they request them.
- Provide metadata on the data stored to speed data discovery.
- Provide free public data discover and viewing services.
- Ensure compatibility with the EU INSPIRE geoportal.

We identify throughout this report – and particularly in Section 9 - the numerous open-access information resources that can be used by government, local authorities and the public to obtain up-to-date information on local or national air quality; this report, in itself, represents one of the extensive range of published, media and web resources intended for this purpose in the UK.

2.1.5 The Pollutant Release and Transfer Register

The United Nations Economic Commission for Europe (UN ECE) Protocol on Pollutant Release and Transfer Registers[B15] was adopted at an 'Environment for Europe' Ministerial Conference in Kiev, May 2003, where it was signed by 36 States and the European Community.

A Pollutant Release and Transfer Register (PRTR) is a national or regional environmental database or inventory of potentially hazardous chemical substances and/or pollutants released to air, water and soil and transferred off-site for treatment or disposal. In the UK, the database meets the requirements of the UN-ECE Protocol. The public is able to access the register free of charge on the internet and can find information using various search criteria. The database allows users to search the register by[B16]:

- Facility, including the facility's parent company or its geographical location.
- Activity.
- Pollutant or waste.
- Environmental medium (air, water, land) into which the pollutant is released.
- Off-site transfers of waste and their destination.
- Off-site transfers of pollutants in waste water.

The UK's PRTR website can be found at http://prtr.defra.gov.uk/.

2.1.6 The Thematic Strategy on Air Pollution

An important focus within the European Community over the period from 2002 to 2012 will be the implementation of air quality standards whilst further increasing the coherency of all air legislation and related policy effort.

The Sixth Environment Action Programme (6th EAP), now in its second phase of implementation, first introduced the concept of 'Thematic Strategies'; these are coherent and joined-up policies addressing specific environmental issues in an integrated manner. This overall approach acknowledges that the effects of decisions in one policy area may impact on others. The 6th EAP generated seven thematic strategies. These covered:

- Waste prevention and recycling
- The marine environment
- Soil
- Pesticides
- Natural resources
- The urban environment
- ***Air pollution.***

The Thematic Strategy on Air Pollution[B17] was published in September 2005. It is one of the seven thematic strategies established under the Sixth Environment Action Programme. It seeks to establish staged health and environmental objectives and emission reduction targets. The focus is to protect EU citizens from exposure to ambient particulate matter and ozone, and to improve the protection of ecosystems from acid rain, excess nutrient nitrogen, and ozone.

The Strategy sets the following objectives for 2020, compared to the base year of 2000:

- 47% reduction in loss of life expectancy as a result of exposure to particulate matter.
- 10 % reduction in acute mortalities from exposure to ozone.
- Reduction in excess acid deposition of 74% and 39% in forest areas and surface freshwater areas respectively.
- 43% reduction in areas or ecosystems exposed to eutrophication.

The Strategy establishes interim objectives for air pollution throughout the European Union and proposes appropriate measures for achieving them. It focuses on:

1. The modernisation, revision and streamlining of existing legislation
2. Revision of the National Emissions Ceiling Directive.
3. The integration of environmental concerns into other policy areas and programmes.

Although it is recognised that there will be significant costs involved in improving air quality, detailed cost/benefit analyses demonstrate that these will be offset many-fold by the overall benefits to society as a whole (Figure 2.2).

It has been estimated that the Strategy will have a net monetary benefit to the European health services of 35 billion Euros per year, with a reduction in premature deaths of approximately 60,000 compared to projections without the Strategy.

Figure 2.2 Cost benefit analysis- an important part of the European Thematic Strategy – demonstrates that the costs of improving air quality throughout Europe are offset by benefits to population health and society as a whole

2.1.7 Delivering the objectives of Thematic Strategy on Air Pollution

It is relatively early to see the results of the 6_{th} EAP, as the actions taken will take time to come to fruition. Nevertheless, an interim review - conducted in 2007 - identified three specific underlying problems that could hamper efficient and effective progress towards 6th EAP objectives over the second half of its life:

- Poor integration of policies
- The existing implementation gap
- Insufficient international co-operation

Even if all relevant technically feasible measures available were applied, irrespective of cost, it would not be possible by 2020 to meet the ambitious objective of attaining "*levels of air quality that do not give rise to significant negative impacts on, and risks to, human health and the environment*". Consequently the Community uses a science-based policy development process that makes extensive use of impact modeling to identify the more promising policy options.

While covering all major air pollutants, the strategy pays special attention to particles and ground-level ozone pollution. This is because, in the view of the European Commission and World Health Organisation, these pose the greatest danger to human health. Moreover, no safe levels have yet been identified for either pollutant.

The Commission has initiated, via Directive 2008/50/EC, the regulation of $PM_{2.5}$. This will require reductions in fine particle concentrations throughout each Member State, together with a cap on concentrations in the most polluted areas. These developments are now having wide-ranging implications for the UK's national monitoring networks measuring particulate matter (see Section 3).

2.2 The UK perspective

Environmental legislation introduced over the past fifty years has provided a strong impetus to reduce the levels of harmful pollutants in the UK; as a result, current concentrations of many recognised pollutants are now lower that they have ever been. However, although the lethal smogs in UK cities caused by domestic and industrial coal burning have now gone for good (Figure 2.3), air pollution remains a problem in the UK.

Figure 2.3 Industrial and domestic coal-burning smog in the Midlands during the 50s

Medical evidence shows that many thousands of people still die prematurely every year because of the effects of air pollution. Air pollution from man-made particles and gaseous pollutants is currently estimated to reduce the life expectancy of every person in the UK by an average of nine months; many more become unwell or may require hospital treatment. Moreover, it is now firmly established that hospital admissions rise during periods of elevated air pollution levels.

The health impacts of this pollution are estimated to cost the UK in excess of £10 billion per year. It is often the very young, old and other sensitive population sub-groups who are particularly affected, as well as people living in deprived areas.

In addition, our sensitive ecosystems are also affected by air pollution. More than half of all natural and semi-natural habitats in Britain still have excessive levels of harmful acidity and/or nutrient deposition.

As highlighted previously, the UK - as a Member State of the European Community - has statutory obligations to address air pollution issues. European Directives and Protocols dictate the methods by which the UK should address these issues, and also set Target and Limit Values for each pollutant. These European tools also feed into the UK's own Air Quality Strategy, discussed below.

2.2.1 The UK Air Quality Strategy

The Air Quality Strategy for England, Scotland, Wales and Northern Ireland was first published in March 1997 and reviewed in 2000 and 2007[B18]. It has established a strong framework for tackling air pollution; this is in line with the Government's aim of sustainable development, providing cleaner air and a healthier life for us now and in the future. The overall objectives of the Strategy are to:

- Map out future ambient air quality policy in the United Kingdom in the medium term
- Provide best practicable protection to human health by setting health-based objectives for air pollutants
- Contribute to the protection of the natural environment through objectives for the protection of vegetation and ecosystems
- Describe current and future levels of air pollution
- Establish a framework to help identify what we all can do to improve air quality

The Air Quality Strategy is informed by the Air Quality Forum, consisting of stakeholders and representatives of Government Departments and the Devolved Administrations. The Forum is a mechanism for exchanging ideas, offering an independent overview of the implementation of the Strategy and progress towards achieving its objectives.

The Strategy has established objectives for eight key air pollutants, based on the best available medical and scientific understanding of their effects on health, as well as taking into account relevant developments in Europe and the World Health Organisation. These Air Quality Objectives are at least as stringent as the Limit Values of the relevant EC Directives – in some cases, more so. These are primarily incorporated into UK legislation for the purpose of Local Air Quality Management by means of the Air Quality Standards Regulations 2007 (No. 64)[B19] - although there are some exceptions for pollutants such as ozone, which are in practice difficult to control by local action.

The UK Air Quality Strategy's main focus is on protecting the health of the population, although it has also established corresponding targets for the protection of vegetation, ecosystems and the natural environment.

Air monitoring – and its results presented in this report - provides a key tool in assessing how far the health objectives and other environmental targets are being met throughout the UK.

The most recent review of the Air Quality Strategy was carried out in 2006; this included a full assessment of:

- The UK's predicted air quality up to 2020
- Progress towards meeting the current AQS objectives
- Costs and benefits of additional policy measures required to improve air quality
- The current Air Quality Strategy Objectives
- The case for new Objectives - in particular for $PM_{2.5}$

The focus of the review was on the impact of measures on concentrations of particles, nitrogen dioxide and ozone, the pollutants for which the achievement of the objectives is likely to be the most challenging. Measures considered affecting road transport emissions and stationary source emissions include:

- Incentivising the early uptake of new tighter European vehicle emission standards and phasing out the most polluting vehicles (Euro 5 and Euro 6 for cars).
- Increasing market penetration of low emission vehicles

- Reducing emissions from ships – reduction of sulphur content of marine fuels, and reducing emissions of NOx from ships' engines
- Introduction of a national road-pricing scheme
- Establishment of Low Emission Zones
- Retrofitting catalyst-based diesel particulate filters to existing HGV vehicles, buses and coaches to bring them up to Euro 5 standards
- Reducing emissions from combustion plants and from domestic combustion by moving away from the use of coal and by introducing product standards for domestic gas fired appliances
- Introduction of a requirement for low sulphur fuel for shipping

A study by the Committee on the Medical Effects of Air Pollution[B20] (COMEAP) on the long-term effects of exposure to air pollution was carried out concurrently with the review; its report was published to coincide with the release of the new strategy, which was launched in July 2007.

All the previously existing Air Quality Strategy Objectives are retained, apart from the provisional PM_{10} objectives originally proposed for 2010 in England, Wales and Northern Ireland. The updated Strategy also introduces an objective for annual mean particulate matter as $PM_{2.5}$, to be achieved by 2020. This acknowledges the latest research, indicating that the health impacts of particulate pollution are particularly associated with this very fine fraction.

There is now clear evidence that there is no 'safe' level for exposure to fine particles – in other words, no threshold below which no health impacts are expected to occur. The Strategy therefore concludes that, for this pollutant, a policy based on achieving limit values alone will not generate the maximum benefit in public health for the investment made. This is because such an approach focuses only on the areas where concentrations are highest, while - in reality - adverse effects on health are likely to be much more widespread.

This exposure reduction approach takes the view that the maximum benefit for the most people will be obtained most cost-effectively by reducing pollutant levels across the whole urban area, rather that focussing action on "hot-spot" areas exceeding Objectives. In summary, there are two aspects to the new Air Quality Strategy's exposure reduction approach for $PM_{2.5}$:

- An air quality objective or limit value, which defines the maximum acceptable concentrations for public exposure. The objectives for annual mean $PM_{2.5,}$ to be met by 2010, are 12 μg m^{-3} in Scotland (where levels are typically lower) and 25 μg m^{-3} for the rest of the UK.
- An exposure reduction target for $PM_{2.5}$ is introduced: urban background annual mean concentrations to be reduced by a set percentage over a defined timescale. The exposure reduction target for the whole UK is for annual mean concentrations in urban background areas to be reduced by 15% between 2010 and 2020.

In addition to the new objectives for $PM_{2.5}$, a new ozone objective has been introduced for protection of ecosystems, in line with the target value set in the relevant EC Directive.

No objectives have been set for ammonia. The nature of ammonia emissions and its behaviour in the environment are complex, and dealing with this pollutant therefore requires a more holistic approach, taking in industrial and agricultural emissions. The Strategy concludes that it is not appropriate at this time to set objectives for ammonia without consideration of the wider environmental issues and regulatory frameworks.

A summary of the current UK Air Quality Strategy Objectives is provided in Tables 2.1a and 2.1b. The new objectives included in the 2007 Air Quality Strategy are highlighted by shading.

Table 2.1a UK Air Quality Objectives for protection of human health, July 2007; new objectives are denoted in shading.

Pollutant	Air Quality Objective		Date to be achieved by
	Concentration	Measured as	
Benzene			
All authorities	16.25 $\mu g\ m^{-3}$	Running annual mean	31.12.2003
England and Wales only	5.00 $\mu g\ m^{-3}$	Annual mean	31.12.2010
Scotland and Northern Ireland	3.25 $\mu g\ m^{-3}$	Running annual mean	31.12.2010
1,3-Butadiene	2.25 $\mu g\ m^{-3}$	Running annual mean	31.12.2003
Carbon monoxide			
England, Wales & N. Ireland	10.0 mg m^{-3}	Maximum daily running 8-hour mean	31.12.2003
Scotland only	10.0 mg m^{-3}	Running 8-hour mean	31.12.2003
Lead	0.5 $\mu g\ m^{-3}$	Annual mean	31.12.2004
	0.25 $\mu g\ m^{-3}$	Annual mean	31.12.2008
Nitrogen dioxide	200 $\mu g\ m^{-3}$ not to be exceeded more than 18 times a year	1-hour mean	31.12.2005
	40 $\mu g\ m^{-3}$	Annual mean	31.12.2005
Particles (PM_{10}) (gravimetric)	50 $\mu g\ m^{-3}$, not to be exceeded more than 35 times a year	24-hour mean	31.12.2004
All authorities	40 $\mu g\ m^{-3}$	Annual mean	31.12.2004
Scotland only	50 $\mu g\ m^{-3}$, not to be exceeded more than 7 times a year	24-hour mean	31.12.2010
	18 $\mu g\ m^{-3}$	Annual mean	31.12.2010
Particles ($PM_{2.5}$) (gravimetric) *	25 $\mu g\ m^{-3}$ (target)	Annual mean	2020
All authorities	15% cut in urban background exposure	Annual mean	2010 - 2020
Scotland only	12 $\mu g\ m^{-3}$ (limit)	Annual mean	2010
Sulphur dioxide	350 $\mu g\ m^{-3}$, not to be exceeded more than 24 times a year	1-hour mean	31.12.2004
	125 $\mu g\ m^{-3}$, not to be exceeded more than 3 times a year	24-hour mean	31.12.2004
	266 $\mu g\ m^{-3}$, not to be exceeded more than 35 times a year	15-minute mean	31.12.2005
PAH *	0.25 ng m^{-3}	Annual mean	31.12.2010
Ozone *	100 $\mu g\ m^{-3}$ not to be exceeded more than 10 times a year	Daily maximum of running 8-hour mean	31.12.2005

** not included in regulations at present.*

Table 2.1b UK air quality objectives for protection of vegetation and ecosystems, July 2007

Pollutant	Air Quality Objective		Date to be achieved by
	Concentration	Measured as	
Nitrogen dioxide *(for protection of vegetation & ecosystems)* *	30 $\mu g\ m^{-3}$	Annual mean	31.12.2000
Sulphur dioxide *(for protection of vegetation & ecosystems)* *	20 $\mu g\ m^{-3}$ 20 $\mu g\ m^{-3}$	Annual mean Winter average (Oct-Mar)	31.12.2000 31.12.2000
Ozone *	18 mg m^{-3}	AOT40[a], calculated from 1h values May- July. Mean of 5 years, starting 2010	01.01.2010

** not included in regulations at present*

a) AOT 40 is the sum of the differences between hourly concentrations greater than 80 µg m-3 (=40ppb), over a given period using only the 1-hour averages measured between 0800 and 2000.

2.2.2 The air quality banding system

Although comprehensive and soundly science-based, the UK's Air Quality Objectives are not necessarily easy for the general public to understand. A simpler air quality banding system is therefore used for media-based reporting of air quality and potential health effects to the public. This allows users to see at a glance whether the air pollution is low, moderate or high. The system is summarised in Box 3.1 and Figure 2.4.

This banding system is used on a daily basis for forecasting pollution levels in the zones and urban agglomerations of the UK. It is also used to categorise the latest hourly measurements sent to the UK Air Quality Archive at www.airquality.co.uk from automatic monitoring analysers.

Figure 2.4 Air Quality bands are designed to be easy to understand

Box 2.1 The UK Air Quality Banding System

- When air pollution is LOW (1-3), effects are unlikely to be noticed even by individuals who know they are sensitive to air pollutants.
- When air pollution is MODERATE (4-6), mild effects unlikely to require action may be noticed amongst sensitive individuals.
- When air pollution is HIGH (7-9), significant effects may be noticed by sensitive individuals and action to avoid or reduce these effects may be needed (e.g. reducing exposure by spending less time in polluted areas outdoors). Asthmatics will find that their 'relief inhaler' is likely to reverse effects on the lung.
- When air pollution is VERY HIGH (10), effects on sensitive individuals, described for HIGH pollution, may worsen.

2.2.3 The air quality indicators for sustainable development

The UK Government's Sustainable Development Strategy[B21], 'Securing the Future', was launched in March 2005. This strategy is designed to enable all people throughout the world to satisfy their basic needs and enjoy a better quality of life without compromising the quality of life of future generations. A suite of 68 national development indicators has been established to cover the following areas:

- Sustainable consumption and production
- Climate change and energy
- Natural resource protection and enhancing the environment
- Creating sustainable communities and a fairer world

The suite contains two air quality indicators:

1. **Annual levels of particles and ozone**. These are the two types of air pollution believed to have the most significant impacts on public health (specifically, long-term exposure to particulate matter (PM_{10}) and daily peak ozone levels).
2. **Number of days in the year when air pollution is moderate or higher**. This may relate to any of five key air pollutants (nitrogen dioxide, sulphur dioxide, ozone, carbon monoxide, particulate matter less than 10µm in diameter) as defined by the banding system used by the Air Pollution Information Service.

National, regional and local progress is reported on a yearly basis against these indicators. This enables us to robustly determine whether the UK is making progress in achieving a better quality of life for everyone.

A more in-depth analysis of the air quality indicator for 2008, and of its trends since monitoring for these pollutants began, is included in Section 6 of this report. More detailed data and information on the indicator are available from the Air Quality Archive at www.airquality.co.uk .

2.2.4 The Openair project

The Natural Environment Research Council's (NERC) openair project provides open-source tools for analysing air pollution data. The project officially commenced in October 2008 and is primarily funded by NERC and Defra. Its main objectives are:

- To develop innovative analysis tools for air pollution measurement data and dispersion modelling output, which will allow users to better visualise, analyse and interpret air quality data.
- To provide those tools to the wider air pollution community.
- To seek the involvement of other researchers nationally and internationally.

Further information and examples of the openair tools can be found at www.openair-project.org/.

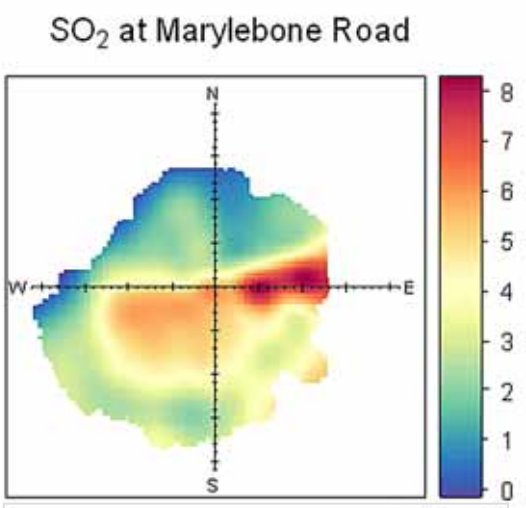


Figure 2.5 Openair- an example polar plot of SO_2 at Marylebone monitoring site (AURN)

2.2.5 Air quality in major incidents

Figure 2.6 Monitoring data will be used in the event of future incidents like Buncefield *

Data held within the UK national Air Quality Archive will in future be used to provide data to the Environment Agency as part of its new Air Quality in Major Incident response capability, which is planned to commence at the end of 2009.

The Archive has been identified as the most easily and quickly accessible comprehensive data source in the event of an air quality incident in the UK.

The data will feed into the decision-making process during any incident, as well as forming part of any post-incident analysis. The response team will also use the database to identify sites within the vicinity of the incident.

Historic data from monitoring sites will provide a baseline concentration from which to assess the severity of the incident.

Real-time data will also be used to assess the situation on the ground, to inform and advise local residents and to track the movement of the plume over time.

2.2.6 Research and advisory groups

UK air quality policy is informed by the work of key advisory groups made up of experts in the fields of atmospheric science, air quality and the effects of air pollution. The **Air Quality Expert Group** (AQEG) is a key advisory group that provides independent scientific advice on air quality. Its main functions are[B2]:

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

The **Committee on the Medical Effects of Air Pollutants** (COMEAP) is a non-statutory advisory non-Departmental Public Body. The Committee members are all independent experts who provide advice to the UK Health Departments on the effects on health of both outdoor and indoor air pollutants on the basis of data currently available; to assess the need for further research; and to liaise as necessary with other Government bodies to assess the effects of exposure and associated risks to human health[B20].

2.3 Local authority air quality management

Central Government and the Devolved Administrations of Scotland, Wales and Northern Ireland are responsible for overall policy and legislation affecting the UK environment, including air quality. However, over recent years, the UK's Air Quality Strategy – discussed in the previous section - has progressively enabled and encouraged Local Government to take a central role in air quality management. Authorities are required regularly to ***Review and Assess*** air quality in their area and take decisive action when the objectives in regulation cannot be met by the specified target dates.

When this happens, an Authority must declare an 'Air Quality Management Area' (AQMA) and develop an Action Plan to tackle problems in the affected areas. Such a plan may include a variety of measures such as congestion charging, traffic management, planning and financial incentives.

Local authorities in England, Scotland and Wales have completed their first, second and third rounds of reviews and assessments against the Strategy's objectives prescribed in the 2000 Air Quality Regulations [B22], together with subsequent amendments [B23, B24, B25, B26]. The fourth round began in 2009.

To date, 237 Local Authorities – roughly 59% of those in the UK - have established one or more AQMAs. Most of these are in urban areas and result from traffic emissions of nitrogen dioxide or PM_{10}. Figure 2.7 shows the percentages of AQMAs in the UK that have been declared as a result of various sources of pollutant emissions (data kindly provided by the University of the West of England [B27]). Road traffic emissions are the main source in over 92% of the AQMAs; only a few have been designated as a result of industrial sources, domestic or non-road transport emissions.

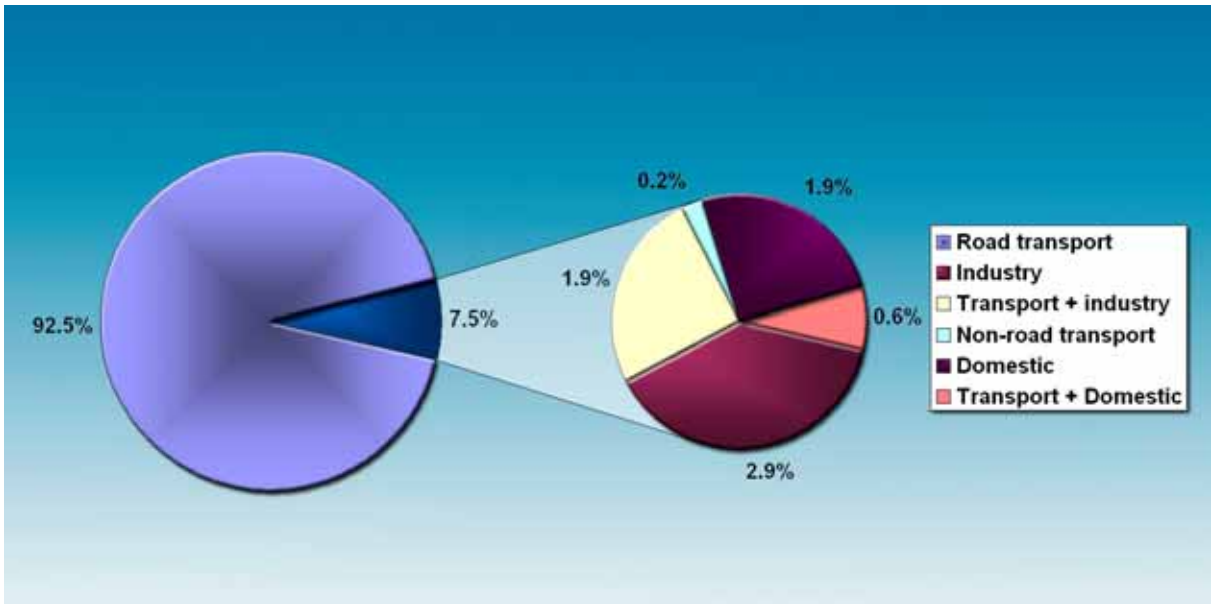


Figure 2.7 Proportion of the UK's current Air Quality Management Areas resulting from various sources- source, University of West of England

The location of current UK AQMAs is shown in Figure 2.8. A full list of the local authorities declaring such areas may be found at: www.airquality.co.uk/archive/laqm/list.php.

More information on AQMAs is summarised in Table 2.2 below.

Table 2.2 Current UK-wide status of Air Quality Management Areas (AQMAs) and appraised Action Plans (as of July 2009)

Region	Total No. of Local Authorities	Number of LAs with AQMAs (July 09)	Due to NO_2	Due to PM_{10}	Due to SO_2	Due to Benz-ene	Action plans submitted (as of July 2009)	Action plans awaited (as of July 2009)
England (excluding London)	292	173	161	35	9	1	140	42
London	33	33	33	28	-	-	32	2
Scotland	32	12	7	4	1	-	7	7
Wales	22	8	7	1	-	-	5	2
N. Ireland	26	11	7	5	1	-	7	4
TOTAL	**405**	**237**	**215**	**73**	**11**	**1**	**191**	**57**

(The total number of Local Authorities has recently decreased from 433 to 405, as 36 Local Authorities in England merged on 1st April 2009 to form eight larger Unitary Authorities).

The local authorities declaring AQMAs have undertaken further detailed assessments of the areas concerned, with a view to submitting a report within 12 months following initial designation of the AQMA. The authorities have been advised to prepare their action plans within 12-18 months of designation.

As shown in Table 2.2, a total of 248 authorities have now submitted action plans or are in the process of preparing them. These formally set out the measures they propose to take to work towards meeting the air quality objectives. Inevitably, the majority of the action plans focus on measures dealing with road traffic, such as:

- Local traffic management schemes
- Setting up Clean Air or Low Emissions zones - particularly in London - or
- Working with the Highways Agency (or the Scottish Government in Scotland, Welsh Assembly Government in Wales) to tackle pollution on the motorways/trunk roads.

Recognising the strong linkage between transport and air quality, English local authorities - other than those classified as 'excellent' - now have the discretion to either produce a standalone Air Quality Action Plan or integrate this plan within their Local Transport Plan.

More details are available from the Defra website at:
http://www.defra.gov.uk/environment/airquality/local/guidance/index.htm

Methodologies for local review and assessment continue to develop and improve throughout the UK, and the number of AQMAs declared has increased. As a result of the 3rd round alone, which was completed in 2008, 87 authorities in England, seven in Scotland and four in Wales have identified the need to designate new AQMAs. The increase in the number of AQMAs required is due in large part to:

- The improved methodologies being employed to identify areas of poor air quality for the second and subsequent rounds
- The increasing scale of monitoring being undertaken by local authorities
- The fact that UK-wide NO_2 concentrations are not decreasing as rapidly as was originally predicted: this was the reason for many of the AQMAs declared in the 2nd round.
- The fact that NO_2 concentrations have actually increased at some locations: this accounts for some of the AQMAs declared as a result of round 3.

Under the Environment (Northern Ireland) Order 2002, Local Authorities in Northern Ireland are also required to carry out a Review and Assessment of their local air quality. All 26 of Northern Ireland's District Councils completed Rounds 1 and 2, which were undertaken on a different timescale to the rest of the UK. The review and assessment timetable in Northern Ireland is now running in parallel to that in the rest of the UK, with Round 4 beginning in April 2009. At the time of writing, in Northern Ireland 16 AQMAs (in seven Districts) have been declared for NO_2, 12 have been declared for PM_{10} (in five Districts) and one AQMA has been declared for SO_2.

Defra and the Devolved Administrations provide Local Authorities with Technical Guidance and Policy Guidance documents, to assist them in carrying out their Review and Assessment, and undertaking necessary activities such as assessment of emissions, modelling and monitoring. During 2008, these guidance documents were updated, with the consultation process happening in the summer of 2008. The updated Technical Guidance and Policy Guidance documents were released in February 2009 and are available via the Air Quality pages of the Defra website, at -

http://www.defra.gov.uk/environment/airquality/local/guidance/index.htm.

Through the UK-wide process of Local Air Quality Management, tackling air pollution is progressively focussing more on local 'grass-roots' concerns, initiatives and actions.

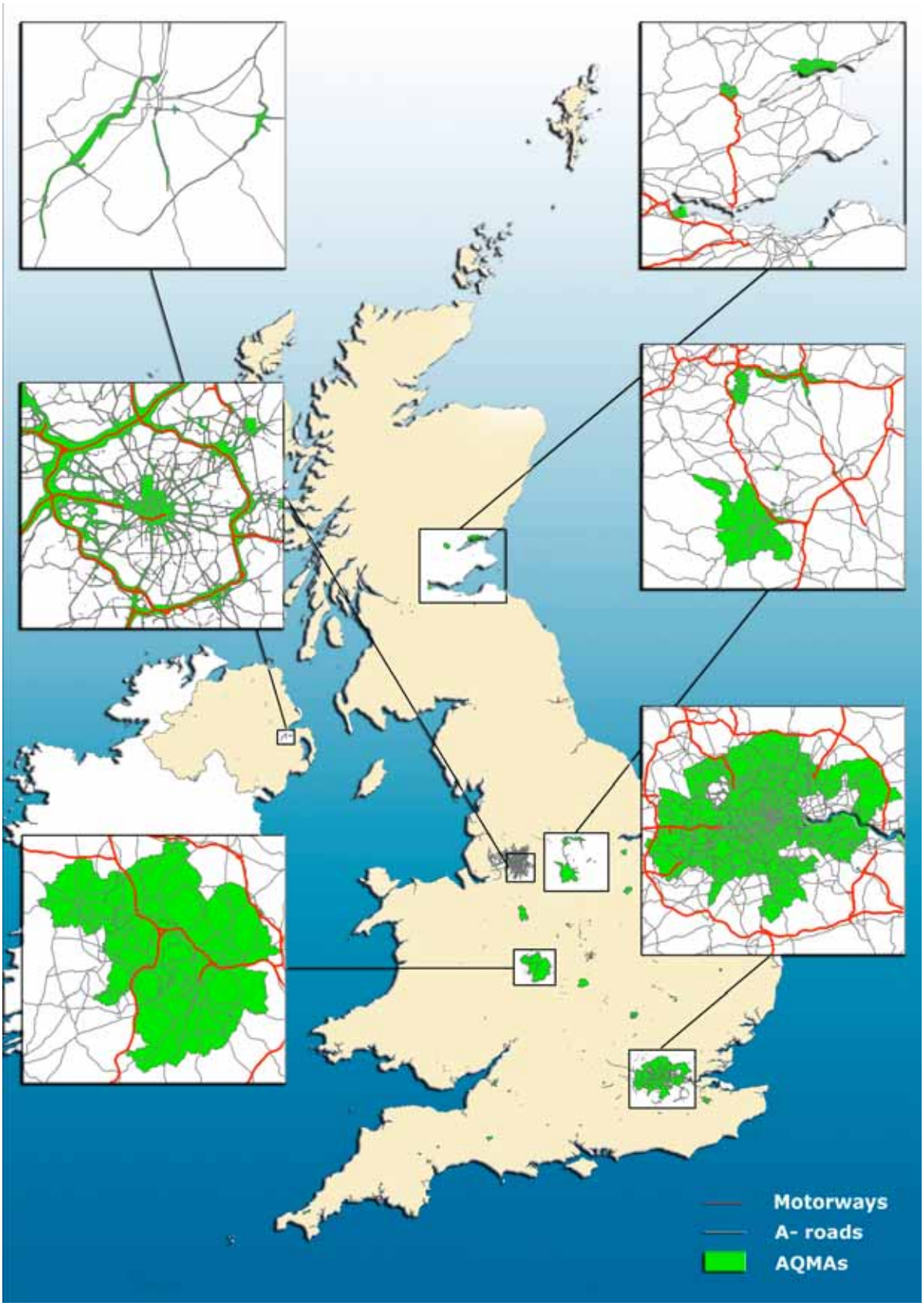


Figure 2.8 Map of UK Air Quality Management Areas (AQMAs), 2008

3 Where, how and why we measure air quality in the UK

To manage something effectively, you first have to measure it…
In this section, we see how this is done in the UK.

3.1 The role of ambient air quality monitoring

Air quality monitoring is a key component of any effective approach to Air Quality Management (AQM). In order to develop or implement an effective air quality management plan at local, city or national level, it is first necessary to obtain reliable information on ambient pollution levels. This point was fully recognised in Agenda 21[C1] of the United Nations Conference on Environment and Development (UNCED), held in Rio de Janeiro in 1992 and during the Johannesburg Summit[C2] held in 2002.

The ultimate purpose of air quality monitoring is not merely to collect data, but to provide the necessary information required by scientists, policy makers and planners to enable them to make informed decisions on managing and improving our environment.

Air monitoring fulfils a central role in this process, providing the necessary sound scientific basis for policy and strategy development, objective setting, compliance measurement against targets, and enforcement action. Viewed in this context, monitoring serves the following essential key functions:

- Comparison of existing air quality against local, national or international standards
- Assessment of population health and ecosystem impacts
- Identification of problem areas and pollutants requiring regulatory/control action
- Provision of baseline data for predictive models and environmental impact assessments
- Validation of emission inventory and model predictions
- Determination of long-term trends
- Assessment of the effectiveness - or otherwise - of control strategies over time
- Raising public awareness and promoting responsible action to tackle pollution

Monitoring data are therefore used - directly or indirectly - by a wide variety of people, from pollution-sensitive individuals to policy makers, toxicologists and epidemiologists.

In the UK, air pollution policy development relies heavily on the national air quality monitoring networks to provide reliable and scientifically robust data on ambient pollution concentrations. These data are used to establish priorities for policy development and to assess the effectiveness of control or regulatory action in reducing air pollution concentrations over time.

Air quality monitoring is also a legislative requirement (see Section 2). The UK is obliged to report levels of various pollutants to the European Commission on a regular basis. These are used to assess compliance with international targets from the European Union's Air Quality Directives. Monitoring data also play a key role in the development of the UK's Air Quality Strategy and in formulating national Air Quality Objectives.

We are all polluters. From the energy we use to supply our homes, the products we buy and – often - the food we eat, almost every aspect of our lives has an effect on the

quality of the air we breathe. Public awareness and co-operation is therefore an important pre-requisite to tackling air pollution at local, national and international level. To ensure a fully informed public, UK monitoring data are communicated rapidly and efficiently to air quality stakeholders and data users through a wide range of web and media outlets. These media and web-based approaches to achieving open and free public access to air quality data are discussed further in Section 9.

3.2 A brief history of monitoring in the UK

Figure 3.1. The notorious London Smog of 1952 © unknown

Air pollution has been a problem in the UK for centuries, with doctors and scientists recognising links between air pollution and health as far back as the 16th century.

Pollution became an increasingly serious problem during the industrial revolution, as coal became the dominant fuel used within industry and for domestic space heating. Inner cities, including London, were particularly badly affected.

During this period, it was not uncommon for the combination of pollution and unfavourable weather conditions to cause serious urban smogs. Historic sources suggest that each smog episode could cause thousands of premature deaths in susceptible people. These lethal 'pea-soupers' finally culminated in the infamous smogs of the 1950s and 60s (Figure 3.1), which finally precipitated both vociferous public concern and decisive Government action.

In response to this situation, the UK Government introduced its first Clean Air Act [C3] in 1956; this targeted both domestic and industrial coal burning with a range of different emission control and regulatory measures. A few years later, in 1961, the UK established the world's first co-ordinated national air pollution monitoring network, called the National Survey, monitoring black smoke and sulphur dioxide at around 1200 sites in the UK. Following the Clean Air Acts, several further pieces of legislation and additional monitoring networks were introduced to combat and measure air quality in the UK.

As discussed at length in "Air Pollution in the UK 2006", the National Survey and its early predecessors were able to monitor for over 50 years the dramatic decline in both black smoke and sulphur dioxide concentrations (Figure 3.2). This historic decline has been due to a number of factors, including fuel switching, the introduction of cleaner fuels and technologies, and successful smoke control legislation.

Over recent decades, black smoke levels have remained low; as a result, monitoring of this species has been scaled down, with black smoke now measured in the UK through a monitoring network of just 22 sites. As coal burning has decreased, however, the importance of other pollutants – primarily those from traffic - has increased. Road transport is currently the dominant source of pollution across the UK – both in cities and sometimes in more rural areas. For this reason, the UK's focus has shifted progressively to the monitoring of pollutants created (directly or indirectly) through vehicular emissions; these include, in particular, ozone, nitrogen dioxide and fine particulate matter.

The earliest air quality measurements used relatively simple, manual techniques. Often, a sample would be collected at a site and then returned to a laboratory for analysis; this approach is still the most appropriate for some pollutants. However, in the 1970s the UK first introduced automatic analysers to the monitoring networks. These had the benefit of low labour costs and could provide highly resolved, continuous measurements. These continuous measurements became a requirement for regulatory purposes and so, in 1987, a UK-wide automatic urban monitoring network was established to monitor compliance with the emerging EC Directive limit values on air quality. This network subsequently expanded, following commitments by Government to prioritise urban monitoring in the UK and improve the public availability of air quality information.

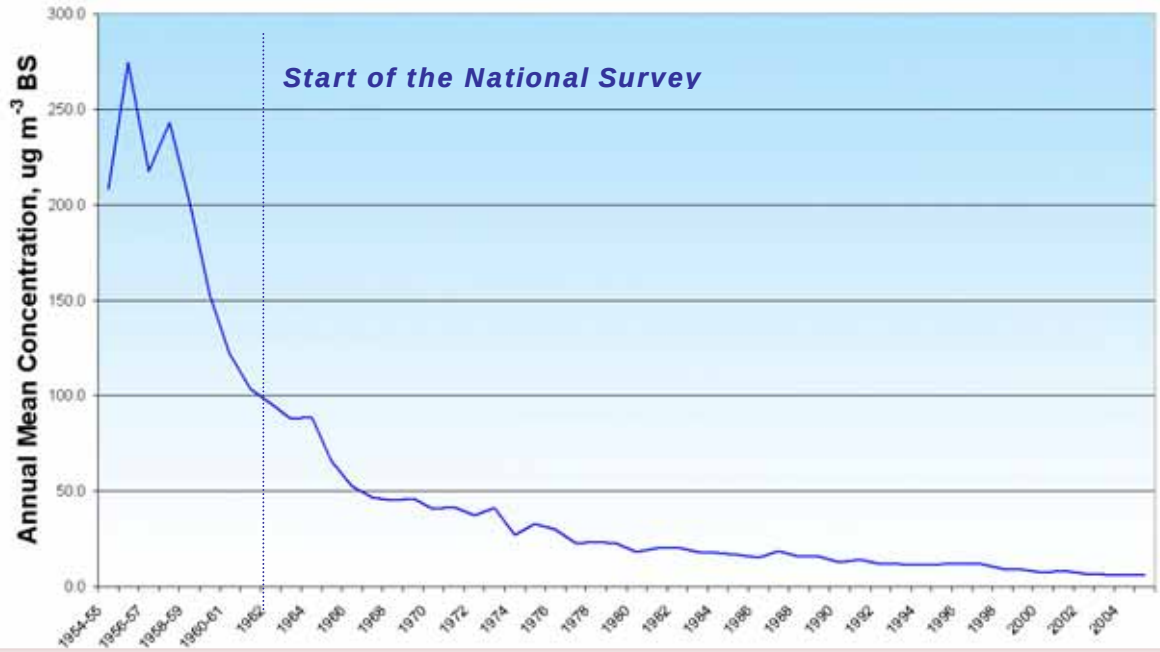


Figure 3.2 The decline in black smoke concentrations in London over 50 years, including data from 1954 to 2006

In 1992, the then Department of Environment established an Enhanced Urban Network (EUN). In 1996, this network expanded following an initiative designed to promote the integration of local authority sites into the national network where-

1) This met national monitoring objectives and
2) When appropriate quality and consistency standards could be maintained

At the same time, increased decentralisation in the management and quality assurance of the networks was actively promoted. The net effect of these measures was to substantially increase the number and diversity of stakeholders and participants in the national monitoring effort, thus increasing competition and improving standards.

In 1995, all statutory and other urban monitoring was consolidated into one comprehensive programme. Throughout the next five years, over 50 local authority sites were integrated into the resulting network, including 14 of the London Air Quality Monitoring Network sites. In 1998, the previously separate UK urban and rural automatic networks were then combined to form the current Automatic Urban and Rural Network (AURN), which is the most important and comprehensive automatic national monitoring network; in 2008 this comprised of 127 sites, operational for all or part of the year.

The expansion in automatic monitoring is clearly illustrated in Figures 3.3 and 3.4, where we show the increase in the number of sites and the total hourly measurements made since the commencement of automatic air quality monitoring in the UK.

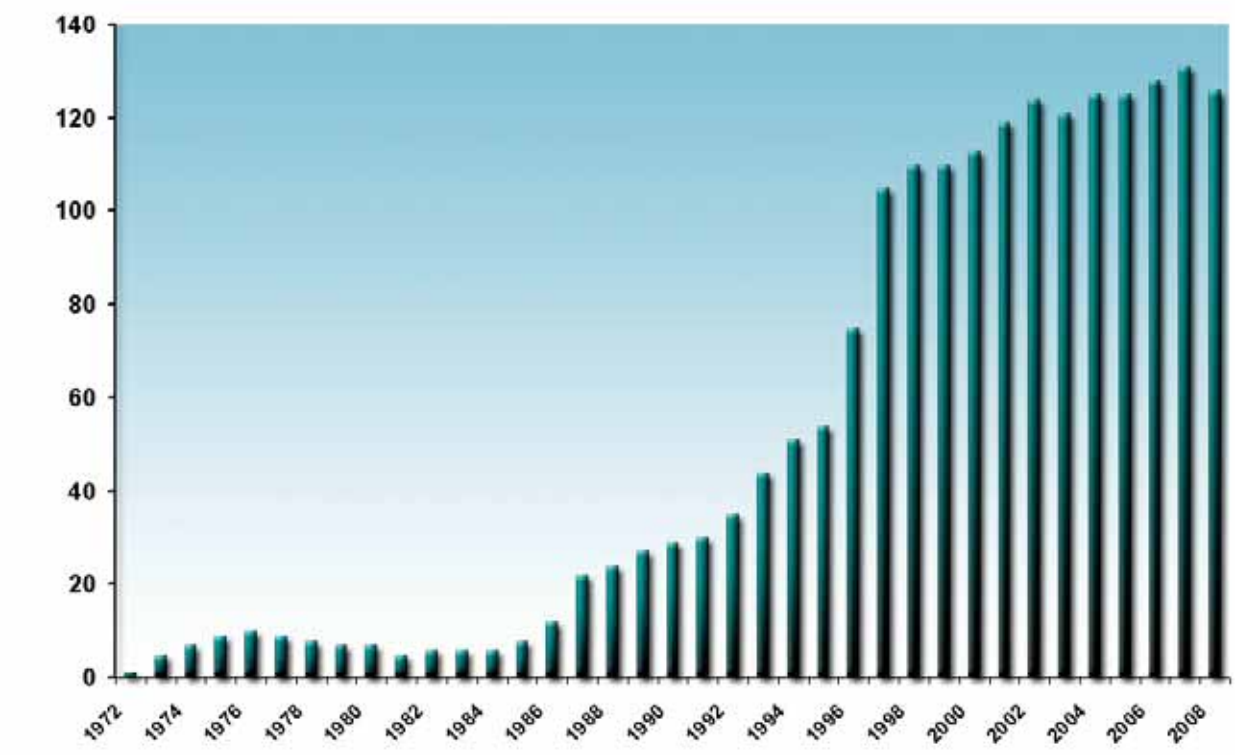


Figure 3.3 The number of government-funded automatic measurement stations in the UK has grown substantially since 1972

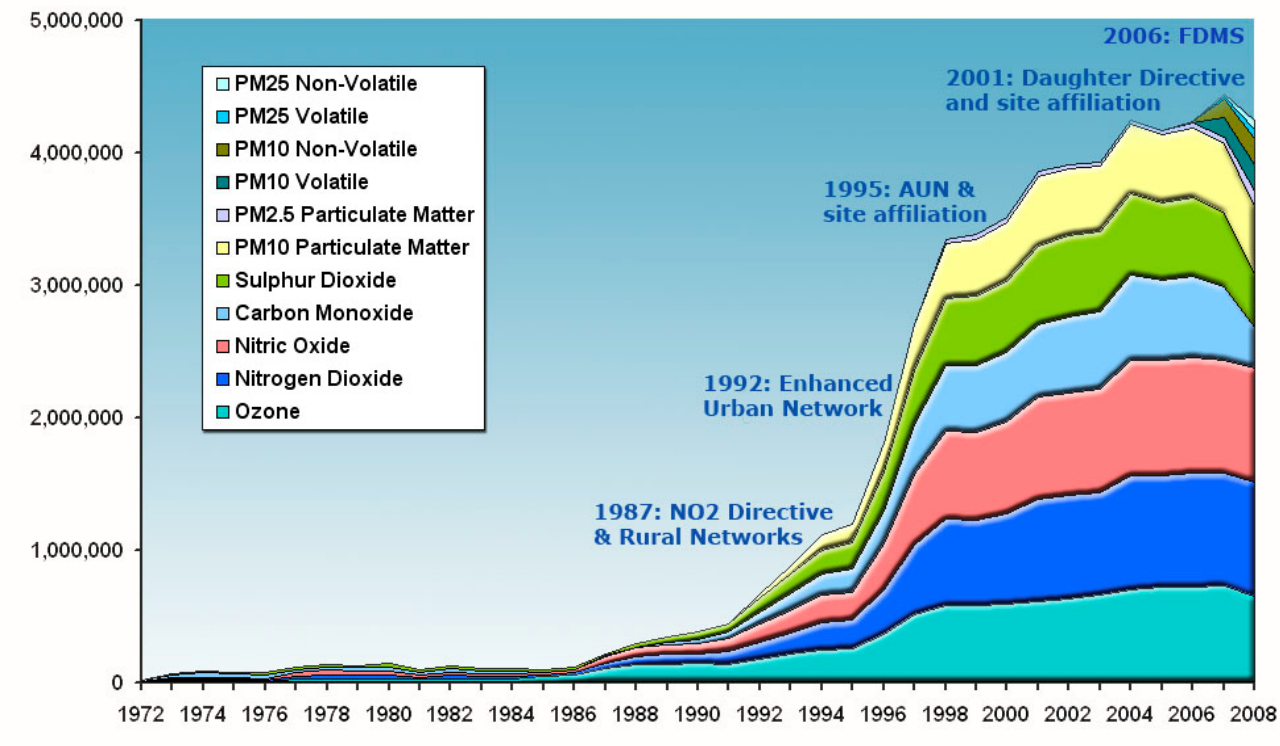


Figure 3.4 The number of hourly measurements made every year has also increased dramatically for all pollutants in the automatic monitoring networks (O_3, NO_2, CO, SO_2 and PM_{10}) and for other UK Strategy pollutants

3.3 Changes in the monitoring networks

Automatic Urban and Rural Network (AURN)

2008 was a year of radical changes in this key UK network. During 2007, the QA/QC Unit and the CMCU Unit of the AURN - in conjunction with Defra and the Devolved Administrations - carried out a comprehensive review of the monitoring network. This was necessary to ensure that the network remained compliant with the new European Air Quality Directive, specifically in relation to:

- Its requirement for a minimum level of monitoring in each agglomeration and zone
- The new requirement to measure $PM_{2.5}$ at many sites.

The need for additional monitoring was substantially met by affiliating suitable sites from other organisations, adding additional analysers at existing sites, or - in a small number of cases - by installing new sites. This process is still ongoing.

Monitoring sites that are no longer necessary for compliance have, in a number of cases, been closed down, or individual analysers at sites have been de-affiliated. Many of these closures occurred in 2008. During 2008, the following overall changes occurred within the AURN network as a result of the network review or as a result of enforced site closures:

- Monitoring of **PM_{10}** ceased at 15 sites
- Monitoring of **NO_x** ceased at 4 sites
- Monitoring of **SO_2** ceased at 2 sites
- Monitoring of **O_3** ceased at 3 sites

Moreover, the following Defra-owned and affiliated sites were closed:

- Somerton
- Bolton
- Norwich Centre
- Stockton-on-Tees Yarm
- Stewartby

In order to meet the requirement for $PM_{2.5}$ analysers to be in operation by 1st January 2009, a number of PM_{10} analysers have been converted to $PM_{2.5}$ - either permanently or temporarily - whilst awaiting the installation of a second analyser at the site. Forty $PM_{2.5}$ analysers were commissioned during 2008, and several more are due for installation during 2009. As part of this process, analysers that did not meet the equivalence requirements were upgraded to newer compliant types. Almost all TEOM particle analysers in the AURN have been upgraded to FDMS as part of this process.

Further changes to the AURN during 2008 are summarised in Table 3.1 below

Table 3.1 Changes to the UK automatic networks in 2008 - I

Sites	Date started up / closed	Pollutants
Newly established sites		
York Bootham	01/01/2008	$PM_{2.5}$ PM_{10}
York Fishergate	01/01/2008	NO_2 PM_{10}
Oxford St Ebbes	01/01/2008	NO_2 $PM_{2.5}$ PM_{10}
Newport	01/01/2008	NO_2 $PM_{2.5}$ PM_{10}
Chepstow A48	01/01/2008	NO_2 PM_{10}
Liverpool Queen's Drive Roadside	01/01/2008	NO_2
Aberdeen Union Street Roadside	01/01/2008	NO_2
Stanford-le-Hope Roadside	22/01/2008	NO_2 SO_2 PM_{10}

Sites	Date started up/closed	Pollutants
Carlisle Roadside	14/02/2008	NO_2 PM_{10}
Leeds Headingley Kerbside	17/02/2008	NO_2 PM_{10}
Newcastle Cradlewell Roadside	10/03/2008	NO_2
Chesterfield Roadside	11/03/2008	NO_2 PM_{10}
Chesterfield	13/03/2008	NO_2 $PM_{2.5}$ PM_{10}
Sandy Roadside	28/07/2008	NO_2 PM_{10}
Saltash Roadside	30/07/2008	PM_{10}
Stockton-on-Tees Eaglescliffe	01/09/2008	$PM_{2.5}$ PM_{10}
Charlton Mackrell	03/09/2008	NO_2 O_3
Warrington	21/10/2008	NO_2 $PM_{2.5}$ PM_{10}
London Harrow Stanmore	16/12/2008	$PM_{2.5}$
Pollutants discontinued at sites which are still operating		
Dumfries	27/03/2008	PM_{10}
Northampton	07/04/2008	PM_{10}
London Bexley	26/05/2008	PM_{10}
Brighton Roadside	29/05/2008	PM_{10}
Coventry Memorial Park	16/12/2008	PM_{10}
Nottingham Centre	19/12/2008	PM_{10}
London Westminster	24/12/2008	PM_{10}
Birmingham Centre	31/12/2008	PM_{10}
New pollutants monitored		
Coventry Memorial Park	16/01/2008	$PM_{2.5}$
Leominster	06/02/2008	SO_2
Derry	21/02/2008	$PM_{2.5}$
London Bexley	25/02/2008	$PM_{2.5}$
Sunderland Silksworth	01/04/2008	SO_2
Port Talbot Margam	23/04/2008	$PM_{2.5}$
London Marylebone Road Partisol[#]	02/05/2008	$PM_{2.5}$ PM_{10}
London N. Kensington Partisol[#]	07/05/2008	$PM_{2.5}$ PM_{10}
London Eltham	15/05/2008	$PM_{2.5}$
Brighton Preston Park	30/05/2008	$PM_{2.5}$
Harwell Partisol[#]	04/07/2008	$PM_{2.5}$ PM_{10}
Bristol St Paul's	12/08/2008	$PM_{2.5}$
Cardiff Centre	13/08/2008	$PM_{2.5}$
Newcastle Centre	24/08/2008	$PM_{2.5}$
Leicester Centre	01/09/2008	$PM_{2.5}$
Hull Freetown	02/09/2008	$PM_{2.5}$
Birmingham Centre	03/09/2008	$PM_{2.5}$
Northampton	05/09/2008	$PM_{2.5}$
London Harlington	16/09/2008	$PM_{2.5}$
Liverpool Speke	17/09/2008	$PM_{2.5}$
Reading New Town	25/09/2008	$PM_{2.5}$
Belfast Centre	01/10/2008	$PM_{2.5}$
Edinburgh St Leonards	01/10/2008	$PM_{2.5}$
Stoke-on-Trent Centre	05/11/2008	$PM_{2.5}$
Southampton Centre	05/11/2008	$PM_{2.5}$
Middlesbrough	13/11/2008	$PM_{2.5}$
Salford Eccles	26/11/2008	$PM_{2.5}$
Wigan Centre	27/11/2008	$PM_{2.5}$
Leeds Centre	02/12/2008	$PM_{2.5}$
Grangemouth	03/12/2008	$PM_{2.5}$
London Teddington	08/12/2008	$PM_{2.5}$
Sunderland Silksworth	09/12/2008	$PM_{2.5}$
Sheffield Centre	10/12/2008	$PM_{2.5}$
Birmingham Tyburn	15/12/2008	$PM_{2.5}$

 # Daily gravimetric samplers installed to run in parallel with existing automatic hourly monitors

Other Monitoring Networks

Changes to monitoring networks are driven by many factors, including increasing concern about health impacts, government's desire to inform the public of the quality of our air, the UK's Air Quality Strategy and a range of European commitments. Several other UK monitoring networks have seen major changes in 2008; these are detailed in Section 3.4 below.

3.4 Current UK monitoring programmes

There are currently over 400 national air quality monitoring sites across the UK, organised into automatic and non-automatic networks; each of these has different objectives, scope and coverage. The non-automatic sites measure average concentrations over a specified sampling period (typically from a day to a month) instead of instantaneous concentrations; nevertheless, these still provide invaluable data for assessing levels and impacts of pollution across the country as a whole. This section seeks to provide a brief description of the largest and most high profile networks.

More information on each network is detailed below:

- Appendix A1 - details of the pollutants measured in these programmes
- Appendix A3 – a detailed guide to the objectives and details of each measurement programme
- Figures 3.6- 3.10: a site map of the networks, split into four overall groupings:
    1. The Automatic Urban and Rural Network
    2. Air Toxics – PAH and TOMPs
    3. Acidifying Species
    4. Hydrocarbons
    5. Black Smoke
- A summary of the UK national networks is provided in Table 3.2.
- The pollutants monitored by these networks are summarised in Table 3.3
- The monitoring home page and section of the UK Air Quality Archive at http://www.airquality.co.uk/archive/networks_home.php

In order to meet the primary objectives of these networks - as summarised in Section 3.1- the data produced must be high quality, robust, and effectively communicated to the appropriate stakeholders. Each network utilises strong quality assurance and control (QA/QC) measures to maximise measurement integrity and reliability (see Section 3.5). Moreover, a strong emphasis is placed on achieving the widest possible dissemination and use of both monitoring data and the information derived from this (see Section 9).

Table 3.2 The major UK Air Quality Monitoring Networks

Network	Auto or Sampler?	Number of Sites
The Automatic Urban and Rural Network (AURN)	A	127 (102 urban, 25 rural, 18 London)
Ammonia Network	S	95
Rural acid deposition, gases and particles	S	38 (acid deposition)
Nitric Acid Network	S	30
Toxic Organic Micropollutants (TOMPS) Polycyclic Aromatic Hydrocarbons (PAH)	S S	7 31
Particle concentrations and numbers	S	4
Black Smoke / Black Carbon	S	22
UK Heavy Metals Monitoring Network	S	24 at end of 2008
Rural Metals Monitoring network	S	10 particle and rain, (including Hg) 2 cloud and rain (excluding Hg) 3 rain only (excluding Hg)
Non automatic hydrocarbon (benzene pumped tubes)	S	36
Automatic Hydrocarbon	A	4

Table 3.3 Summary of UK measurements made for the key air pollutants

Pollutant	Major sources	Site Numbers	Areas Covered
Volatile Organic Compound (VOCs)	Industry, transport, solvent use and some natural sources.	5 automatic, 36 non-auto benzene	Mostly urban
Dioxins and PCBs	Combustion (dioxins) and historic uses (PCBs).	7 non-auto	Urban and rural
Particulate Sulphate	Industry and fuel combustion	5 non-auto	Rural
Polycyclic Aromatic Hydrocarbons (PAH)	Industry, domestic combustion and traffic (PAH).	31 non-auto	Industrial, urban rural
Metals- Pb, Cd, As, Ni and Hg	Industrial and other processes	39 non-auto	Industrial, urban rural
Black Smoke	Road transport, industry, construction and natural sources.	22	Mostly urban
Acid Deposition	Atmospheric reactions involving fuel burning, agricultural and other emissions.	38 non-auto	Rural
Ammonia	Agricultural activities - decomposition and volatilisation of animal wastes.	95 non-auto	Rural
Nitric Acid	Combustion and photochemistry.	30 non-auto	Rural

1) Automatic Urban and Rural Network (AURN)

The AURN is currently the largest automatic monitoring network in the UK. In 2008, there were 127 operational multi-pollutant sites, split between the different countries as shown in Table 3.4, Table 3.5 and Figure 3.6. These sites provide high-resolution hourly information on a range of pollutants; this information is communicated rapidly to the public, using a wide range of electronic, media and web platforms (Section 9).

Table 3.4 AURN sites across the UK

Country	Site numbers
England	99
N. Ireland	3
Wales	10
Scotland	15

Figure 3.5. (Opposite) AURN station at Swansea Morriston, Wales

Table 3.5 Summary of measurements made by the AURN in 2008

Pollutant	Major sources	Site Numbers (Total in 2008)	Areas covered
Nitrogen Dioxide (NO_2)	Road transport and industry	111 automatic	Mostly urban Rural
Ozone (O_3)	Sunlight and heat, acting on road transport and industrial emissions	80 automatic	Urban and rural
Particles (PM_{10}, $PM_{2.5}$)	Road transport, industry, construction, soil and natural sources	77 PM_{10} 53 $PM_{2.5}$	Mostly urban
Sulphur Dioxide	Industry and fuel combustion	45 automatic	Urban and rural
Carbon Monoxide (C0)	Road transport	27 automatic	Urban

2) Ammonia Network

The UK National Ammonia Monitoring Network was established in 1996 to quantify the spatial and temporal distribution and long-term trends in concentrations of atmospheric ammonia (NH_3). Since 1999, the network has also included measurements of ammonium (NH_4^+) particles. Results are used to validate models and contribute to national Nitrogen (N) deposition estimates for assessment of acidification and eutrophication effects.

There are currently 95 sites. Monthly measurements of atmospheric NH_3 and NH_4^+ are made with an established *Denuder for Long-Term Atmospheric* (DELTA) system at 59 sites, augmented by NH_3 measurements with the high sensitivity A*dapted Low-cost Passive High Absorption* (ALPHA) sampler at 48 sites, with the latter subject to continuous calibration. 12 intercomparison sites with both methods are operated in parallel. Please see Figure 3.7.

3) Acid Deposition Monitoring Network

The Acid Deposition Monitoring network was established in 1986 to monitor the composition of precipitation nationwide. This provides information on deposition of acidifying compounds in the UK, and assessment of their potential impacts on ecosystems. Other measurements – including sulphur dioxide, nitrogen dioxide, and particulate sulphate - have also been made within the programme, in order to provide a more complete understanding of precipitation chemistry in the UK.

The acid deposition network currently comprises 38 sites in the UK, measuring wet bulk deposition on a fortnightly basis; 24 measuring NO_2 by diffusion tubes at rural sites; and five measuring daily particulate sulphate. This network also includes the monitoring of gaseous nitric acid, sulphur dioxide, hydrochloric acid and aerosol nitrate, sulphate, chloride, plus base cations - by DELTA measurements - on a monthly basis at 30 locations. The Acid Deposition Monitoring Network became the United Kingdom Eutrophying & Acidifying Pollutants Network after December 2008. The new network is operated jointly by AEA and CEH.

Historic results from the acid deposition monitoring programme are reviewed in Section 7 of this report. Please also see Figure 3.7.

4) PAH and TOMPs Monitoring Networks

Polycyclic aromatic hydrocarbons (PAH) are a large group of persistent bio-accumulative organic compounds with toxic or human carcinogenic effects; they are produced from a wide range of industrial, chemical and combustion processes. A target value of 1 ngm^{-3} has been set for the 'marker' PAH, benzo[a]pyrene, by the European Fourth Daughter Directive.

During 2008, there were 31 sites utilising high volume samplers to capture gas and particle-phase PAH on glass fibre filters and polyurethane foam pads. The pollutant is extracted from the filter media in a laboratory and the 39 PAH species are subsequently analysed by gas chromatography-mass spectrometry.

Toxic Organic Micro Pollutants (TOMPs) include several highly toxic and persistent species, many of which are formed as unwanted by-products during various industrial, chemical and combustion processes. These were measured at three urban background and four rural sites during 2008. Four of the TOMPS sites were also part of the PAH network (Figure 3.8).

5) Particulate Concentrations and Numbers Network

This research-oriented network currently consists of four measurement sites; two in London, one rural site at Harwell, Oxfordshire and one in Birmingham. The following pollutants are measured:

- Total particle numbers per cubic centimeter of ambient air
- Particle numbers in different particle size fractions
- Nitrate, sulphate, and chloride
- Organic and elemental carbon

The network provides data on the chemical composition of particulate matter, primarily for the use of researchers of atmospheric processes, epidemiology and toxicology.

6) Black Smoke Monitoring Network

In September 2006, the large and long-running national network measuring black smoke and SO_2 finally came to an end after over forty years of operation. Results from this historic measurement programme were comprehensively reviewed in the 2006 annual report.

The Smoke and SO_2 network was replaced by a smaller programme measuring black smoke only, at 21 sites across the UK. In the earlier programme, black smoke was collected daily onto paper filters; the resulting smoke stains on the filters were measured using a reflectometer, and used to calculate a "black smoke index". This dated equipment was replaced for the new network. Between October and December 2008, an automatic instrument called an aethalometer was deployed; this directly measures black carbon using a real-time optical transmission technique.

Table 3.6 Black Smoke / Black Carbon Network, 2008

Site Name	Site Type	Other Particulate Analysers at the same site
Edinburgh St Leonard's	Urban Background	FDMS TEOM PM_{10}
Glasgow Centre	Urban Centre	FDMS TEOM PM_{10}
Manchester Piccadilly	Urban Centre	FDMS TEOM PM_{10}
Belfast Centre	Urban Centre	FDMS TEOM PM_{10}
Stoke Centre	Urban Centre	FDMS TEOM PM_{10}
North Kensington	Urban Background	FDMS TEOM PM_{10} + nitrate + number counting + manual $PM_{2.5}$
Nottingham Centre	Urban Centre	FDMS TEOM PM_{10}
Birmingham Tyburn	Urban Background	FDMS TEOM PM_{10}
Folkestone, Kent Network	Rural	TEOM PM_{10} + PM $_{2.5}$
Norwich	Urban Background	FDMS TEOM PM_{10}
Harwell	Rural	FDMS TEOM PM_{10} + FDMS TEOM PM $_{2.5}$ + nitrate + number counting + manual $PM_{2.5}$
Marylebone Road	Roadside	FDMS TEOM PM_{10} + PM $_{2.5}$ + nitrate + number counting + manual $PM_{2.5}$
Strabane 2	Urban Background	none
Cardiff 12	Urban Background	none
Halifax 17	Urban Background	none
South Kirkby 1	Urban Background	none
Dudley Central	Urban Centre	none
Sunderland 8	Urban Background	none
Dunmurry 3	Urban Background	none
Woolwich 9	Urban Background	none
Bath 6	Urban Background	none
Bradford Town Hall	Urban Centre	none

Black smoke measurements ceased at all sites when the aethalometer was installed - except for Edinburgh St Leonard's, Halifax, Birmingham Tyburn, North Kensington and Marylebone Road, where parallel measurements will be made for 12 months to aid the long-term intercomparison of measurements.

An aethalometer was not installed into the Norwich site, as it was planned to relocate this in early 2009. Black smoke measurements continued in Norwich to the end of 2008.

Figure 3.9 shows the 22 black smoke monitoring locations in operation during 2008: the red dots show sites which are also part of the AURN, whilst the yellow dots show sites which were incorporated from the old Black Smoke Network. Full site details are provided in Table 3.6.

7) Urban Heavy Metals Network

This network provides data to demonstrate compliance with European Directives. PM_{10} particulate samples are collected weekly onto cellulose filters, which are analysed in a laboratory environment, by digestion of the samples in a hot acidic solution, followed by analysis by mass spectrometry. Twelve different metals are analysed, including the four regulated by Europe: arsenic, cadmium, lead and nickel. Eleven of the sites also measure vapour-phase mercury.

The network was expanded in 2008, to include the required number of sites in the zones and agglomerations in the UK. Four sites were closed and eleven new sites opened, giving a total of 24 sites in operation at the end of 2008. The locations of the sites are shown in Figure 3.8.

8) Non-automatic Hydrocarbon Network

Benzene emissions arise from the evaporation and combustion of petroleum products, and measurements of the concentrations of these species in ambient air are necessary to determine compliance with the new European Directive (see Section 2).

In this network of 36 sites, ambient concentrations of benzene are measured by pumping air across an adsorption tube to trap the compound, which is later analysed in a remote laboratory by gas chromatography.

In anticipation of the siting requirements in the new Air Quality Directive, some site locations in the Network were changed during a process that started in 2007 and was completed in 2008. These changes involved the closure of 10 existing sites and the opening of 11 new non-automatic benzene monitoring sites. The changes are shown in Table 3.7 overleaf, and site locations are shown in Figure 3.10.

9) Automatic Hydrocarbon Network

During 2008, the UK Automatic Hydrocarbon Network consisted of four sites, located at Glasgow, Harwell (Oxfordshire), London Eltham, London Marylebone Road and Auchencorth Moss (Midlothian). This network uses two different types of automated gas chromatographs to determine concentrations of up to 29 different hydrocarbons on an hourly basis, including:

- Benzene – this is regulated by Europe and the UK
- 1,3-butadiene - this has an associated objective in the national Air Quality Strategy
- Ozone precursors – measurement data must be reported to the European Commission

The two monitoring sites at Harwell and Auchencorth Moss are also designated EMEP 'supersites', reporting data to the international co-operative programme for monitoring

and evaluation of the long-range transmissions of air pollutants in Europe. Please see Figure 3.10.

Table 3.7 Changes to the Non-Automatic Hydrocarbon Network, 2007 and 2008

Sites	Date started up / closed	Pollutants
Sites closed in 2007		
Belfast Roadside	09/10/2007	benzene
Portsmouth	25/10/2007	benzene
Bournemouth	26/10/2007	benzene
Southend on Sea	30/10/2007	benzene
Cwmbran	31/10/2007	benzene
Hull Freetown	14/11/2007	benzene
Edinburgh	27/11/2007	benzene
Reading	04/12/2007	benzene
Hove	05/12/2007	benzene
Leeds Roadside	11/12/2007	benzene
Sites commencing operation in 2007 and 2008		
Birmingham Tyburn	18/12/07	benzene
Camden Roadside	19/12/07	benzene
Bury Roadside	17/01/08	benzene
Bath Roadside	28/01/08	benzene
Oxford St Ebbes	30/01/08	benzene
Cambridge Roadside	04/02/08	benzene
York Fishergate	13/02/08	benzene
Carlisle Caldergate	09/04/08	benzene
Chesterfield	06/06/08	benzene
South Killingholme	02/09/08	benzene
Eaglescliffe - Yarm	30/09/08	benzene

Local authority monitoring

In addition to the AURN and other non-automatic national monitoring networks, there are also many non-network monitoring sites, operated by Local Authorities as part of their Local Air Quality Management obligations. Many of these sites contribute data to nationally organised measurement programmes that are funded and supported by Central Government and the Devolved Administrations. However, it should be noted that this report deals only with measured data from national monitoring programmes, including Local Authority sites that are affiliated to these programmes.

Many of the networks, and particularly those involving automatic measurements, are large-scale and involve a wide range of participating organisations. There is also an important role for local organisations, which are typically responsible for ongoing site operations. The data from these and similar networks therefore represent the end product of the efforts of many persons and organisations in the private sector, local and central government.

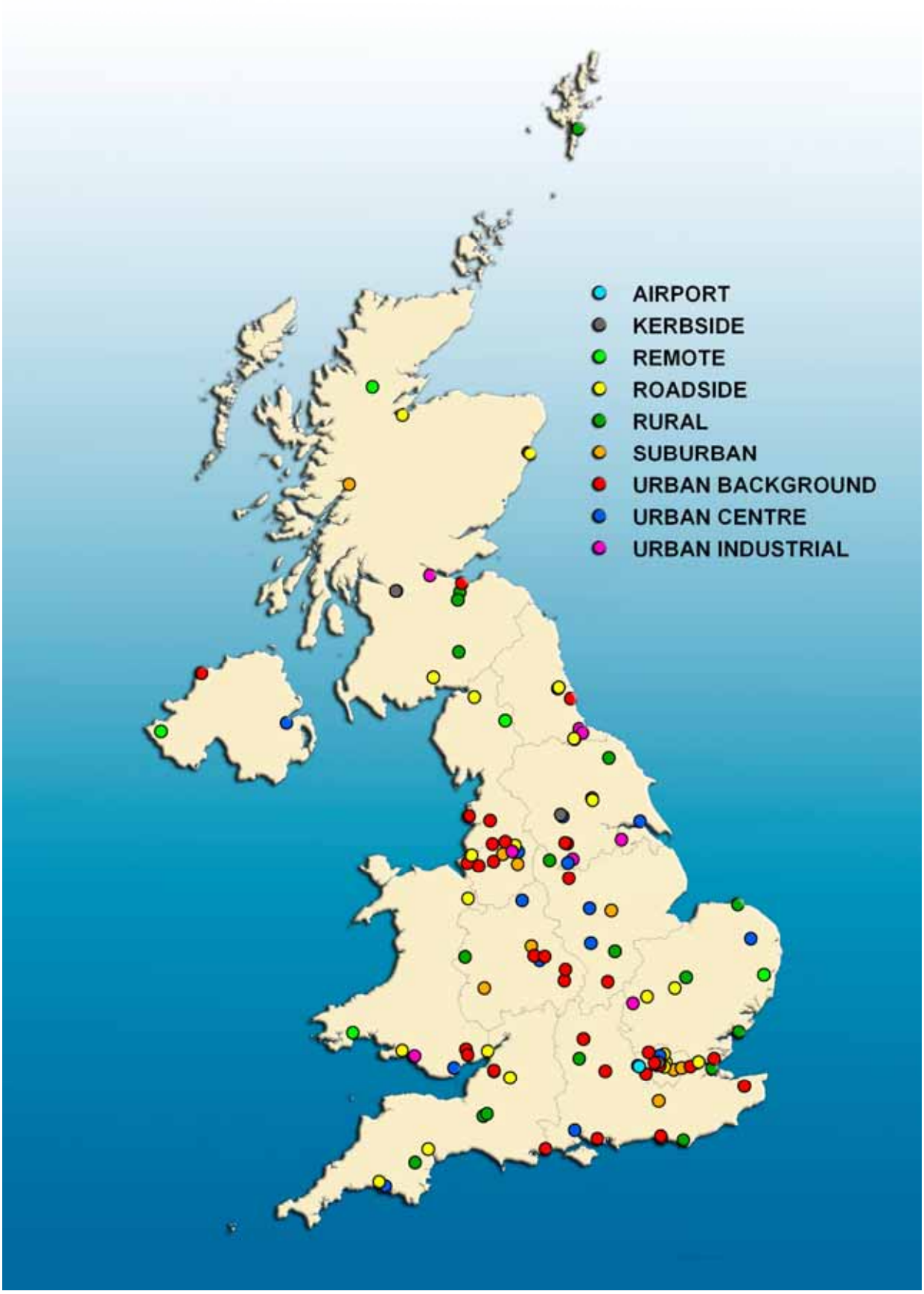


Figure 3.6 Automatic monitoring stations in the National Automatic Urban and Rural Network (AURN) during 2008

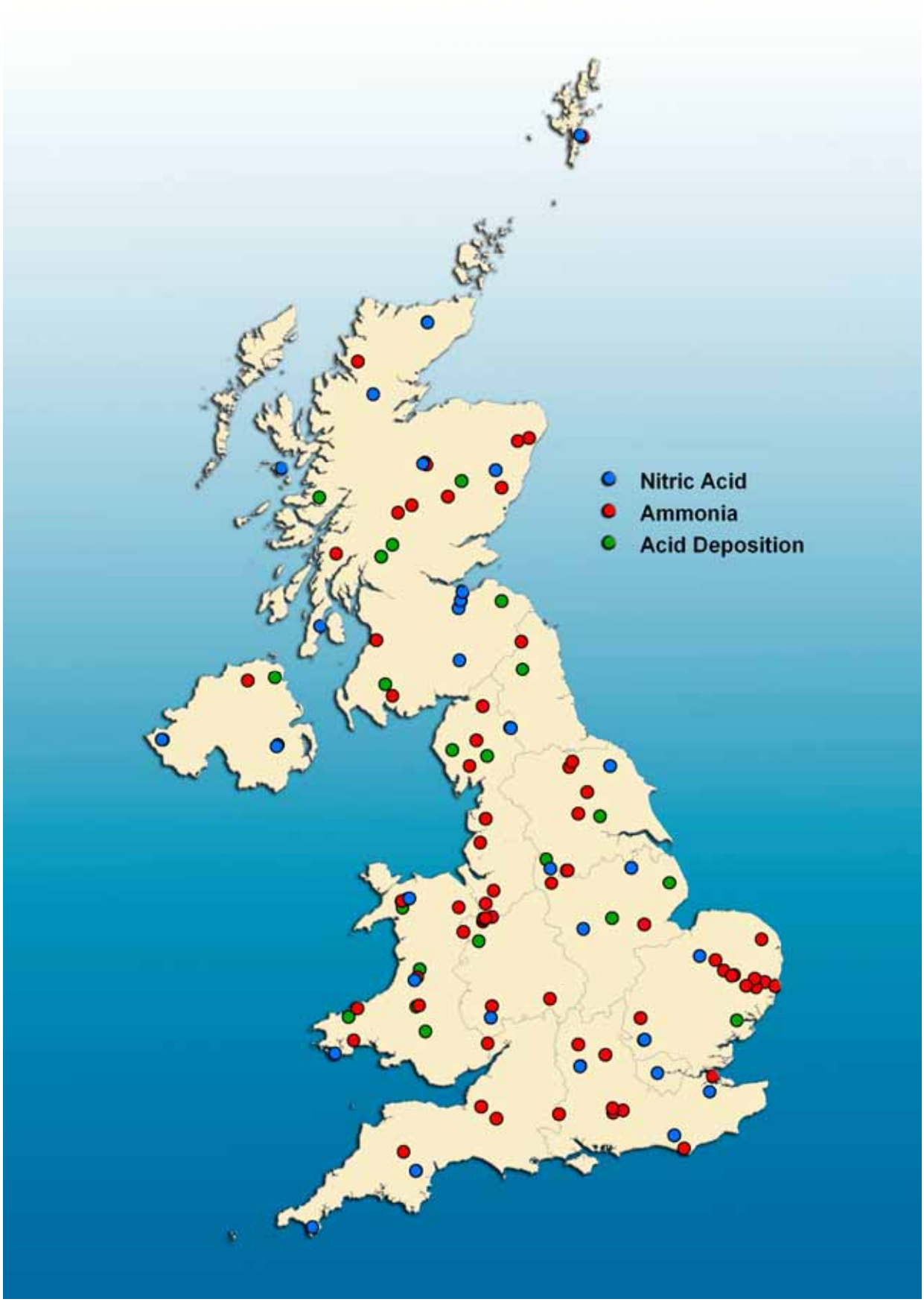


Figure 3.7 Non-automatic monitoring stations for acidifying pollutants- acid deposition, nitric acid and ammonia during 2008

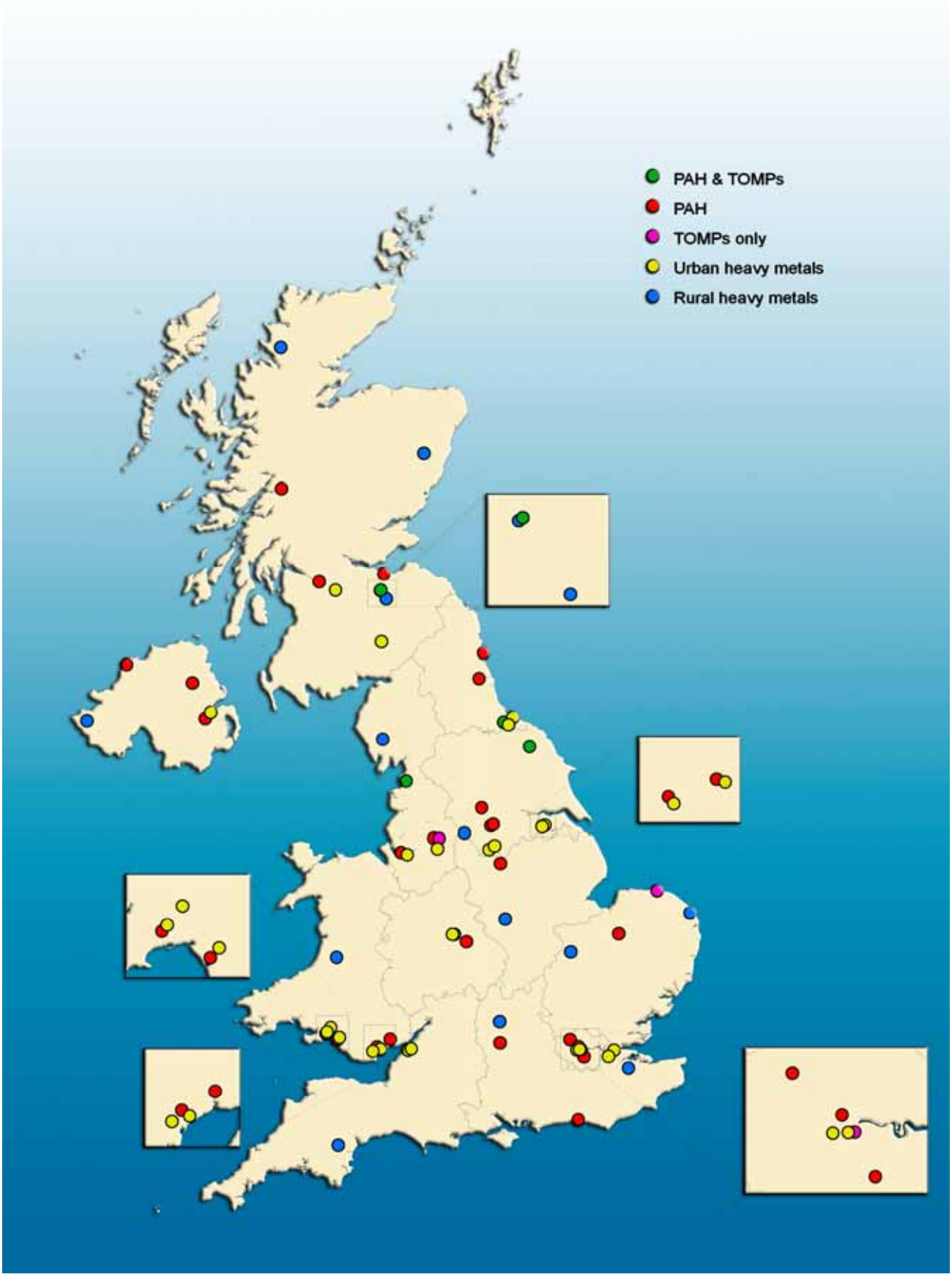


Figure 3.8 Non-automatic monitoring stations for air toxics- metals, PAHs (Polyaromatic hydrocarbons) and TOMPs (Toxic Organic Micro Pollutants)

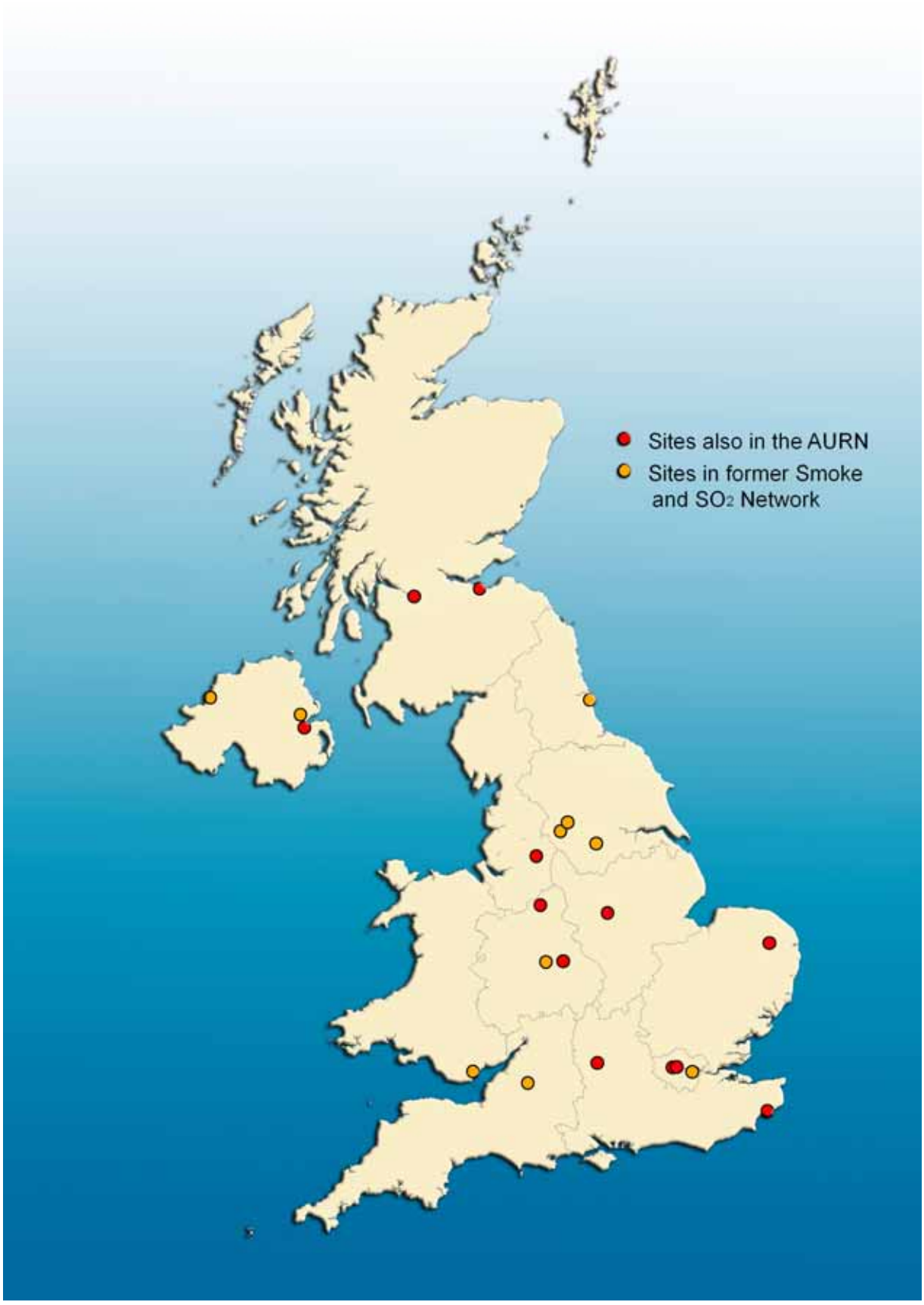


Figure 3.9 UK Black Smoke monitoring stations during 2008

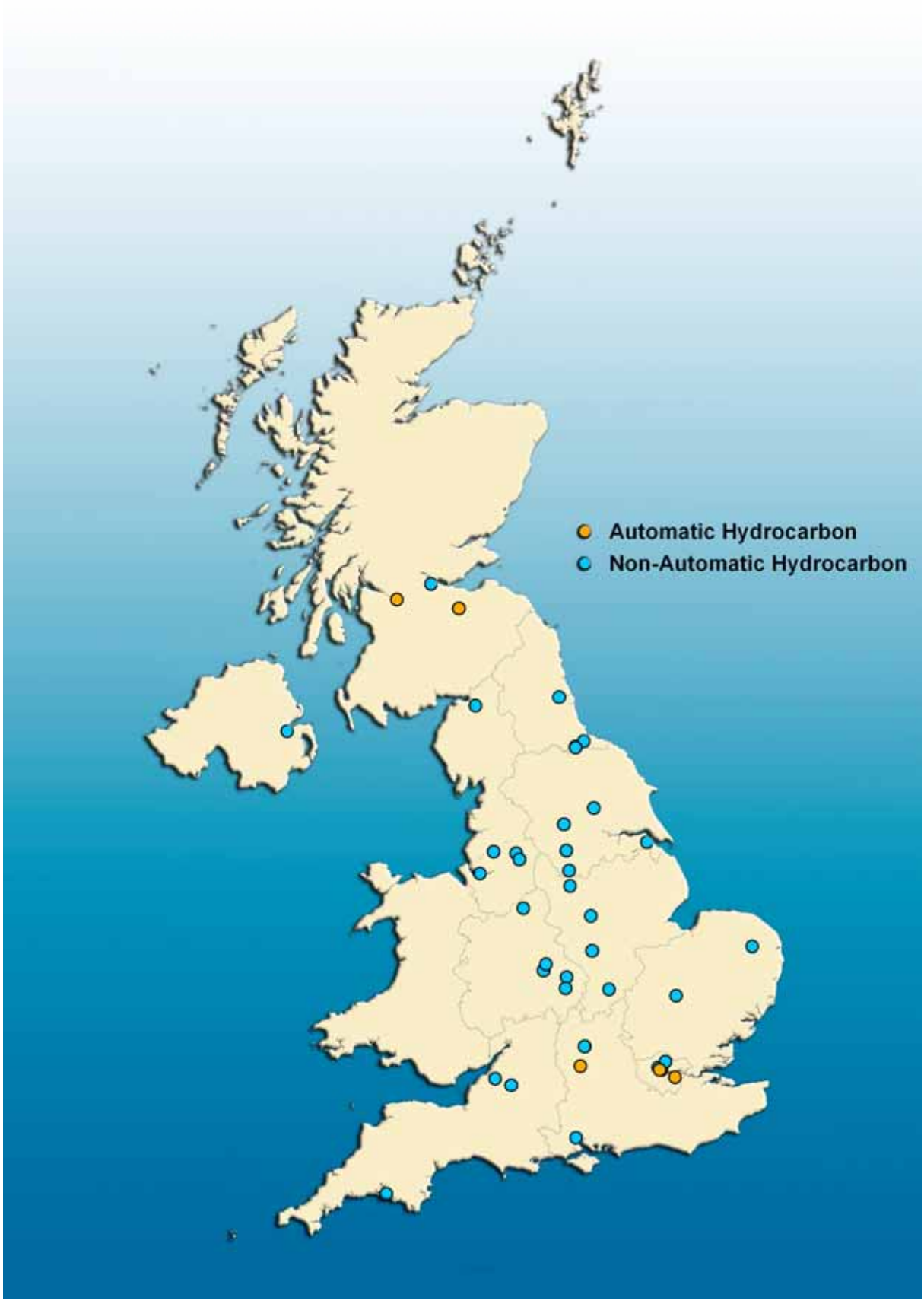


Figure 3.10 UK monitoring stations for automatic and non-automatic hydrocarbons during 2008

3.5 Our emphasis on data quality

The UK's national air monitoring networks currently generate over 20 million raw individual measurements every year; in the AURN alone, this amounts to over 9 million hourly measurements archived. All measurements, whether from automatic or manual samplers, are subject to a rigorous procedure of validation and ratification before they are published on the national Air Quality Archive. This currently contains over 200 million data records and statistics- making it a very large and comprehensive database!

Accurate and reliable measurements are essential if the monitoring data are to fulfill the objectives listed in Section 3.1. Considerable scientific development, time and attention are invested in each measurement procedure, to provide data that are of suitable quality to be used by all stakeholders for their different purposes.

Quality Assurance and Control

A system of activities that assures that measurements meet defined standards of quality with a stated level of confidence. The system includes quality assurance of the measurement process and quality control of the measurement outputs.

Each UK network therefore has in place a strong QA/QC programme designed to ensure that its measurements meet defined standards of quality with a stated level of confidence. Essentially, each programme serves to ensure that the data obtained are:

- Genuinely representative of ambient concentrations existing in the various areas under investigation
- Sufficiently accurate and precise to meet specified monitoring objectives
- Comparable and reproducible. Results must be internally consistent and comparable with international or other accepted standards, if these exist
- Consistent with time. This is particularly important if long-term trend analysis of the data is to be undertaken
- Representative over the period of measurement; for most purposes, a yearly data capture rate of not less than 90% is usually required for determining compliance with EC Limit Values where applicable
- Consistent with the Data Quality Objectives and methodology guidance defined in EC Daughter Directives for relevant pollutants and measurement techniques.

The UK's Quality Assurance and Control programmes typically include a broad spectrum of system design, operational management, training and review activities. These differ from programme to programme, depending on network objectives, methodologies and data quality targets. We here highlight some of the core procedures and overall principles employed for selected programmes.

i) Uncertainty

Measured pollutant concentrations are assigned an uncertainty, which essentially gives a range of values that could be correct. Consider the following statement:

The PM_{10} concentration is 20 ± 2 μgm^{-3} (95% confidence)

This means that we are 95% certain that the correct concentration lies between 18 and 22 μgm^{-3}, and that it is most likely to be 20µg m^{-3}. The probability of the concentration being at the extremes of the stated range is small. Within the EU Air Quality Directives, specific Data Quality Objectives define the maximum acceptable uncertainty levels (at 95% confidence) for a range of pollutants. These are summarised in Table 3.8:

Table 3.8. Data Quality Objectives for ambient air quality assessment

Pollutant	Sulphur dioxide, nitrogen dioxide and oxides of nitrogen and carbon monoxide	Particulate matter (PM_{10}/$PM_{2.5}$) and lead	Ozone and related NO and NO_2
Uncertainty at 95% confidence (±)	15%	25%	15%

This section summarises the QA/QC procedures that are undertaken within the AURN to achieve these requirements. Full details are provided in the reference document for QA/QC within the AURN[C4].

ii) Structure of UK monitoring networks

Responsibility for the UK monitoring networks rests with the UK Government and the Devolved Administrations. Key tasks are contracted to a number of organisations. The structure of the AURN, depicted below in Figure 3.11, is intentionally decentralised, in order to:

1) Maximise the involvement of different public and private sector participants in the programme
2) Maximise locally-based involvement
3) Ensure that QA/QC activities are fully independent operational

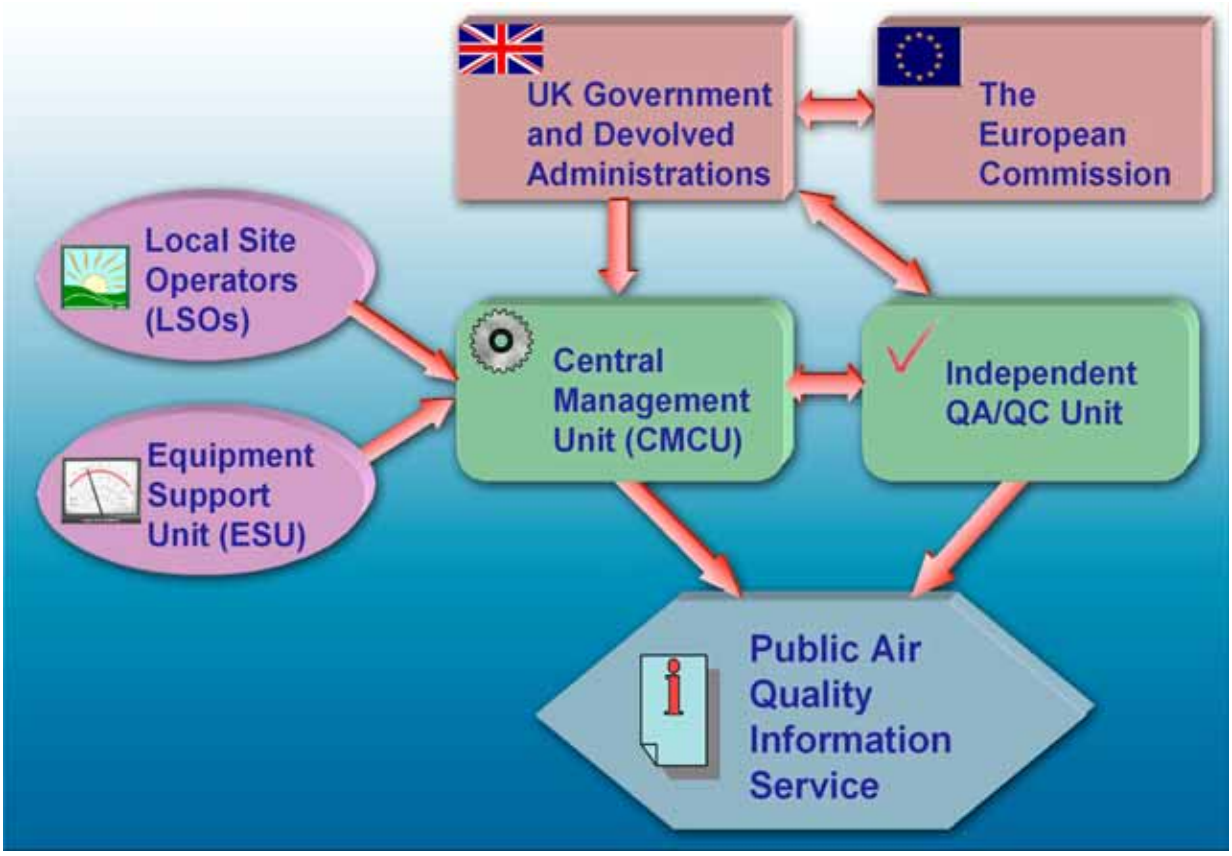


Figure 3.11 Devolved monitoring network structure, as currently utilised within the Automatic Urban and Rural Network (AURN)

iii) Standardisation of methods

The European Committee for Standardisation (CEN) has published a series of Standard Methods for the measurement of air pollutants. UK air quality monitoring experts continue to work closely with CEN to develop appropriate methods for ensuring high quality data, and integrating these into the networks. The following are examples of relevant standards:

- BS EN14211: 2005 (NOx)
- BS EN14212: 2005 (SO_2)
- BS EN14625: 2005 (O_3)
- BS EN14626: 2005 (CO)
- BS EN12341: 1999 (PM_{10})
- BS EN14907: 2005 ($PM_{2.5}$).

These standards describe in detail how analysers are to be tested, approved for use, calibrated and their ongoing performance determined. In the UK, testing of ambient air pollution analysers is undertaken by SIRA (http://www.sira.co.uk/index.html), to performance specifications developed within the UK Environment Agency's MCERTS scheme (http://www.environment-agency.gov.uk/business/regulation/31829.aspx). These performance requirements are based the CEN standard requirements.

The use of tested and approved analysers and harmonised on-going QA/QC procedures allow Member States to reliably and consistently quantify the uncertainties associated with their measurements of air pollution. The CEN/BS procedures are specifically targeted at quality assurance of a monitoring network, by ensuring that the quality of the measurement inputs and systems are tightly specified. These BS EN standards have been incorporated into the latest EC Directive on Air Quality (2008/50/EC), making it mandatory for Member States to operate monitoring networks to these standards by June 2010.

The majority of the tests required by CEN are either undertaken already, or require only minor modifications to ensure full compliance with the requirements. The procedures used to perform these tests are continuously refined and revised; they are sufficiently developed that they will be fully compliant with CEN well in advance of required timeframes.

iv) Traceability of the measurement to International Standards

Traceability requires an unbroken chain of measurements all with stated uncertainties - from a primary international or national standard to the final measurement result. Each step in the measurement chain results in a slight increase in overall uncertainty.

The traceability chain for the gaseous pollutants in the AURN is indicated in Figure 3.13. The 'chain' is shown in red – from International standards to individual measurement sites. The check procedures adopted in the UK are also highlighted, being shown in green.

v) Overall measurement uncertainty

Through the use of CEN standard methods of measurement and CEN QA/QC procedures, the overall uncertainty of the measurements can be calculated and compared with the Data Quality Objectives specified in the EU Directive. Table 3.9 shows that the UK complies fully with the Directive requirement. The range of uncertainties quoted arises from the slightly different uncertainties associated with the different analysers used within the AURN.

Figure 3.12. All AURN automatic monitoring stations are audited regularly as part of their core quality assurance and control programme.

This involves:

- Performance tests of all analysers on-site
- Verifying calibration gases
- Inter-calibration of the network as a whole
- Monitoring performance of local site operators
- Providing training

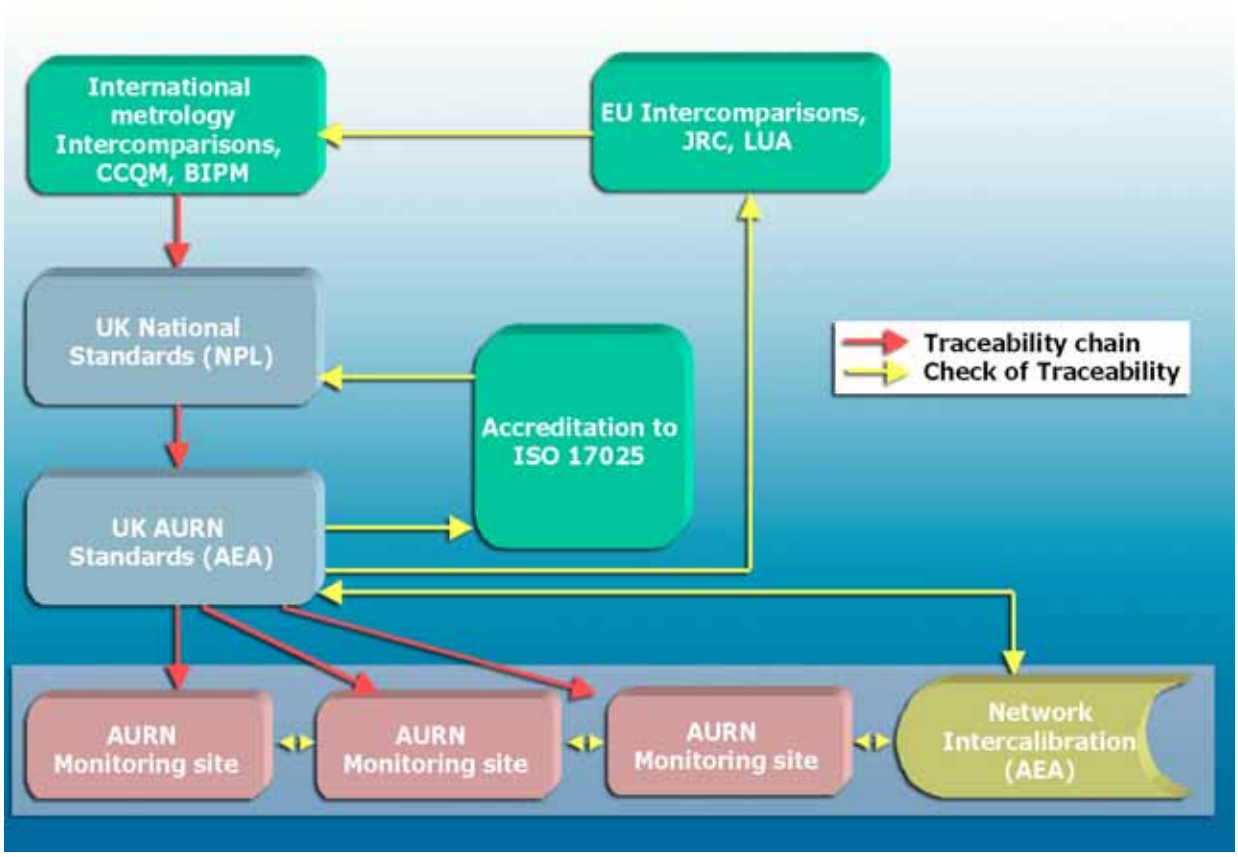


Figure 3.13 Traceability chain and traceability checks for AURN gaseous measurements.

vi) Demonstration of quality assurance and quality control

However, QA/QC is not just about measurement data uncertainty. To fully comply with the Directive, it is necessary to conform to many other requirements: for example, having the correct number of monitoring stations in the correct locations. Table 3.10

summarises the QA/QC activities used in the AURN; however, these are broadly applicable to any network-based air pollution measurement processes.

Table 3.9 Overall uncertainty of measurements within the AURN

	NO_x	CO	SO_2	O_3
AURN Data Uncertainty	10-14%	10-14%	11-13%	9-12%
Directive Requirement	≤15%	≤15%	≤15%	≤15%

vii) QA/QC for the Acid Deposition Network

Chapter 7 of this report discusses the long-running Acid Deposition Network and its achievements to date. Hence, it is appropriate to provide here a brief summary of the QA/QC procedures applied in this network.

The Acid Deposition Network uses a variety of measurement methodologies, but the QA/QC procedures applied follow the same generic principles adopted for other networks. These include:

- Careful selection of appropriate measurement methods
- Careful selection of site location
- Detailed routine operating procedures
- Periodic site audits
- Careful sampling handling protocols
- Sample analysis by accredited methods
- Data checking, validation and ratification
- International intercomparisons.

Much of the monitoring undertaken within the Acid Deposition Network is linked to the UK contribution to EMEP (European Monitoring and Evaluation Programme), which is a scientifically based and policy driven programme under the Convention on Long-Range Transboundary Air Pollution[C5] for international co-operation to solve transboundary air pollution problems.

EMEP has formulated a monitoring strategy[C6], which sets out specific requirements for monitoring sites, parameters to be monitored, monitoring intervals and monitoring methods.

The UK Acid Deposition Network sites and monitoring equipment have been selected to conform with these recommendations, as far as possible. Details of the monitoring equipment selected and validation trials on the equipment used are provided in the network annual reports[C7]. Detailed procedures have been prepared for routine site operation by local site operators and for annual site audits.

Procedures for the annual site audits include:

- General site check, cutting back vegetation etc.
- Equipment integrity check
- Calibration of flow meters
- Leak check
- Ensuring that the local operator knows and understands all routine procedures.

Detailed procedures have also been prepared to cover all laboratory procedures related to sample preparation, chain of custody, dispatch and reception from site and preparation for analysis.

All samples are analysed by methods accredited by the United Kingdom Accreditation Service (UKAS) to provide assurance of analytical quality and consistency.

Table 3.10 Typical Network QA/QC activities for the AURN and similar networks

Quality assurance (of measurement processes)	
Activity	**Function**
Advice on network design, site selection and siting	To ensure the data quality objectives of a network are fulfilled at the design stage
Support in instrument selection and sample system design	To ensure that the equipment used to sample ambient air are fit for purpose
Development of operations manual and monitoring compliance	To ensure that all monitoring stations are operated according to a consistent standard
Operator and personnel training	To ensure that all network participants perform to a consistent standard
Rigorous equipment testing and method development	To ensure the instrument and method is fit for purpose and meets specifications set by CEN
Duplicate measurements	To allow estimation of the uncertainty in the measurement and increase confidence in the result
Sample/instrument conditioning	For consistency between measurements and instruments; to remove the effect of external factors such as weather on the measurement
Routine maintenance and cleaning of equipment	For optimal instrument performance as intended by the manufacturer
Calibration of instruments and standards	To ensure the result is accurate, traceable and thus comparable across Member States
Quality control (of measurement outputs)	
Activity	**Function**
Monitoring routine site visits and operations	To check that calibrations and operations are undertaken according to the prescribed procedures
Monitoring calibration gases and instrument response	To check that the equipment and gases used are performing within acceptable limits
Routine data inspection review and validation	To check daily that the data from analysers are scaled provisionally and are free from any obvious errors
Drift corrections	To improve accuracy of the result by removing variations in instrument sensitivity over time
Data ratification/finalisation before archival	Comprehensive checks every three months to: scale data, identify and remove any spurious information, use the network audit results to confirm satisfactory analyser performance
Quality Assessment	
Activity	**Function**
Regular network audits and site inspections including measurement of sampler flow rates and leak checks	These tests assess the performance of the entire measurement system at a site: the stability of the site calibration cylinders, the performance of the analysers, ability of the Local Site Operators and the safety and general environment around the monitoring station.
UKAS Accreditation	UKAS accreditation to BS EN17025 for the calibration of site gases and the on-site calibration of analysers
Inter-comparisons	To compare the measurement result of different countries, laboratories or analysers when measuring the exact same sample
Recovery and/or testing against certified reference materials	To validate the response of the instrument, and measurement results against a known sample

Rainwater analysis data are checked using an ion balance technique. The rapid analysis of a large number of rainwater samples in which concentrations vary over several orders of magnitude is a complex task. To verify the analytical results, the ion balance, *I* is calculated for each rainwater sample, and any individual samples which fall outside of the defined acceptance criteria are re-analysed.

An important data intercalibration is organised annually by the EMEP Chemical Co-ordinating Centre (CCC) at the Norwegian Institute for Air Research (NILU) in order to assess data quality. Each July, samples are sent to approximately 36 analytical laboratories in Europe, and approximately 25 additional internationally recognised analytical laboratories. The intercomparison exercise is required as part of the EMEP monitoring programme; such a fundamental check on analytical performance is essential if response to emission reductions is to be observed consistently throughout Europe. Year 2008 was the 26th such intercomparison in which the UK participated. The samples provided by the CCC for this intercomparison included nitrogen dioxide in absorbing solution and synthetic rainwater samples.

Following a previous intercomparison, a comprehensive series of method updates had been instigated in the UK. In this latest intercomparison, these updated methods were tested. The results showed that, though the agreement for sulphate was not as good as previously, the agreement for nitrate, ammonia, magnesium, sodium, chloride, potassium and pH was the same or better than that found for previous samples.

These procedures and intercomparisons demonstrate that the Acid Deposition Network provides robust and reliable measurement data.

ix) Local authority NO_2 diffusion tube monitoring

Despite the closure in 2005 of the national diffusion tube monitoring network, many UK Local Authorities continue to use diffusion tubes as a cost-effective and convenient way of monitoring ambient concentrations of NO_2. These are 'passive' samplers, which work by absorbing the pollutants directly from the surrounding air and therefore need no power supply. The type of NO_2 diffusion tube most commonly used in the UK is the Palmes-type sampler [C8], shown in Figure 3.14: this consists of a small plastic tube, approximately 7 cm long. During sampling, one end is open and the other closed. The closed end contains an absorbent for the gaseous species to be monitored, in this case NO_2.

Figure 3.14. Diffusion Tubes

Tubes are mounted vertically at the measurement site (for example, fixed to a lamp post or other street furniture) with the open end at the bottom. Ambient NO_2 in the atmosphere diffuses up the tube during exposure, and is chemically absorbed as nitrite.

After the exposure period - typically several weeks or a month- the tube is removed for analysis. The average ambient pollutant concentration for the exposure period is easily calculated from the amount of pollutant absorbed.

Diffusion tubes are available for a wide range of pollutants (see Figure 3.14 opposite), but those most commonly used in the UK in the context of Local Air Quality Management (LAQM) are for nitrogen dioxide (NO_2).

A typical deployment method for diffusion tubes is illustrated in Fig. 3.15 below.

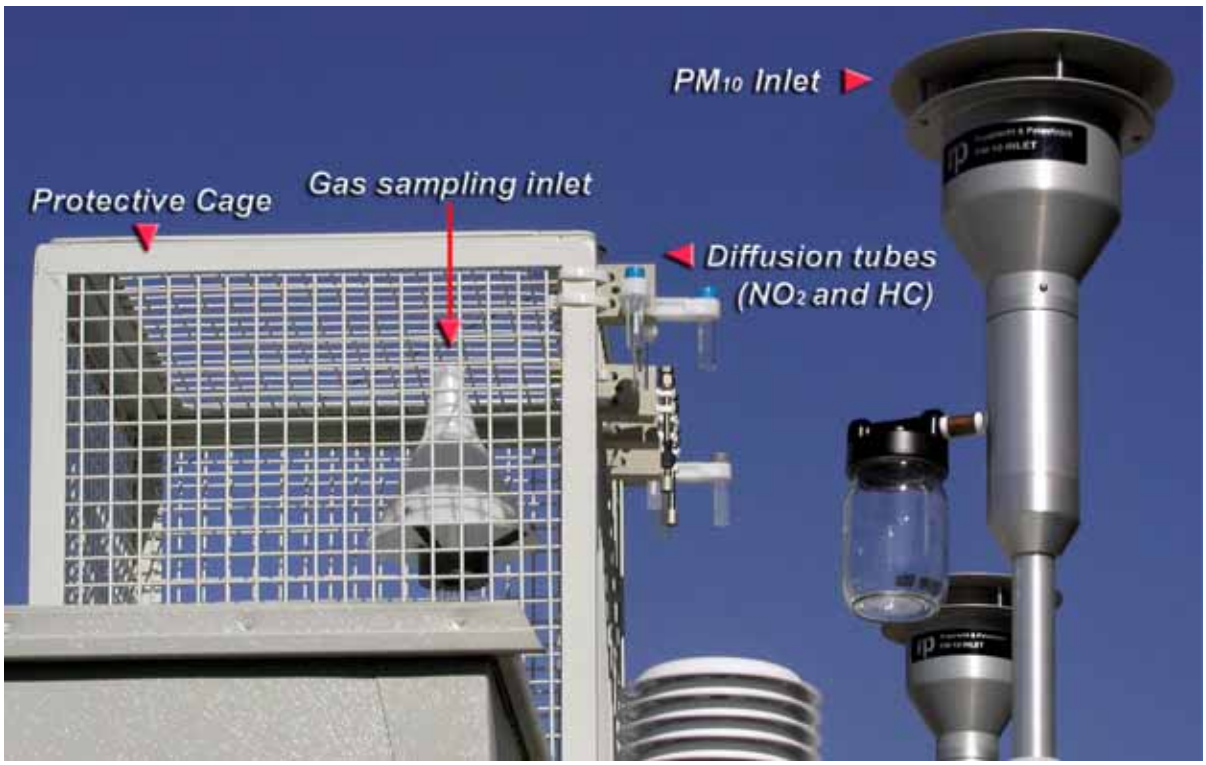


Figure 3.15 Typical deployment of diffusion tubes (NO_2 and BTX) on the rooftop of an automatic air monitoring station- *(photo by Jaume Targa)*

Diffusion tubes are an indicative measurement method: they do not provide the same level of precision and accuracy as automatic monitoring methods; for example, the accuracy of diffusion tube measurements is typically recognised as ~ ±25%. Nor can they be used for short-term (hourly or daily) measurements. However, they are a useful, low-cost supplement to more expensive and sophisticated automatic methods. Often, indicative sampler-based methods such as diffusion tubes can be used where it is not practical to install an automatic analyser. NO_2 diffusion tubes have therefore become a widely used tool in Local Air Quality Management throughout the UK.

Accordingly, since the closure in 2005 of the former national NO_2 Diffusion Tube Network, Defra and the Devolved Administrations have continued to provide a range of support services to Local Authorities using diffusion tubes, as part of the overall contract 'Support to Local Authorities for Air Quality Management'; this also includes the Air Quality Monitoring and Modelling Helpdesks, discussed further in Section 9.

These support services include:

- QA/QC support for laboratories supplying and analysing NO_2 diffusion tubes
- Information and guidance to the Local Authorities using them.
- A web-based central NO_2 diffusion tube data collation system - a convenient way for Local Authorities to store and share their diffusion tube data.
- Operation of a Working Group aimed at harmonisation of diffusion tube methods for NO_2. This completed its work in 2007, and produced in 2008 a comprehensive practical guidance manual[C9] detailing harmonised methods for diffusion tube preparation, deployment and analysis, available from http://www.airquality.co.uk/archive/reports/cat05/0802141004_NO2_WG_PracticalGuidance_Issue1a.pdf.

Further details of the overall national support project for diffusion tube users can be found at http://www.laqmsupport.org.uk

3.6 Particle concentration measurements

History

The AURN (then the Enhanced Urban Network) first began measuring the PM_{10} fraction of ambient particulate matter in 1993, as part of an expansion of the UK's pollution monitoring. At that time, the instrument selected for measurement of this parameter was the Tapered Element Oscillating Microbalance (TEOM). This instrument was chosen because it is able to provide continuous, automatic, on-line monitoring of ambient PM_{10} with an averaging time of 15 minutes. This enables the UK monitoring networks to provide near real-time data that can be used to forecast and provide rapid alerts of elevated levels of this important air pollutant.

However, one salient technical feature of the TEOM instrument is that the sample inlet is heated to 50°C in order to minimise the effects of water vapour within the sampled ambient air stream. Since its introduction to the network, the TEOM instrument has undergone much scrutiny because of this procedure. Research has concluded that, in addition to water vapour being lost, volatile and semi-volatile aerosol components are also lost by evaporation in the heated inlet. If not corrected, this would cause the TEOM to underestimate the actual ambient PM_{10} concentration.

In addition, alternative automatic PM_{10} measurement methods, using techniques such as beta attenuation and light or laser scattering, have become available from a variety of manufacturers. With an increasing number of different techniques and instruments available, a method for demonstrating equivalence was required. Accordingly, the European Union tasked the CEN technical committee TC264 to develop a standard for the measurement of particulate matter, both PM_{10} and $PM_{2.5}$, in ambient atmospheres.

Figure 3.16. PM_{10} sampling inlet of the TEOM at Port Talbot, steelworks in the background (© Jon Bower, Apexphotos 2009)

EU reference methods

The CEN working group tasked with the development of the standards produced:

- ***EN12341:1998 Air quality*** - Determination of the PM_{10} fraction of suspended particulate matter. Reference method and field test procedure to demonstrate reference equivalence of measurement methods [C10]

and

- ***EN14907 Ambient air quality*** – *Standard gravimetric measurement method for determination of the $PM_{2.5}$ mass fraction of suspended particulate matter*[C11].

These reference methods for measuring ambient concentrations of PM_{10} and $PM_{2.5}$ are gravimetric techniques. They are based on sampling ambient air through a filter, at a controlled flow rate for 24 hours. The filter is weighed prior to sampling and again following sampling. The mass difference between the two weighings is deemed to be attributable to the particulate accumulated on the filter during sampling. A mean particle concentration is then calculated, from the volume of air sampled and the mass of particulate collected. In order to eliminate effects of temperature and humidity on the weighing process, a method of filter conditioning has been introduced. The filter conditioning criteria state that the filter media should be stored in an atmosphere at 20°C and 50% relative humidity for set periods prior to weighing.

However, from the point of view of the AURN, these reference methods have the significant disadvantage that exposure data are not available for many days (or weeks) after the filters are exposed. They cannot, therefore, provide near real-time data in the same way as – for example – the TEOM or the beta attenuation monitor (BAM). Much interest has therefore focussed on whether the results from such samplers were equivalent to those of the CEN reference method.

Equivalence programme

Many studies have been undertaken to investigate whether the results from alternative, automatic methods of PM monitoring can be made equivalent to the CEN reference methods. In 2005, an extensive international equivalence study was undertaken. It showed that:

1. The TEOM FDMS – Type B (a TEOM with a retrofit modification intended to overcome the problem of the heated inlet causing loss of the volatile component) met equivalence for both PM_{10} and $PM_{2.5}$
2. For PM_{10}, two types of Met One BAM, the OPSIS SM200, and one daily gravimetric sampler (the R&P Partisol) were equivalent.
3. The TEOM FDMS, the OPSIS SM200 (beta) and the Partisol required no correction to be applied to the data.
4. However, the Met One BAM and the OPSIS SM200 (mass) required correction factors to be applied to the data.
5. The unmodified TEOM – as widely used in the AURN and by UK Local Authorities - failed the equivalence criteria. For this reason, it is now widely accepted that historic automatic PM_{10} data does not accurately reflect gravimetric PM_{10} exposure in the UK.

The results of this study are summarised in Table 3.11.

During 2008, there has been an extensive upgrading process throughout the AURN to:

1. Convert TEOM PM_{10} monitors to EU equivalent automatic methods and
2. Install $PM_{2.5}$ EU equivalent automatic methods to satisfy the new requirements to monitor this pollutant.

Table 3.11 Summary of UK PM Equivalence Tests 2005

Instrument	Outcome of Test
TEOM (PM_{10})	Fails the equivalence criteria
FDMS "Model B" (PM_{10})	Meets the equivalence criteria
FDMS "Model B" ($PM_{2.5}$)	Meets the equivalence criteria
Partisol 2025 (PM_{10})	Meets the equivalence criteria
OPSIS SM200 (PM_{10})	Beta - Meets the equivalence criteria Mass – Meets the equivalence criteria with correction for slope and intercept
Met-One BAM (unheated) (PM_{10})	Meets the equivalence criteria with correction for slope

Notes:
1) The "Model B" FDMS instrument has been superseded by the "Model C", and is no longer commercially available. The "Model C" instrument is currently undergoing further equivalence tests.
2) The Partisol 2025 was operated with Teflon coated glass-fibre filters

In addition, in 2008, two further assessments of PM analyser performance commenced. Firstly, an EC-led programme of instrument inter-comparison was undertaken at Port Talbot, South Wales (Figure 3.16), where ambient PM_{10} and $PM_{2.5}$ data reported by the national network were compared against reference method measurements made at the site by the European Reference Laboratory. This was a snapshot study and was not conducted under a full equivalence methodology.

Figure 3.17. European particulate measurement intercomparison underway at Port Talbot in 2008. Image by Brian Stacey

In addition, an Environment Agency-led programme of assessment was initiated to measure the performance of a range of monitoring equipment against PM_{10} and $PM_{2.5}$ reference samplers.

Finally, parallel monitoring of PM_{10} and $PM_{2.5}$ with both EU equivalent automatic monitors and gravimetric daily samplers will in future be undertaken at six sites with the UK. This will provide an on-going long-term check on the equivalence of the automatic methods selected for the network.

The King's College London Volatile Correction Model

While the UK equivalence trial of 2005 was underway, King's College London undertook a research programme to identify links between data from the older TEOM instruments and the newer (modified) TEOM FDMS instrument. If a relationship could be identified between the measurements from the older TEOM and the newer (reference equivalent) instrument, then data from the older instruments could be corrected to reference equivalent. Given the prevalence of the older instrument in the UK at the time, such a relationship would prove useful.

The relationship was established and has been proven to be effective. TEOM data can be corrected for the loss of the volatile component using data from a nearby TEOM FDMS. The relationship holds true provided the TEOM and TEOM FDMS are within 130 km of each other, which means that data from old-style TEOMS across much of the UK, from 2007 onwards, can now be reliably corrected to gravimetric equivalent.

This correction has now been released as a web-based tool referred to as the Volatile Correction Model (VCM). A series of screens (Figure 3.18) helps the user select the various parameters required in order to undertake the correction. Once these steps have been completed, a spreadsheet is produced for the user to paste their TEOM data into; the corrected data are then presented in a separate worksheet.

Defra has given its approval for Local Authorities to use the VCM for Local Air Quality Management purposes, to correct data from older TEOM instruments which do not meet the equivalence criteria.

Figure 3.18 The King's College London Volatile Correction Model web portal

4 High pollution episodes

Why do pollution episodes happen? By examining periods during 2008 when pollution levels were particularly high, either locally or UK-wide, we can identify their causes and assess potential impacts.

4.1 Causes and types of air pollution episode

Air pollution levels can vary considerably from day to day, as well as from one part of the country to another. In this section, we'll look at short-term variations over time, and in particular some recent periods when pollution levels were particularly high. These are usually referred to as ***episodes***.

Pollution levels can vary significantly over time; these variations are driven by:

1) Changing pollutant emissions
2) Changes in atmospheric conditions that either -
   - Allow pollution levels to build up
   - Lead to the transport of pollutants from other areas or
   - Encourage their formation through chemical reactions

All episodes occur because of a combination of these factors.

There are two major types of seasonal pollution event in the UK - winter and summer episodes. ***Winter Episodes*** typically occur in cold, still and foggy weather; this traps pollution produced by motor vehicles, space heating and other sources close to the ground and allows it to build up over time. City areas - in particular those close to major roads - are usually worst affected, together with sheltered or low-lying parts of the country. Winter episodes are usually characterised by elevated levels of nitrogen dioxide (NO_2), particles (PM_{10}) and volatile organic compounds (VOCs) such as benzene. High sulphur dioxide levels can also occur in some industrial or coal-burning regions.

Winter smogs seem to have been becoming increasingly infrequent over recent mild UK winters. This trend continued in 2008, with no substantial winter episode reported.

Summer episodes occur in hot and sunny weather. Sunlight and high temperatures accelerate photochemical reactions in mixtures of air pollutants that are emitted from road vehicles, fuel burning and solvent usage. The pollutants that cause such an episode can often travel long distances - sometimes from other parts of Europe. During this large-scale air movement, they react together to produce high levels of ozone (O_3), together with other pollutants such as nitrogen dioxide and fine particles. Unlike the ozone layer in the upper levels of the atmosphere that protects us from ultraviolet radiation, ground level ozone produced in this way is harmful both to human health and vegetation, as well as damaging some man-made materials.

As is the case for winter episodes, summer smogs have been relatively infrequent over recent years, primarily due to the absence of prolonged 'heat wave' conditions.

Another important type of pollution episode can be caused by ***long-range transport*** of pollutants from Europe, or occasionally from North Africa or North America. This tends to occur during the summer months, either in isolation or in combination with summer smog. Local transport episodes involving elevated levels of primary (directly emitted) pollutants may also occur in the proximity of busy roads or large industrial plant.

Air pollution episodes in the UK vary widely in terms of the size and location of the areas they affect, as well as their duration and seriousness. Episode numbers can also vary markedly from year to year, as we have seen throughout this series of annual reports.

In this section, we review the most significant UK air pollution events during 2008. We examine some photochemical episodes occurring in June and July and take the opportunity to review the frequency of this type of episode over recent years. We also analyse an interesting particle episode in January, during which elevated PM_{10} and $PM_{2.5}$ levels were observed throughout southern parts of the UK, due primarily to the transport of very large quantities of dust from the Sahara.

This is the first episode of its type for which $PM_{2.5}$ measurements - quantifying very fine particulate matter with aerodynamic diameters below 2.5 microns - have been available nationally, together with some limited laser-based measurements of a range of particle size fractions.

4.2 A particle episode involving long-range transport: 23- 24th January 2008

As noted in the previous section, long-range transport of pollutants from outside the country can, on occasions, affect parts of the UK. Here we examine one such incident.

The measurements

Over the period from Wednesday 23rd to Thursday 24th January, eight sites in the UK Automatic Urban and Rural monitoring network (AURN) measured levels of PM_{10} particulate matter at air pollution index 7 (HIGH) or above, and two of these sites also went on to record VERY HIGH pollution at index 10. Over the same period, an additional eighteen monitoring sites recorded MODERATE PM_{10} air pollution at index 4 to 6.

A time series plot of hourly averaged gravimetric equivalent measurements made at selected sites nationwide is shown in Figure 4.1 below.

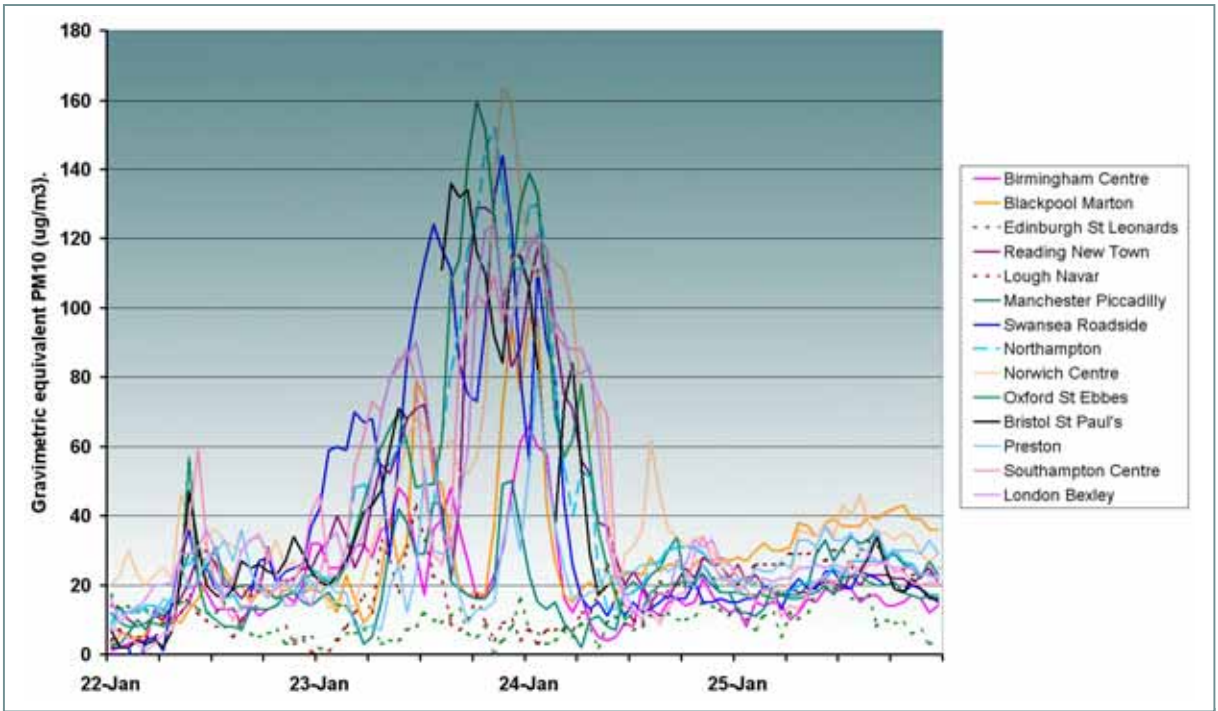


Figure 4.1 Hourly mean PM_{10} measurements at selected sites in the UK from January 22nd to 25th 2008

Of the eight sites measuring PM_{10} at index 7 or above, three were located in London, two in the South East and three in South Wales. In additional to three roadside sites reaching the HIGH band, index 7 or above was measured at one remote site in Wales, one urban centre and one rural site in the south of England and an urban centre site in London. At sites affected by this episode, PM_{10} levels were typically 3 times higher than 'normal' background concentrations.

The increase in particle levels was first detected along the south coast of England during the early hours of Wednesday 23rd. During the course of the day, the band of increased pollution then moved northwards across the UK. No significant increase in airborne particulate matter was recorded across Scotland or Northern Ireland over the duration of the episode, the most northerly site measuring a MODERATE band exceedence being located in Norwich.

Figure 4.2 below shows the provisional $PM_{2.5}$ and PM_{10} hourly averaged measurements made at the Harwell AURN site over the period 21st to 25th January in gravimetric equivalent units. The high PM_{10} to $PM_{2.5}$ ratio clearly shows the major contribution to the episode was from predominantly coarse fractions- i.e. large diameter particles.

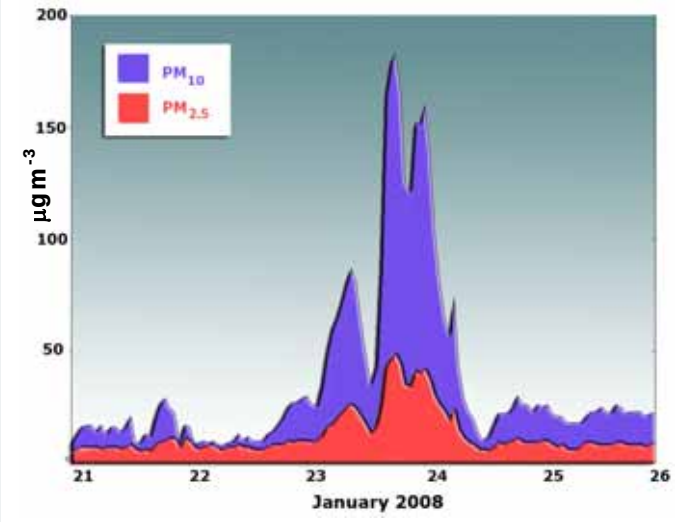


Figure 4.2 Provisional PM_{10} and $PM_{2.5}$ particle measurements ($\mu g m^{-3}$) taken at Harwell AURN site during this episode

These interesting measurements were supplemented by size-fractionated particle data from an optical laser 'Osiris' instrument deployed at the Slough Colnbrook (non-AURN) site.

The instrument's measurement range is from 0.5 to 20 microns particle diameter; it can monitor PM_1, $PM_{2.5}$, PM_{10} and total suspended particulates (where TSP = PM_1 to PM_{20}) simultaneously.

A range of research studies [D1, D2] have demonstrated typical measured PM fine/coarse ratios at varying distances of travel over the North Atlantic as follows*:

Saharan dust at source (no travel)	**0.11**
Saharan dust after 2k km of travel	**0.13**
Saharan dust after 5k km of travel	**0.38**

** where PM_{fine} = $PM_{2.5}$ and PM_{coarse} = PM_{10} - $PM_{2.5}$.*

Hourly averaged PM_{fine}/PM_{coarse} ratios were plotted using data from the Osiris instrument ; these are shown in Figure 4.3 overleaf.

This figure shows the very marked change of particle composition during the episode. The measured particle fraction ratios entered the range consistent with long-range transport of dust in the morning of the 23rd, and remained within the band of expected ratios until the end of the episode in the late morning of the 24th. By examining the modelled air-mass trajectory path from North East Africa to the UK, the actual distance of travel for the Saharan dust reaching the UK on January 23rd was estimated to have been in the range of 3500-5000 km. After the episode had ended, the ratios measured returned to those typical of an urban environment.

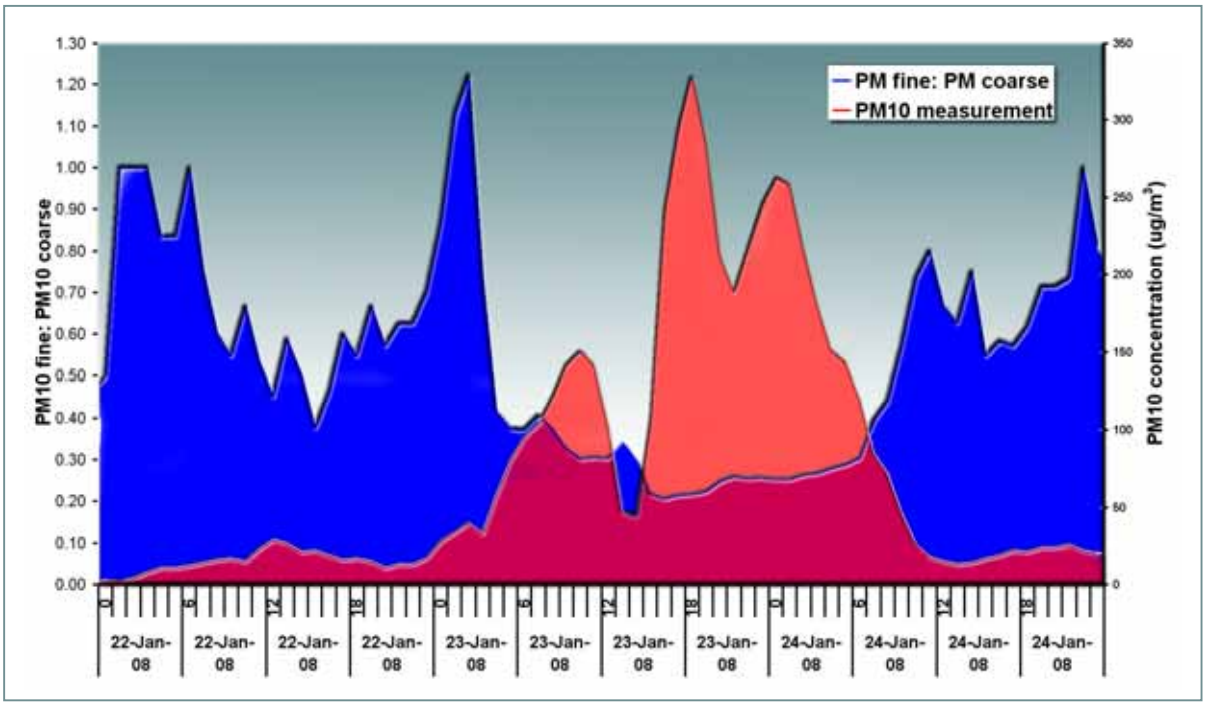


Figure 4.3 Particle size fraction ratios derived using measurements from the laser optical Osiris instrument at Slough Colnbrook.

Measurements made by the FDMS TEOM instrument (please see Section 3) at Reading New Town in the south east of England show that the volatile fraction associated with the episodic particulates arriving in the UK was very low, which is consistent with the air having passed over no significant areas of pollution.

Causes of the episode

As we have seen from the previous section, measurements of particle composition - in particular fine/coarse ratios – during the episode were consistent with long-range transport of Saharan dust from West Africa. Other measurements of volatile fractions suggested transport of the dust over relatively unpolluted areas.

A variety of other analyses were also indicative of these episode characteristics. For example, 96-hour air mass back-trajectory data illustrate that the air arriving in Southern England and Wales on the 23rd January had originated from the west coast of Africa and had traveled exclusively over the Atlantic, as shown in Figure 4.4. At the same time, however, northern parts of the country experienced clean westerly airflow. By contrast, corresponding airmass trajectories after the episode had ended were exclusively westerly- the January 25th trajectory in Figure 4.5.

Two hypotheses were initially considered for the episode causation:

1) Sandstorms across Africa
2) Smoke from forest fires in Africa

Dust from sandstorms in western Africa had been observed by MODIS (Moderate Resolution Imaging Spectroradiometer, housed onboard a NASA satellite) on the 20th January, as shown in Figure 4.6.

At the same time, however, extensive fires were observed, again by MODIS, on the 21st January in the area of Guinea and the Ivory Coast, as shown in Figure 4.7. These fires were thought to have been likely the result of agricultural burnoff during the dry season.

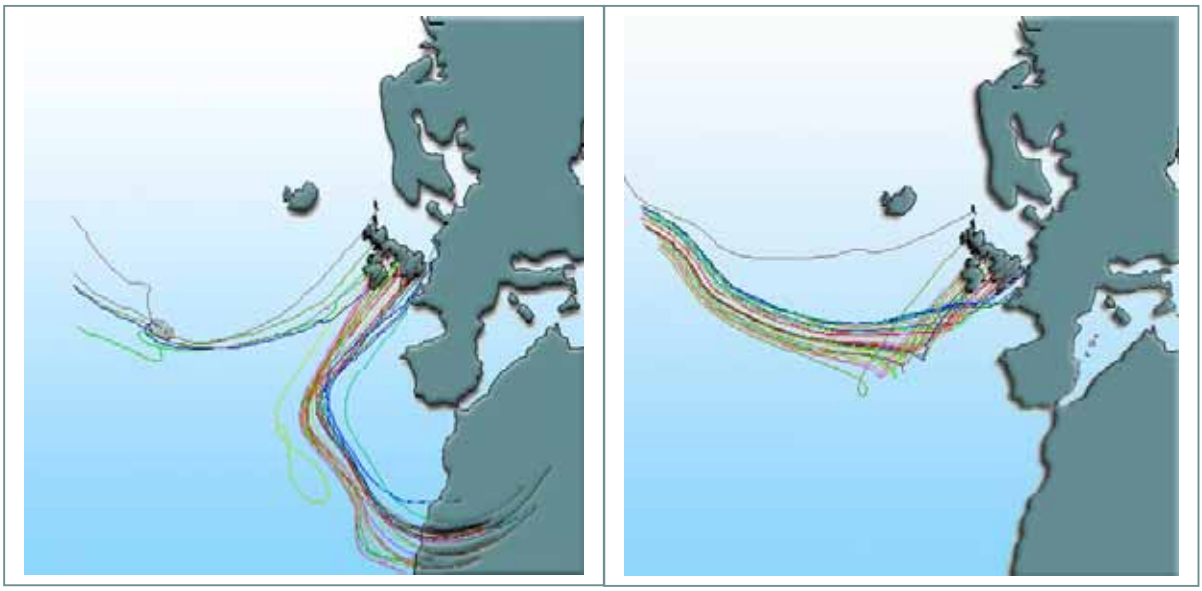


Figure 4.4 (left) airmass back trajectories on 23rd January, start of episode
Figure 4.5 (right) back trajectories after the episode, 25th January

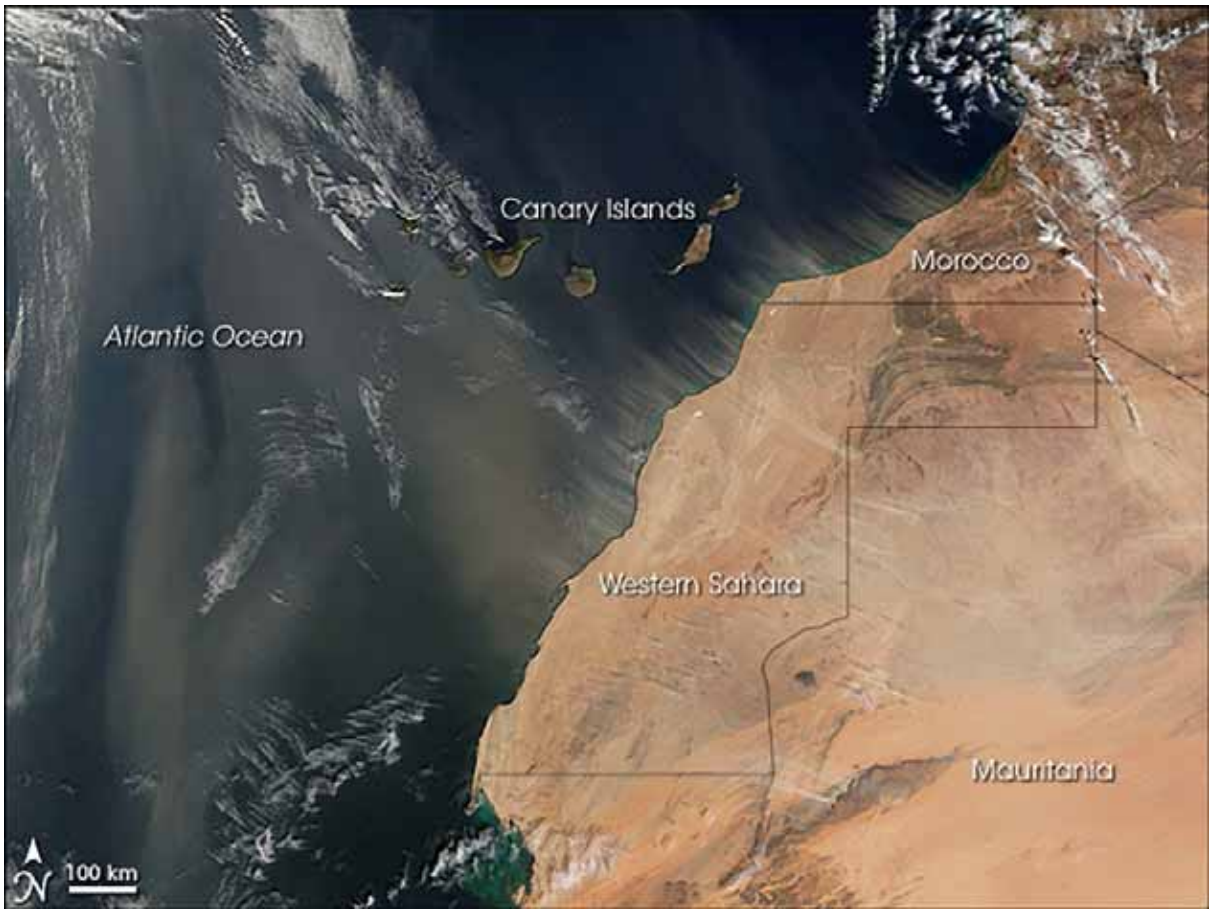


Figure 4.6 Satellite image of large clouds of particles over the Atlantic Ocean on 20th January, with more issuing from the Western Sahara.

Figure 4.8 overleaf shows the relative global positions of these two concurrent events.

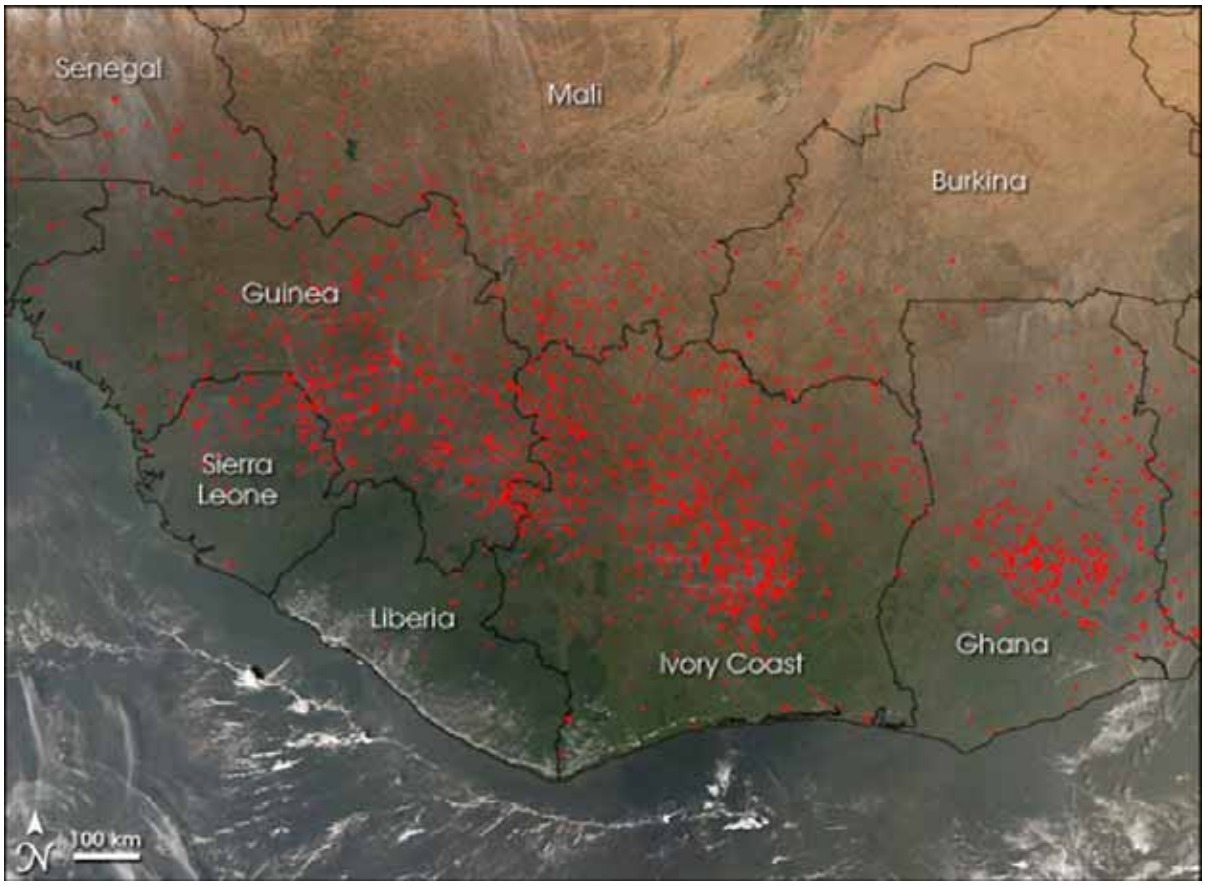


Figure 4.7 Satellite image of biomass fires in W Africa on 21st January

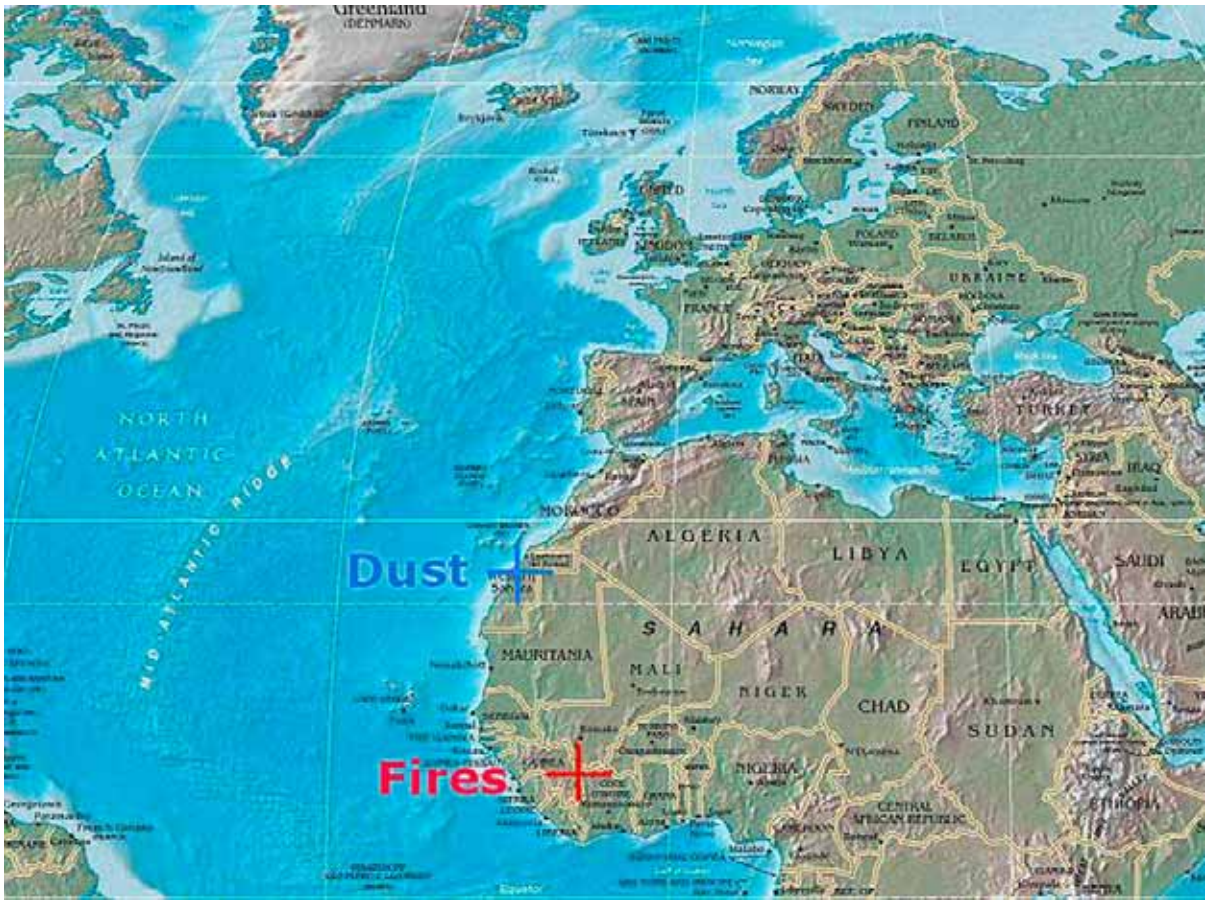


Figure 4.8 Relative global positions of Saharan dust storm and biomass fires

The Met Office NAME atmospheric dispersion model was run over the episode period. Figure 4.9 shows the modelled dust concentration in the air both arriving and over the UK and Europe over the period 1200 UTC on the 23rd January. An independent Skiron Dust Forecast and model issued daily by the University of Athens shows very similar predictions during this period (Figure 4.10).

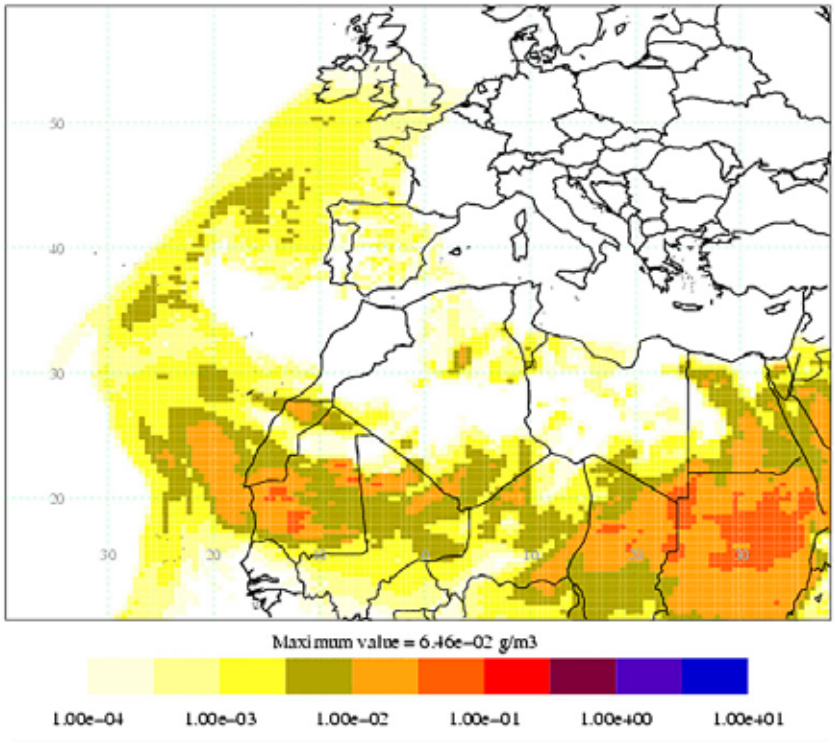


Figure 4.9 Modelled particle concentrations 23rd January (NAME) - courtesy Met Office

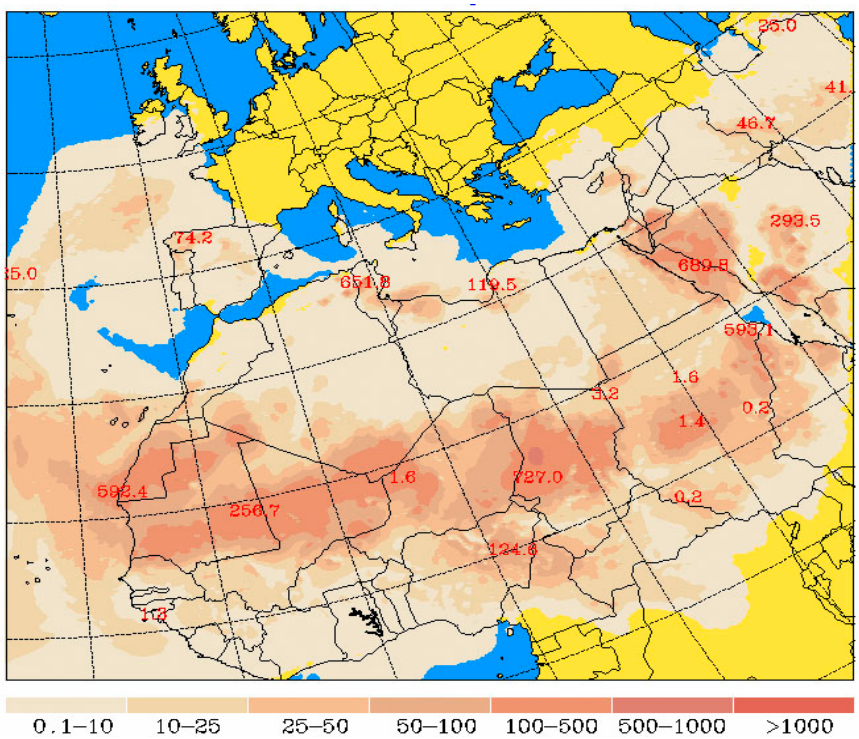


Figure 4.10 Modelled particle concentrations 23rd January (Skiron) - courtesy University of Athens

Both these models also show significant particle impacts over other parts of Europe, an observation which was subsequently confirmed.

In fact, the entire episode proved to be trackable by satellite; for reasons of space, this cannot be done here. Detailed day-by-day analyses are, however, available elsewhere [D3.]

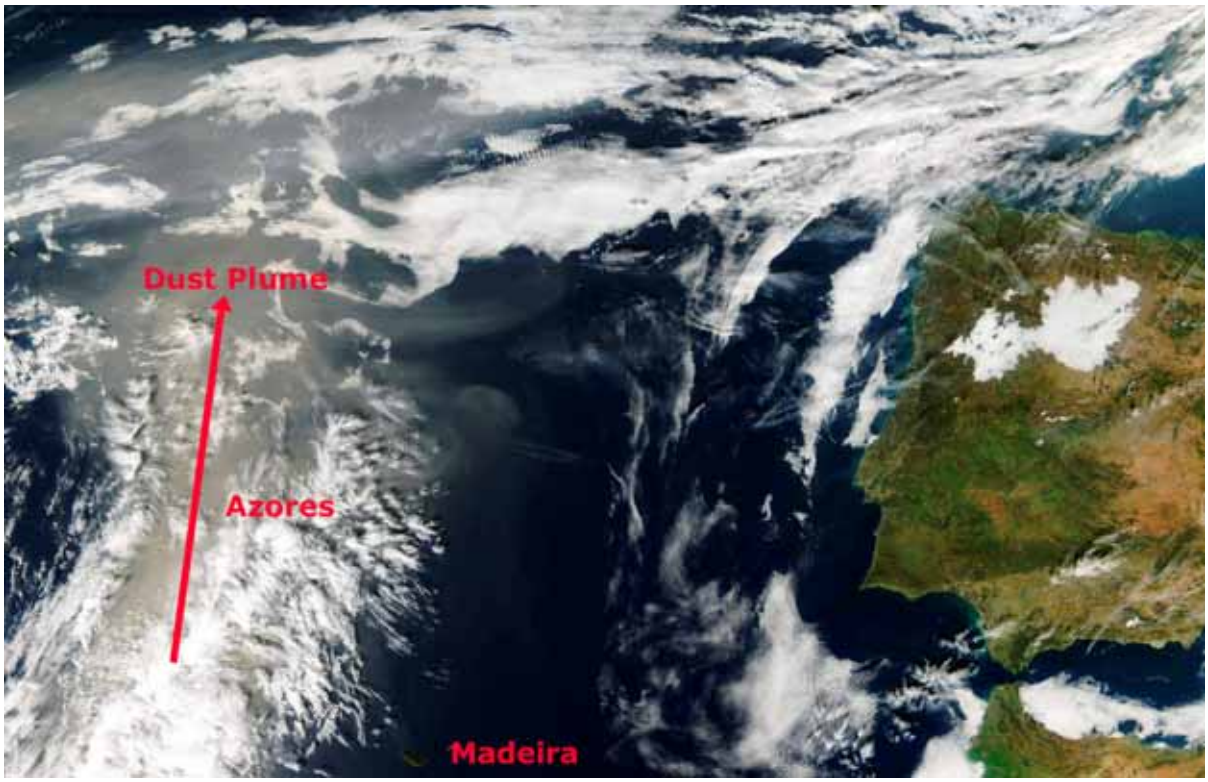


Figure 4.11 High resolution satellite image of dust plumes in transit over the Atlantic, to the west of the Iberian Peninsula, on 21st January

Satellite imagery of this episode is provided in Figure 4.11. The main features of the January 2008 particulate episode may be summarised as follows:

- Dust which had blown from the Western Sahara desert was transported over the Atlantic, and eventually reached the UK on air currents between the 23rd and 24th January 2008; this caused MODERATE or HIGH levels of PM_{10} to be measured at many sites across the south of England and South Wales.

- Scotland and Northern Ireland were not significantly affected by the episode, due to the position of a cold front associated with an area of low pressure air which had spread over the UK from the north-west.

- Following the two-day episode in the UK, much of continental Europe received the dust laden air stream and recorded elevated particle levels.

Long-range transport of Saharan dust is an important and recurring atmospheric phenomenon. Extreme summer daytime heating in the Sahara Desert causes instability in the lowest levels of the atmosphere. Dust-laden air rises and begins moving westward. As the dust-laden airmass travels - often over several days - it continues heating. When this Saharan Air Layer moves off the African coast and over the Atlantic Ocean, it is often undercut by cooler, wetter layers of air. Air normally cools with altitude, but the hot Saharan Air Layer passing over cooler air currents causes a temperature inversion, which suppresses further mixing and dispersion of the polluted air.

As a result, Saharan dust can often travel long distances across the Atlantic. As in this particular episode, it may swing eastwards to cause impacts over the UK or Europe. However, it may also be carried by prevailing easterly airflow across the Atlantic to the Americas (Figure 4.12).

In general, Saharan dust is very much a mixed blessing in the Western Hemisphere. Impacts over Europe or America can add to overall particle burdens in the atmosphere, causing respiratory illness and soiling. In some tropical or Caribbean areas, it may even damage ecosystems and bleach or damage coral. Yet this large-scale atmospheric phenomenon also brings valuable soil to Caribbean islands and the Amazon Rainforest.

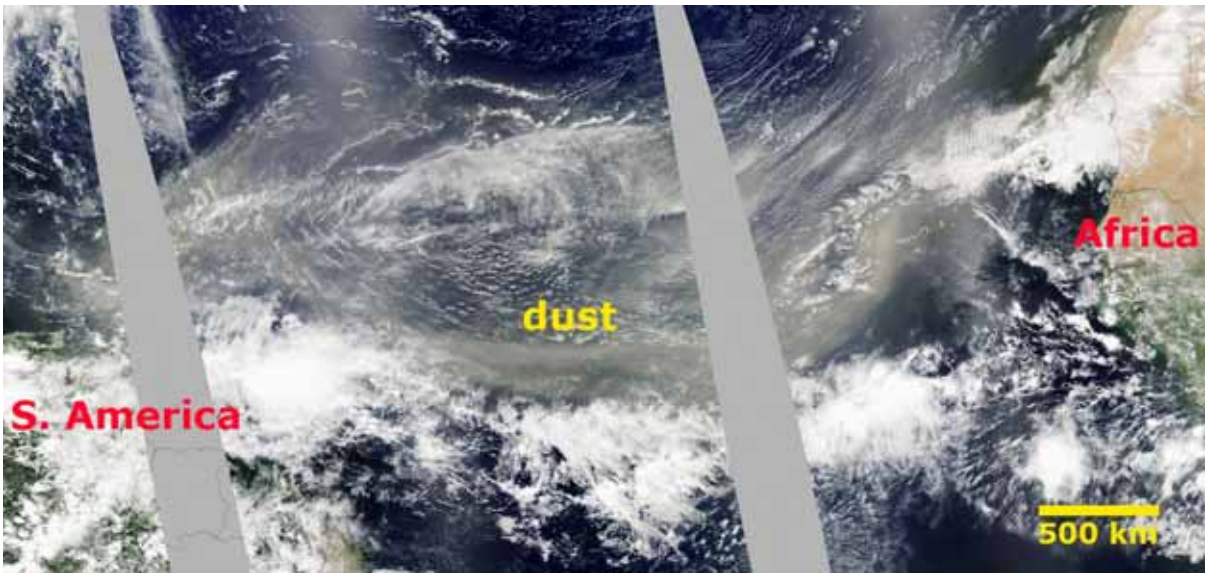


Figure 4.12 High resolution satellite image of dust plumes in transit over the Atlantic to South America and the Caribbean (June 27th, 2009)

4.3 Summer photochemical episodes in 2008

The UK can often experience periods of elevated ozone pollution during late spring and the summer months. This is because the formation of ozone, through the photochemical reaction of volatile organic compounds in the presence of oxides of nitrogen, is dependent on sunshine and high temperatures.

During 2008, there were 79 sites monitoring ozone in the Automatic Urban and Rural Network, providing comprehensive coverage of conditions in a wide variety of location types throughout the country. There were no periods of significant data loss during the year, and average data capture was 95.6% for May to July 2008.

MODERATE (index 4 to index 6) levels of air pollution were measured across the Automatic Urban and Rural Network (AURN) during May and July 2008. During these periods, HIGH ozone levels were also measured at one location, Hull Freetown. Compared to hourly measurements made since 1973, however, the peak ozone levels measured at the AURN network during the two episodes in May and July 2008 are relatively low.

The two episodes are, however, of interest due to their differing causation. The May episode was primarily influenced by air transported from Continental Europe; by way of contrast, the July episode was of UK origin, resulting from a combination of high spring and summer temperatures and still air throughout the UK. Both episodes were accompanied by elevated levels of particulate matter at some sites, probably with a significant component of secondary aerosols due to the weather conditions. We will now examine the May and July episodes in greater detail.

Episode 1 6th – 12th May 2008

May 2008 was uncharacteristically warm, with temperatures in England on average 2.4^{o}C higher than normal. The month was also approximately 5% sunnier than normal (Box 4.2). Globally, May 2008 was the eighth warmest on record. Temperatures in Europe were up to 3^{o}C higher than average, with the exception only of Spain and Portugal. Similarly, much of Europe experienced above average temperatures in July, and globally this month was the fifth warmest July since records began.

HIGH ozone levels were recorded at Hull Freetown, on two days in May. The highest hourly average was 194 μg m^{-3} (index 7). During this period, 75 sites recorded MODERATE ozone (100 μg m^{-3} and above); 41 of these reached index 6 on one or more days. Sites in Scotland, England, Wales and Northern Ireland were all affected

During the 2008 ozone pollution episodes a number of new map-based data reporting systems were operational for the first time - see Section 9. Figure 4.13 shows UK-wide ozone levels on 11 May, using the Google Earth mapping feature of www.airquality.co.uk, whilst Figure 4.14 shows the corresponding Europe-wide ozone levels using the European Environment Agency's live online reporting service at www.eea.europa.eu/maps/ozone.

Until the 6th May, airmass trajectories show relatively clean air being brought into the UK from the Atlantic. From the 6th May, however, the air circulating over Europe, combined with high temperatures, was the cause of the ozone episode. The characteristic continental airflow over UK during this period is clearly shown in Figure 4.15; the close tracking between pollution levels and temperature is clearly shown in Figure 4.16.

Using a comprehensive range of meteorological, airmass tracking, dispersion models and expert analysis, air quality forecasting undertaken by AEA successfully predicted the episode several days in advance, and a warning- the first of the year- was issued on 9th May (Box 4.1).

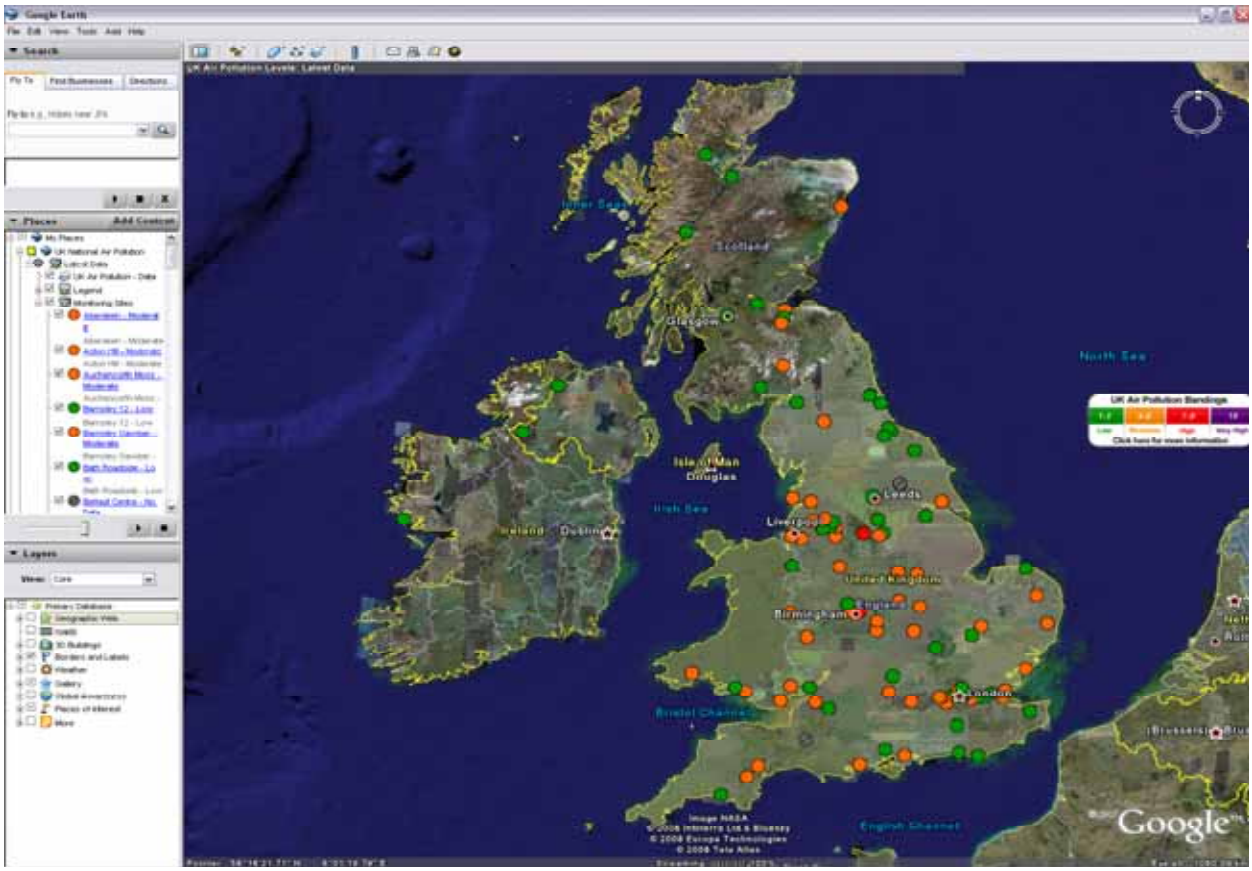


Figure 4.13 Google Earth map of ozone levels, 10th May (www.airquality.co.uk)

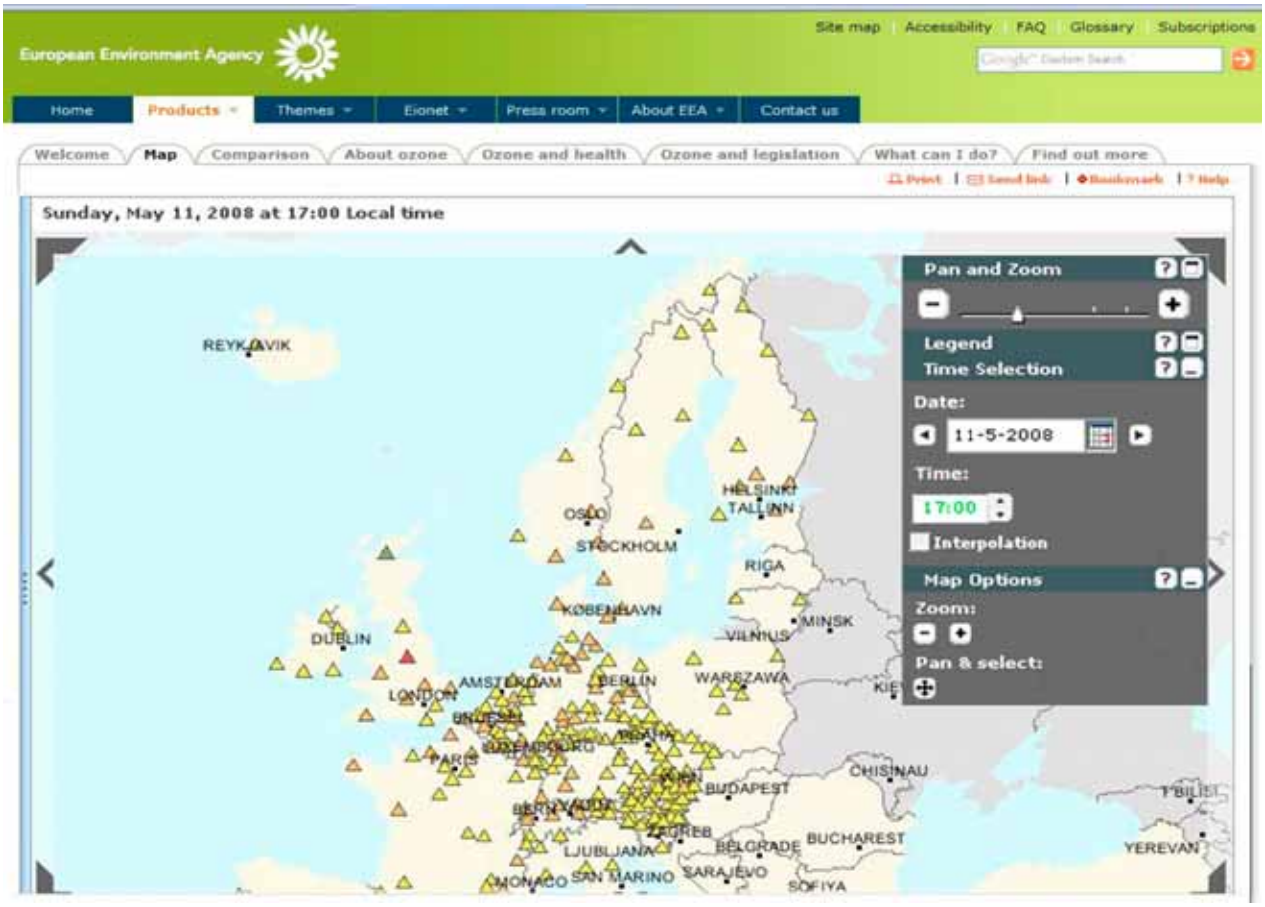


Figure 4.14 European ozone levels, 11 May (www.eea.europa.eu/maps/ozone)

Box 4.1 Air quality forecasting email on 9th May

From: Jaume Targa, AEA
To: Air Quality Forecast Recipients
Subject: HIGH episode - Air Pollution Forecast Friday 9th to Monday May 12th

09/05/2008 09:56

Dear Colleagues,

The first HIGH ozone episode is likely to be today and continue over the weekend!

The High-pressure system over Denmark is bringing sunny and warm weather over England and Scotland. Maximum temperatures are likely to reach 26 degrees over the South East, 22-23 degrees over the Midlands and 21 degrees over Scotland. This is likely to continue until Monday.

During the past 2-3 days, we have been experiencing moderate (index 5-6) levels across the UK. As weather conditions remain stable and become warmer, we are likely to be reaching HIGH levels (index 7) of air pollution due to ground level ozone.

Air mass back trajectories re-circulating over the continent will be approaching the UK, bringing less clean air with PM, NO_2 and ozone precursors. This coupled with UK own emissions; warmer temperatures and long hours of sunshine will result in the first High ozone episode in the UK.

The likely areas affected over today and the weekend are:

Friday - High levels over England and south Scotland (Index 7)
Saturday - High levels over England and Wales (less likely over Scotland) (Index 7)
Sunday - High levels over England and Wales (Index 7)
Monday - High levels over England, Wales and Northern Ireland (Index 7)

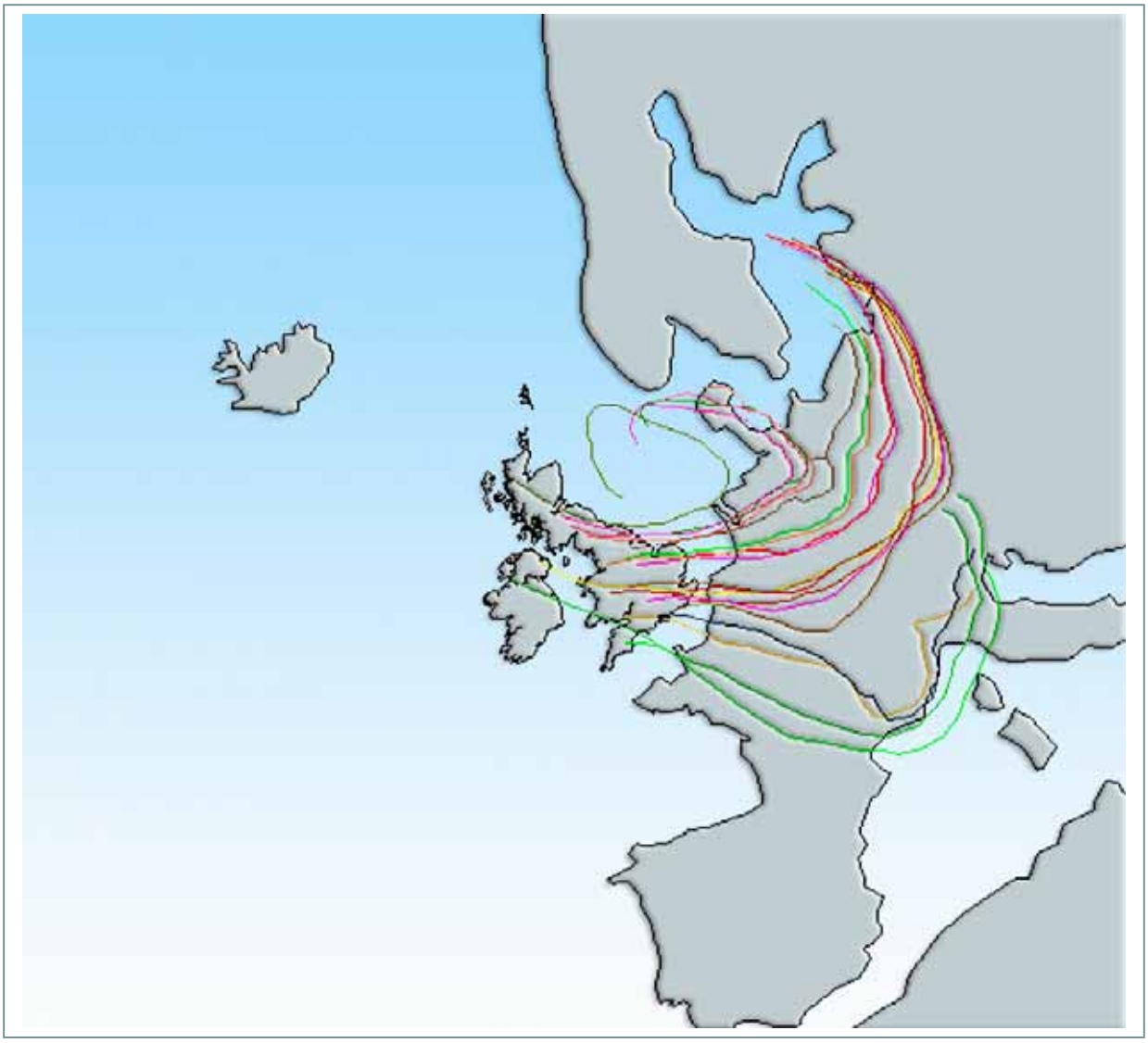


Figure 4.15 Airmass trajectories on 9th May, showing strong and consistent air movement from Continental Europe during the episode

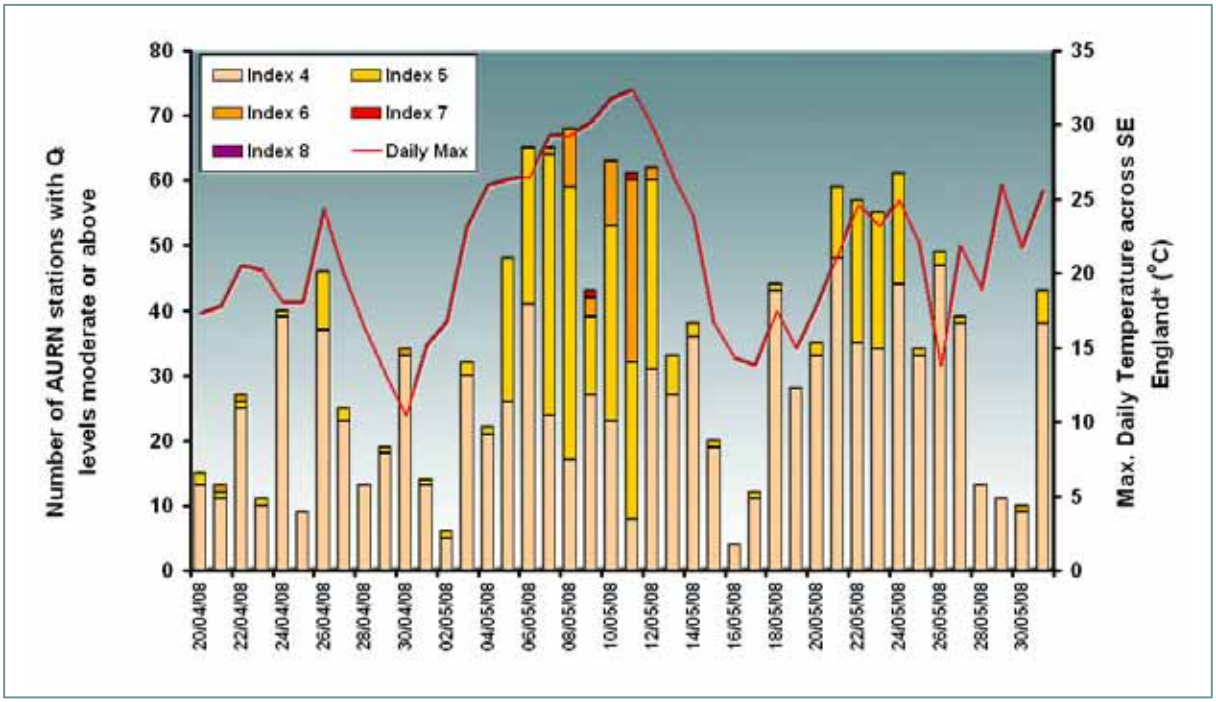


Figure 4.16 Number of network sites with MODERATE and HIGH levels during May episode, together with the temperature profile across the South East; note the distinct correlation between ozone and temperature!

Episode 2 23rd –31st July 2008

July was also warmer than usual, but to a lesser extent. Both months experienced about 5% more sunshine than average (Box 4.2).

Box 4.2 Monthly weather summaries for May, July 2008 (Met Office)

May	July
Mean temperatures generally 2 to 3 °C above average, but only 1 to 2 °C above average across eastern parts of Scotland and NE England. Provisionally, the warmest May in the series back to 1914 for the UK, Scotland and Northern Ireland. Rainfall well above average across southern areas of England and Wales, but below average across central and northern areas of the UK. Sunshine ranging from below average across southwestern areas of the UK to well above average across northern areas of Scotland.	Mean temperatures ranged from close to average across SW England and S Wales to over 1 °C above average across Scotland. Rainfall was generally above or well above average across Northern Ireland, England and Wales, but close to average across East Anglia. Rainfall over Scotland ranged from below average across the north-west to above average across the south-east. Sunshine was generally close to average across the UK.

Source: www.meto.gov.uk/climate/uk/2008/index.html

As in the May episode, sites all over the country registered ozone levels in the upper band of MODERATE; in fact, 71 sites recorded MODERATE ozone, with 13 of these reaching index 6 or above on one or more days. However, HIGH ozone levels were only recorded at Hull Freetown, on one day in July. The highest hourly average was 182 μgm^{-3} (index 7). Please see Figure 4.17 - showing concentrations during this period not tracking with temperature - and 4.19.

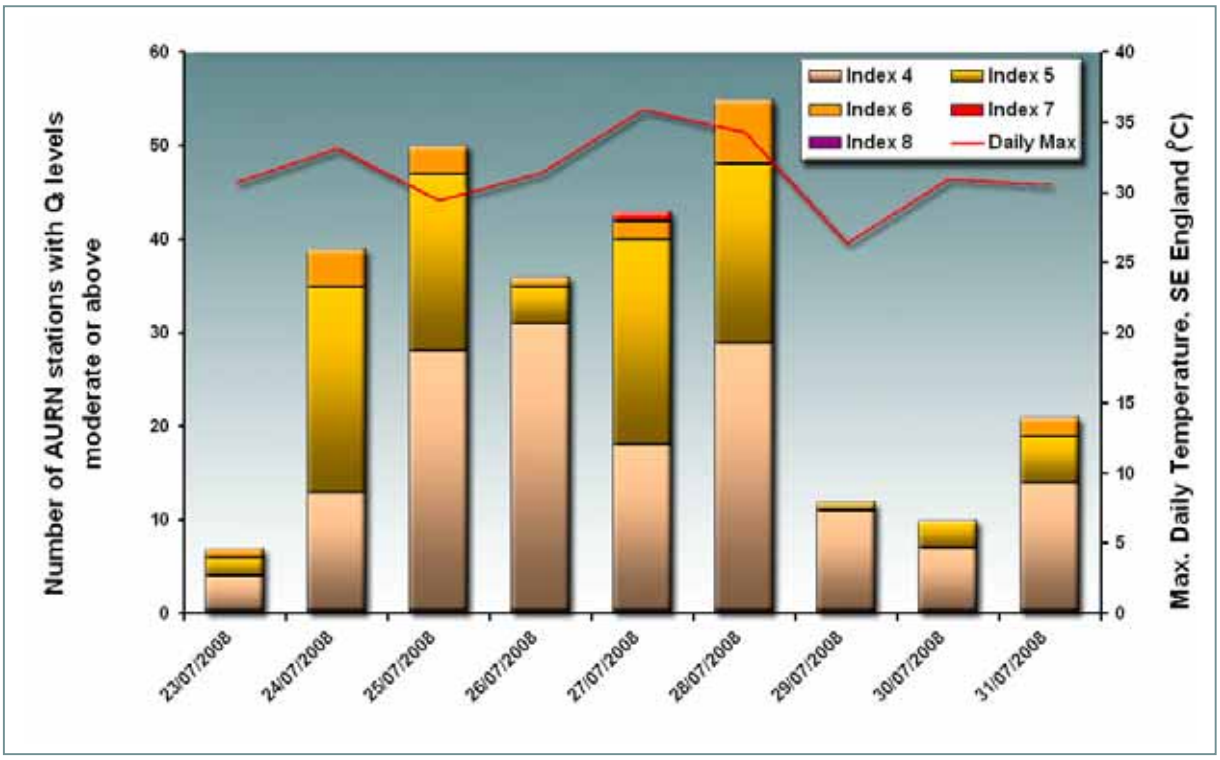


Figure 4.17 Number of Stations with MODERATE and HIGH levels during July Episode, with temperature profile across the South East.

Air quality forecasting in the UK relies substantially on the analysis of air masses and their movements. We use back-trajectory plots to show the movement of air masses over the past few days. Air originating and travelling over low-pollution areas, such as the Atlantic Ocean, tends to bring clean air to the UK. Conversely, air that has travelled over polluted land, or has been circulating over a small area for a long period of time, is likely to bring elevated levels of pollution.

Airmass trajectories for the earlier May episode were very characteristic of the former type: continental airflow that had passed over built up areas of Europe. By way of contrast, the July episode was very characterised by sustained domestic airflow (Figure 4.18).

Before the July episode, air masses arriving in the UK had originated or passed over the clean Atlantic Ocean. However, by the 27th July, much of the air influencing the UK had been moving sluggishly over a very small area - the UK and Western Europe – for the past 96 hours. This re-circulation did not allow the dispersion of pollutants and, coupled with temperatures of over 35°C in some parts of the UK, this was sufficient to cause elevated levels of ozone at many AURN stations, together with an exceedence of the information threshold at Hull Freetown on the 27th July.

The contrast between ozone episode types and their corresponding characteristic airmass trajectories is very marked when comparing Figures 4.15 and 4.18.

During both the May and July ozone episodes, a wide range of other air pollutants continued to be measured at AURN monitoring stations. Figure 4.19 confirms that there is a correlation between ozone concentration at Hull Freetown and high ambient temperature (as measured in SE England). It also shows peaks in the concentrations of PM_{10} and to some extent, NO_2, during the episodes, specifically on the dates 9th May, 11th May, 27th July and 31st July.

This is expected; photochemistry of 'stale' air masses in the atmosphere results not just in elevated ozone, but also increases aerosol content. Chemical reaction of ozone with

primary emissions of nitrogen oxides from both traffic and stationary combustion sources also result in elevated nitrogen dioxide (NO_2).

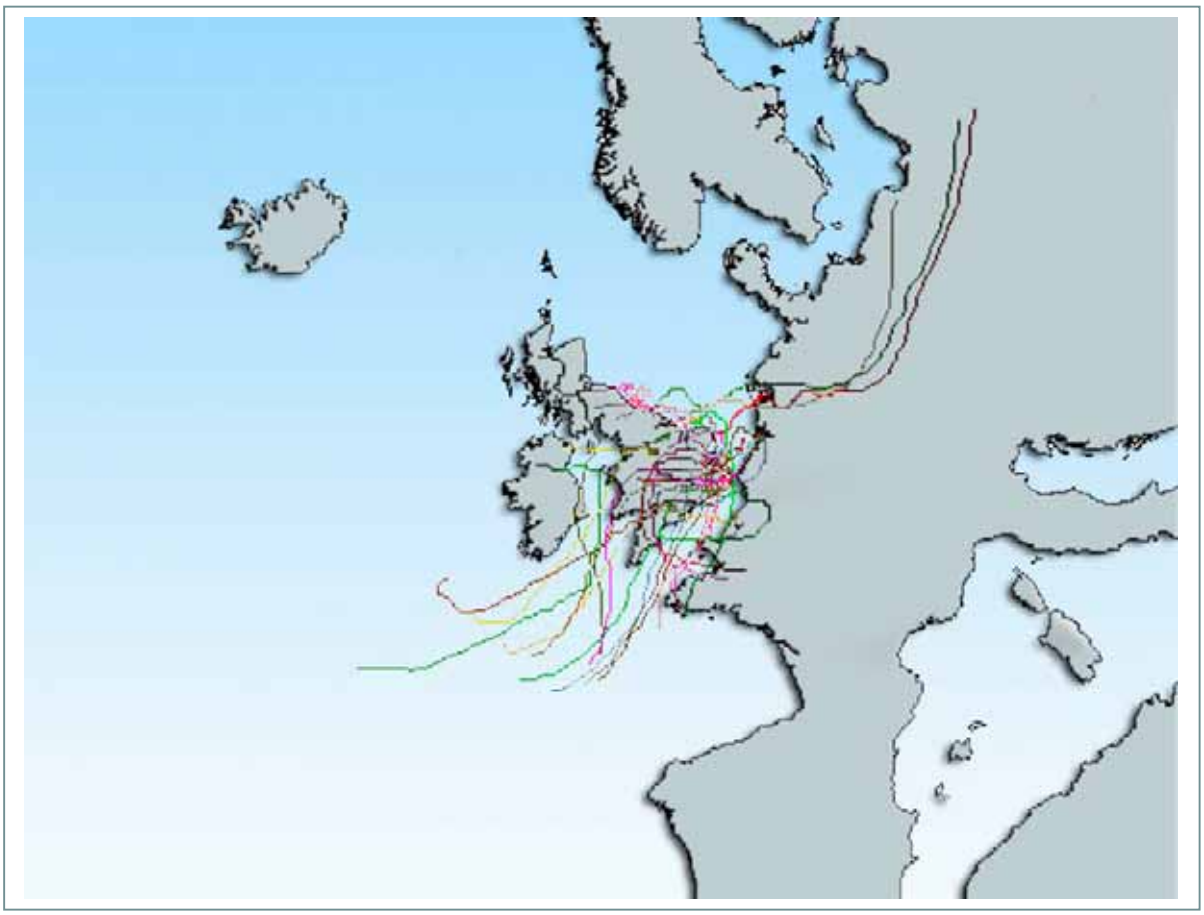


Figure 4.18 Airmass trajectories on 27 July, showing air re-circulation over UK and parts of Europe; contrast this with the situation shown in Figure 4.14

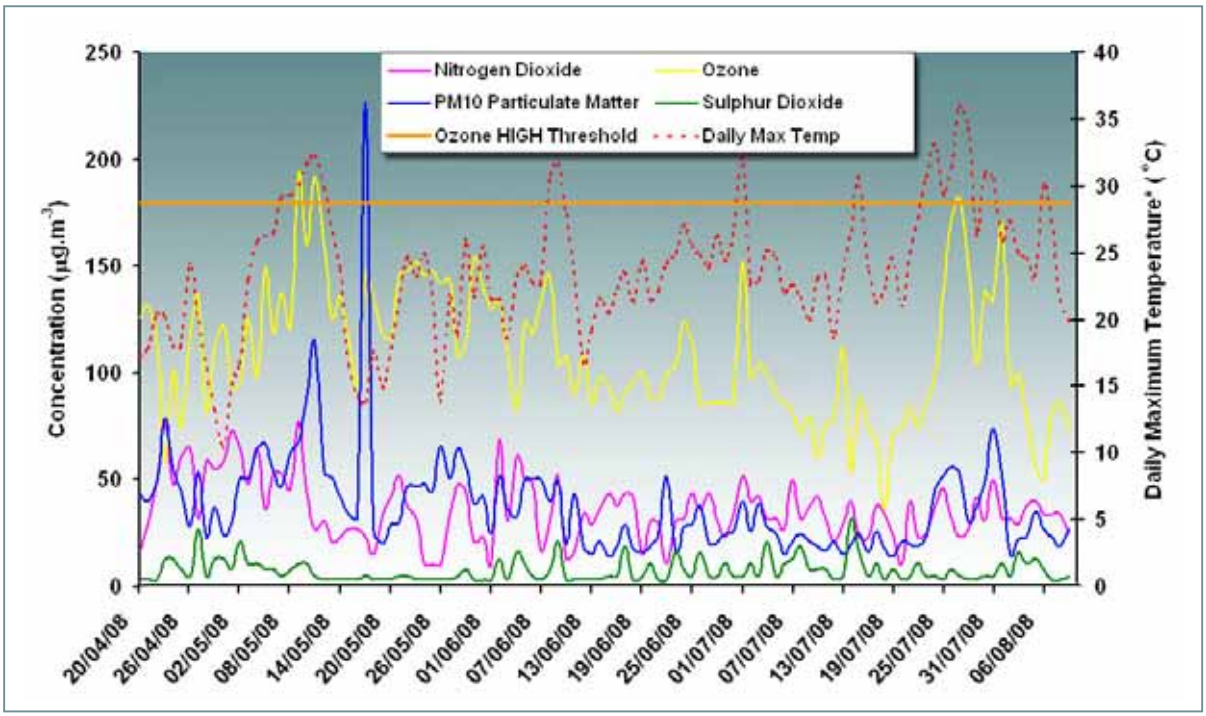


Figure 4.19 Maximum hourly concentrations of a range of measured pollutants at Hull Freetown during the period of 20th April to 9th August 2008.

4.4 Overall UK and European contribution to elevated summer ozone levels, 2000- 2008

Year on year variations

Having reviewed in previous sections some of 2008's major pollution events, we now turn to examining broader long-term variations in the number of UK summer photochemical ozone episodes over the past decade.

Figure 4.20 shows the number of network days measured above various episode thresholds for ozone over the summers of the last nine years. The total number of days in the MODERATE band in 2008 was very similar to that seen in 2000 and 2007. In 2007, the very poor, wet summer led – for the first time- to no high days or days exceeded he EC alert threshold level of 240 μgm^{-3} hourly average concentrations.

By contrast, 2008 proved to be fairly typical – a median year in terms of both MODERATE and HIGH band exceedences. However, there were no alert threshold exceedences.

The elevated number of both high and EC alert days in the hot summers of 2003 and 2006 are also particularly clearly evidenced in this figure.

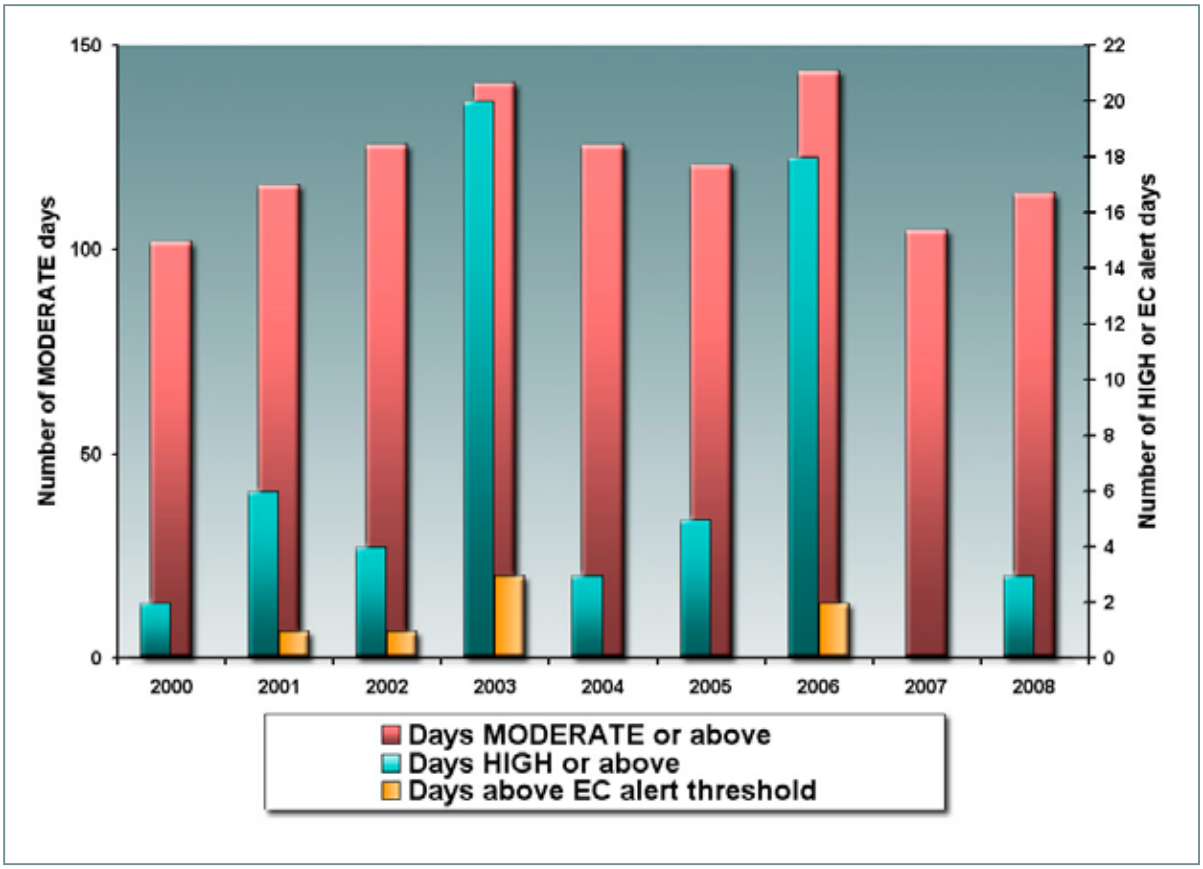


Figure 4.20 –Total network days exceeding various thresholds for ozone over the summers of 2000 onwards.

Even longer-term variations in ambient levels of ozone – and other pollutants – are considered and analysed further in Section 7 of this report.

Domestic and European influences

It is also of interest to compare the proportion of 'home grown' domestic ozone against Continental European ozone contributions during this decade. The May and July episodes discussed in the previous section have already highlighted instances variously dominated by European and UK emissions and airflow.

Accordingly, Figure 4.21 shows the percentage contribution to the UK's ozone from 1) mainland Europe 2) from within the UK. The red coloured (lower) bars show the percentage of days with ozone levels categorised as 'moderate' or above, when the UK was receiving air masses from the Atlantic, or air was being re-circulated over the UK. The darker green (upper) bars show the percentage of days with "moderate or higher ozone, when the UK was receiving air from mainland Europe. Summer data only are shown, for summers 2000 onwards. The data for this chart have been derived from analysis of one-day ahead forecast air mass back-trajectory plots for all moderate' days from April to the end of September.

Figure 4.20 shows that 2008 was the highest year seen so far, over the past 9 years, for the percentage contribution of European air masses to UK ozone levels. Despite the high European air mass contributions experienced during the summer months, however, the number of observed MODERATE and HIGH band exceedences for ozone was average when compared to recent years.

This somewhat counter-intuitive observation could be explained by the fact that, on more than twice the number of days during April and May when compared to 2007, the UK received air from Europe. These months are typically the time of year during which the highest number of MODERATE exceedences for ozone are measured in the UK resulting from 'background' Atlantic air. Therefore the higher number of days when the UK received air from Europe during the early summer may not have had a significant impact on the number of ozone exceedences measured during the summer as a whole. As with 2007, the warmest months, June to August, were predominantly characterised by Atlantic air masses.

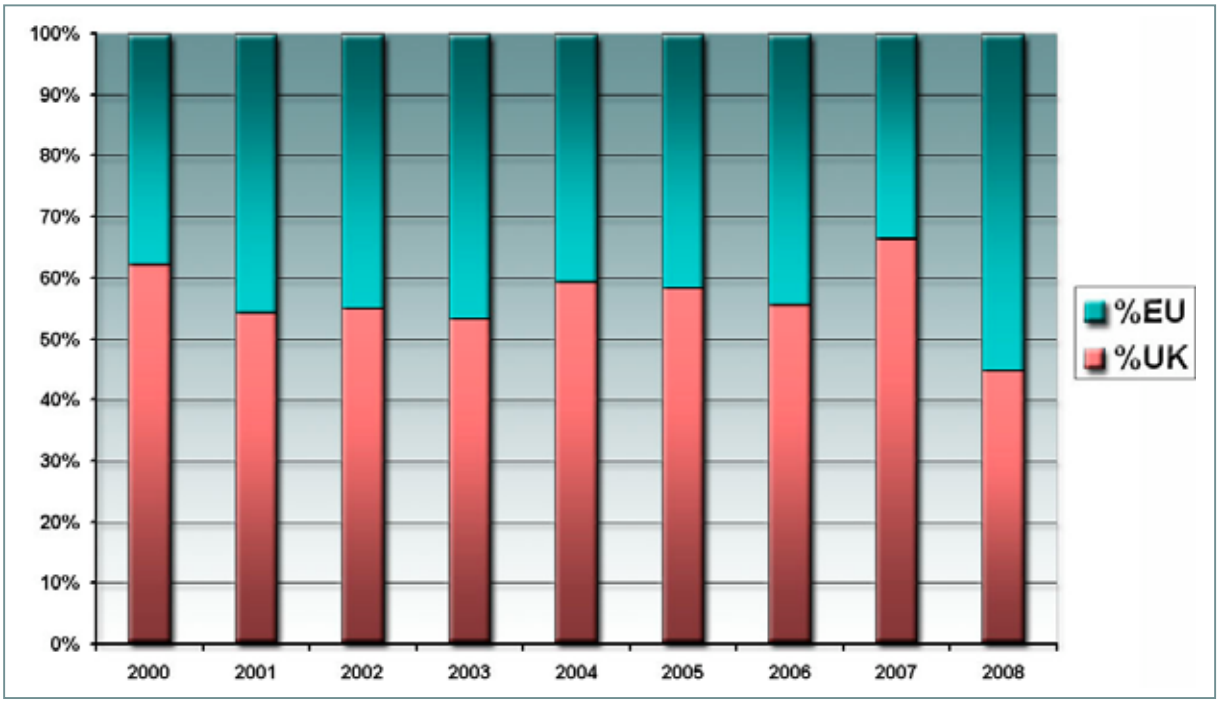


Figure 4.21 – Continental and Domestic source contributions for MODERATE or above ozone over summers from 2000 to 2007.

5 How air pollution varies across the UK

Why do some places in the UK tend to have more air pollution than others? We examine how levels of air pollution vary across the country, and see how these variations relate both to emissions and the behaviour and transport of pollutants once emitted into the atmosphere; this year, we also investigate how these patterns are changing over time.

5.1 Introduction

Levels of air pollutants vary markedly across the country. Measurements from the national air monitoring networks clearly show that these patterns differ for each pollutant, depending on how they are formed and where their major sources are located.

Levels of ***primary pollutants***, those emitted directly into the atmosphere, tend to be highest around their sources; these are usually located in urban and industrial areas. Sulphur dioxide provides a good example of such a pollutant, with domestic or industrial fuel burning being its major source nationwide.

Motor vehicles are a major source of primary pollution in many large cities. In particular, traffic is an important source of carbon monoxide, oxides of nitrogen and volatile organic compounds (VOCs) such as benzene and 1,3-butadiene; it also emits a significant proportion of particles ($PM_{2.5}$ and PM_{10}). Concentrations of all these pollutants are therefore usually highest in built-up urban areas.

In general, concentrations of ***secondary pollutants*** such as ground-level ozone and secondary particulate matter, which are formed by chemical reaction in the atmosphere, show markedly different patterns from those of primary pollutants; they are characteristically less dependent on local emission patterns, and tend to be more strongly influenced by regional emission patterns, meteorology and atmospheric chemistry. As a result, they also change more from year to year than those of primary pollutants.

The vast majority of Air Quality Management Areas (AQMAs) in the UK are due to current or predicted exceedences of air quality objectives for nitrogen dioxide (NO_2) or PM_{10}.

Maps of NO_2 and PM_{10} and ozone for 2008 are presented in this section. The trends in measured air pollutant concentrations with time are discussed in more detail in Section 6. For the first time in this report series, maps of NO_2 and PM_{10} for 1995 and model projections to 2020 are also included in this section; this illustrates how concentrations have changed in the past and are expected to change in the future as a result of shifting patterns in pollutant emissions. Projected ozone maps are not available on the same basis, but a comparison of ozone in 1995, 2003 and 2008 illustrates the impact of meteorology in different years on ozone concentrations.

5.2 Mapping methodologies

We have used two different approaches for modelling and mapping levels of air pollution across the UK. For NO_2 and PM_{10}, the maps have been estimated using a combination of:

1) Atmospheric dispersion models
2) The UK's National Atmospheric Emissions Inventory (NAEI) and
3) Data from the UK monitoring networks.

Together, these provide the basis for robust pollutant models, which enable us to produce detailed maps (at 1km resolution) of annual average pollutant concentrations

across the country. The mapping method is detailed in a number of published reports on the UK Air Quality Archive: for example, Grice et al (2009) [E1]. Similarly, the mapping methods for $PM_{2.5}$ and PM_{10} have been described in detail by Stedman et al (2007) [E2]

An important feature of these models is that they are directly related to the real-world measurements. Unlike monitoring, however, modelling can help the understanding of the source apportionment of air pollutants and predict future concentrations by taking into account the projected changes in emissions over the coming years.

The maps produced by our modelling enable the UK to fulfil its European commitments to assess nationwide pollution patterns as part of implementing the European Air Quality Directives. They also provide an extremely powerful tool for identifying pollutant 'hot-spots' and managing UK-wide air quality problems in the most direct and cost-efficient manner.

We have adopted an empirical approach to map a range of metrics describing ozone concentrations. These maps have been calculated by interpolation of measurements from rural monitoring sites. Ozone concentrations are generally lower in urban areas, as a result of reaction with local emission of nitric oxide (NO). This has been taken into account by the application of an empirically derived urban decrement, which is related to the mapped local concentration of oxides of nitrogen (NO_x). The methods used to map ozone concentrations have been fully described by Stedman and Kent (2007) [E3].

The mapped air pollutant concentrations presented in this section are clearly subject to greater uncertainty than corresponding values derived directly from measurements made at monitoring sites. This is due to a number of factors including:

- Uncertainties surrounding the emission inventories
- Uncertainties relating to the atmospheric dispersion model
- Complexities of the atmospheric chemistry
- Uncertainties relating to the source apportionment of ambient concentrations; this is particularly important for PM_{10}, for which a number of the sources are less well characterised.

The mapped concentrations have, however, been verified by comparison with automatic monitoring data, including data from non-national network sites that are of known high quality. Emission inventory projections have been used to calculate the maps of projected concentrations for 2020. These projections are subject to greater uncertainty associated with the predictions of economic growth and activity, the impact of measures to reduce pollutant concentrations, such as the Euro standards for new vehicles, and the response of atmospheric processes to changes in emissions.

5.3 Nitrogen dioxide, NO_2

UK-wide patterns of annual mean nitrogen dioxide concentrations in 1995, 2008 and projected to 2020 are shown in Figure 5.1. Although some NO_2 is emitted directly from vehicles or other sources, most is formed by rapid chemical reaction (oxidation of emitted NO) in the atmosphere. This pollutant therefore has both primary and secondary characteristics.

Concentrations of NO_2 tend to be highest in urban areas such as in London, where traffic levels are high. Moreover, the data mapped in these figures – particularly for 1995 but less so for 2005 and 2020 - clearly follow the country's major motorways and road network infrastructure.

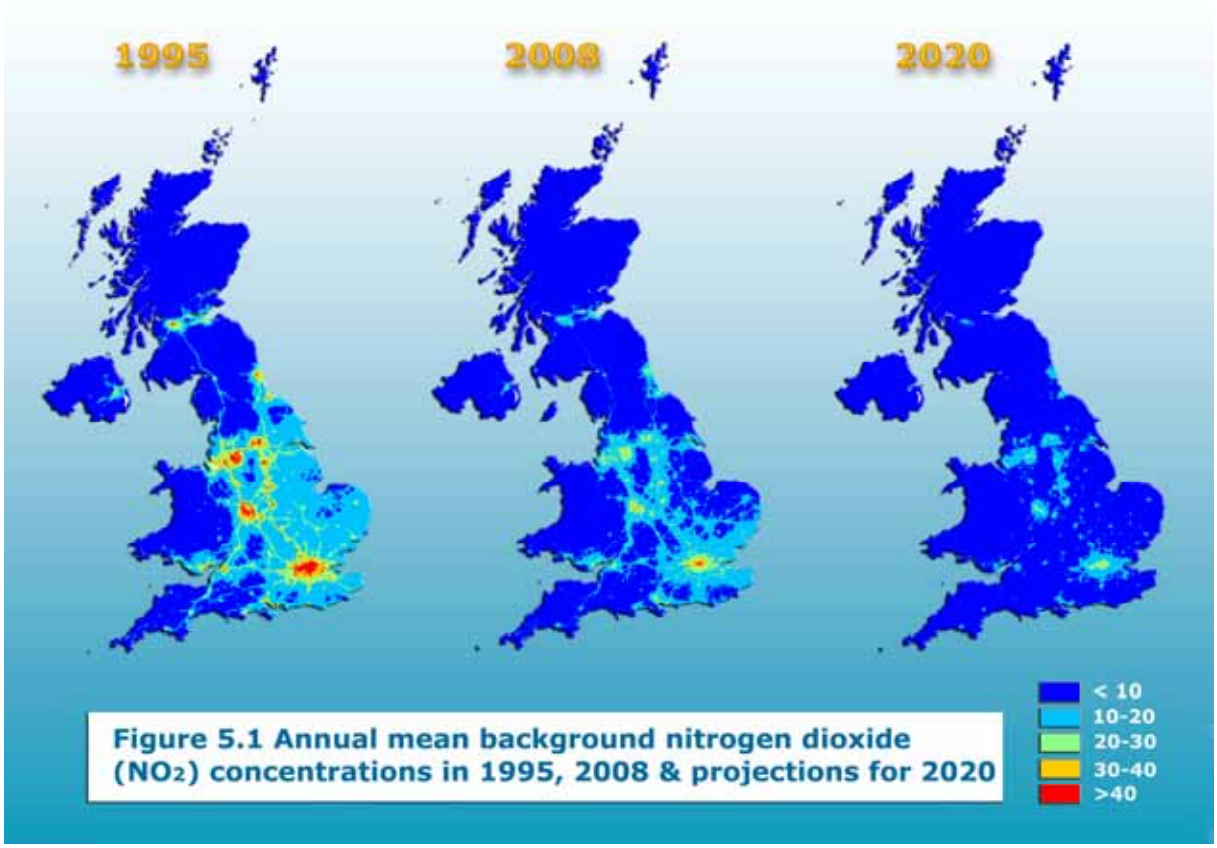


Figure 5.1 Annual mean background nitrogen dioxide (NO_2) concentrations in 1995, 2008 & projections for 2020

Concentrations of NO_2 have clearly declined between 1995 and 2008, as a result of reductions in emissions of NO_x. These reductions have principally been in relation to emissions from road traffic, resulting from the Euro standards for new vehicles, and emissions from industry and power stations. Further reductions in UK-wide concentrations are expected as emissions decline further towards 2020.

5.4 PM_{10} particles

Particulate matter (PM) is not a distinct chemical species like the other pollutants measured in the automatic networks; rather, it consists of material from many sources and is usually classified on the basis of particle size and not chemical composition. PM_{10} is PM of average aerodynamic diameter less than 10 microns (where a micron is 1×10^{-6} m or a thousandth of a millimetre).

Maps of PM_{10} annual mean concentrations for 1995, 2008 and 2020 are shown in Figure 5.2. PM includes a wide range of chemical species, which can be usefully broken down into primary, secondary, and other PM. However, it is important to realise that ambient particulate matter can both be transported and react chemically in the atmosphere; in consequence, individual particles generally include a range of components from a variety of sources.

The contribution from primary PM is generally greatest in urban areas, close to emission sources. The sources of primary PM are diverse. Elemental and organic carbon are produced by combustion processes such as from motor vehicles, fuel burning and industrial emissions. There is also a contribution from mechanically generated particles, produced by building work and quarrying, soil and road dust, and sea salt.

A significant proportion of PM is secondary, formed by the reaction of gases in the air. Sulphate, nitrate and ammonium (secondary inorganic aerosol, SIA) are formed by

chemical reactions in the atmosphere from emissions of SO_2, NO_x and NH_3. Similarly, secondary organic aerosol is formed from reactions of organic compounds.

Like ozone, these time-dependent reactions can result in secondary PM being produced considerable distances from the original emission sources. In consequence, secondary PM concentrations are generally greatest in the south and east of the UK: these areas are more often downwind of and closest to polluted areas of Northern Europe.

Concentrations of PM_{10} have declined between 1995 and 2008, primarily as a result of reductions in emissions of primary PM. These reductions have principally been in emissions from road traffic - as a result of the Euro standards for new vehicles - and in emissions from industry and power stations. The concentrations of SIA have also declined as regional UK and European emissions of NO_x and SO_2 have fallen. Further reductions in concentrations are expected as emissions decline further to 2020, although further dramatic changes are not expected in this time frame.

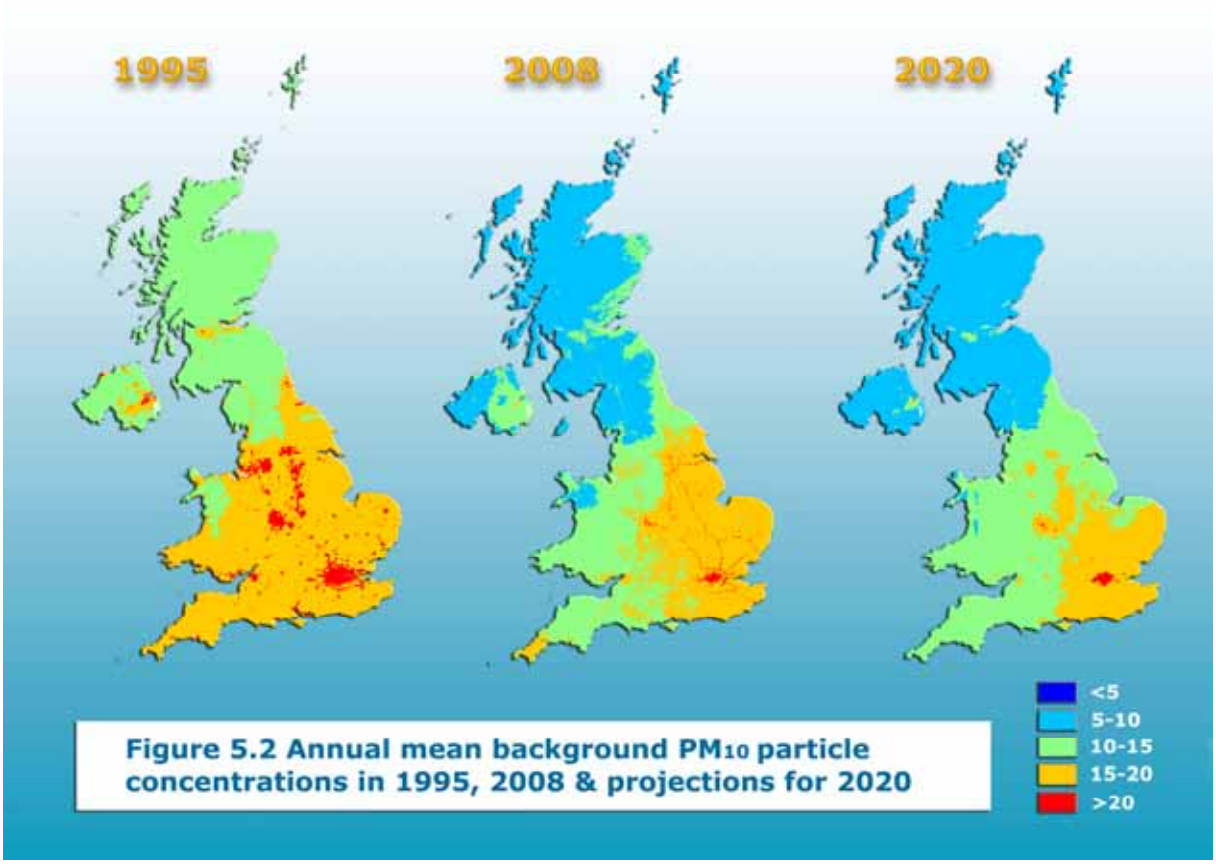


Figure 5.2 Annual mean background PM_{10} particle concentrations in 1995, 2008 & projections for 2020

5.5 Ozone

Ground-level ozone is formed by a series of chemical reactions involving precursor pollutants - NO_x and hydrocarbons – together with oxygen. Ultraviolet radiation drives these reactions and, as a result, ozone production rates are highest in hot, sunny weather. Ozone formation can take from hours to days to complete. Consequently, high levels of ozone can often be formed considerable distances downwind of the original pollution sources in UK or Europe.

A number of factors influence how the amount of ozone air pollution varies from year to year.

- Ozone concentrations are generally highest at locations where concentrations are elevated due to summer ozone episodes. The highest summer ozone concentrations are seen in the rural parts of South and Eastern England; these areas tend to be hotter and sunnier than other parts of the UK, and are often downwind of polluted areas of Northern Europe.
- Meteorology is also important. As discussed previously, years with warm summers and predominantly easterly winds tend to have higher ozone concentrations
- Regional emissions of ozone precursor pollutants (NO_x and hydrocarbons) have declined since the 1970s, resulting in generally lower concentrations during ozone episodes
- Urban emissions of NO_x have declined since a peak in the early 1990s, resulting in urban ozone concentration becoming more similar to those in the countryside.

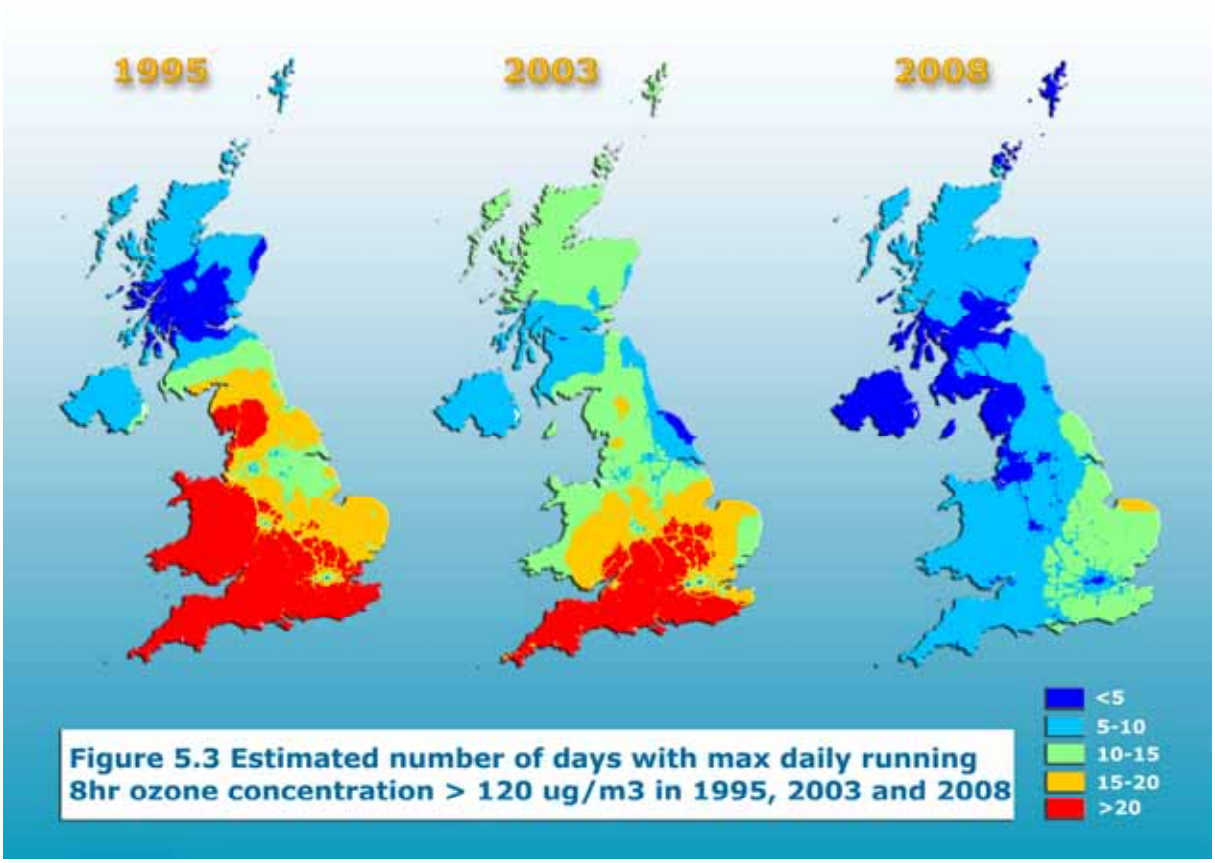


Figure 5.3 Estimated number of days with max daily running 8hr ozone concentration > 120 ug/m3 in 1995, 2003 and 2008

Figure 5.3 shows UK ozone concentrations, expressed as the number of days with running 8-hour mean concentrations greater than 120 $\mu g\ m^{-3}$ for the years 1995, 2003 and 2008. (The target value for the protection of human health within the EU Ambient Air Quality Directives is that this level should not be exceeded more than 25 times per year, averaged over 3 years. The long-term objective is that this level should not be exceeded).

Both 1995 and 2003 were hot summers and there were many days with elevated ozone concentrations, particularly in the south of the UK in 2003. Urban emissions of NO_x were lower in 2003 and 2008 than in 1995, which will have tended to make the difference in ozone between urban and rural areas smaller. Overall ozone concentrations were much lower in 2008 than in 1995 or 2003, primarily as a result of the cooler weather and less frequent easterly winds during the summer.

6 How UK Air Pollution has changed over time

Is air pollution in the UK getting better or worse over time? Here we investigate, but the answers are not always clearcut.

6.1 Introduction

Ambient concentrations of air pollutants can vary markedly over different time scales. Concentrations of primary pollutants - those directly emitted into the atmosphere, such as sulphur dioxide - can fluctuate considerably in the short-term. Such changes depend primarily on:

- The quantities emitted
- The timing of those emissions
- The distribution of the emission sources
- Atmospheric conditions affecting the dispersion and transport of pollutants

By contrast, concentrations of secondary pollutants - those that are created in the atmosphere, like ozone – characteristically tend to change more slowly over time; although the same factors as noted above still apply, variations are smoothed out as the chemical reactions that control their formation vary.

Changing air pollution concentrations can have important negative human health effects, as well as impacts on the health of crops and vegetation. In the short-term, air pollution episodes can trigger asthma attacks or exacerbate cardio- respiratory conditions in sensitive individuals. In the long-term, exposure to air pollution affects our quality of life and overall life expectancy.

Whilst the previous part of this report examined spatial patterns of pollution in the UK, this section focuses on long-term trends in our air quality. It examines how our overall exposure to harmful air pollutants is changing over time and attempts to answer the question "to what extent is air quality in the UK improving or deteriorating?"

This is not an easy question to answer, given the variation in measured concentrations relating to meteorological conditions. For example:

- Ozone concentrations are directly related to photochemical activity driven by sunshine and high temperatures
- PM_{10} concentrations decline with increasing precipitation
- Concentrations of all pollutants are reduced by rising wind speeds that improve dispersion

As a result, it is sometimes hard to tell whether measured variations in pollutant concentration are the direct result of policy measures or are associated with meteorological conditions. Despite these technical difficulties, assessing these changes is an important step in:

- Gauging the effectiveness of current regulations and legislative controls on emissions and
- Deciding whether new or additional regulatory, planning, fiscal or emission control measures are needed at a local, national or international level

Historically, this assessment was undertaken by concentrating on the major industrial emissions of the day – 'Black Smoke' and SO_2, both of which have decreased markedly throughout the UK in response to changing emission patterns and the success of emission control measures and policies. As levels of these pollutants have fallen, attention has progressively focussed on addressing the impacts of secondary pollutants, particles and traffic-related species.

Increased monitoring activities in the UK, as highlighted in Section 3, have made it possible to examine UK pollutant trends in great detail. This section considers these trends in the context of:

- The UK Government's air quality indicators (Section 2.1)
- Compliance with specific objectives set out in the UK Air Quality Strategy (Section 2.1)

It should be noted that the Devolved Administrations in Scotland, Wales and Northern Ireland are increasingly setting their own air quality indicators and targets. For example, in Wales the 'Environment Strategy for Wales' sets specific outcomes for air quality that are supported by a series of indicators; these are reported on annually as part of the state of the environment report for Wales. While both the outcomes and indicators are similar at present to those in the rest of the UK, these may diverge in future. Similarly, Scotland has set more stringent targets for some pollutants than England, in particular for PM_{10} and $PM_{2.5}$.

6.2 Pollution indicator 1 – PM_{10} & ozone (O_3)

The Government's Sustainable Development indicators for Air Quality provide two significant measures of how the air quality has changed since 1990. The first of these indicators is shown in Figure 6.1. This indicator, first established in 2005, shows trends in two specific pollutant parameters: the annual mean of daily maximum 8-hour ozone concentrations and annual mean particulate matter (PM_{10}) concentrations. This indicator illustrates the special prominence of these two pollutants, which are believed to pose the most significant threats to public health through long-term exposure.

Figure 6.1 shows that ozone concentrations have been rising more rapidly at urban background locations than at rural sites over the last decade; this has reduced the historic gap between urban and rural environments, which has been primarily due to ozone 'scavenging' by traffic-related NO_X emissions in urban areas.

Measured ozone concentrations in 2003 and 2006 were comparatively high, as a result of heat wave conditions during the summer season across the UK and the associated increase in photochemical activity that generates this secondary pollutant. Extensive analyses of these periods, together with assessments of their potential health impacts, are available for download from the UK Air Quality Archive at www.airquality.co.uk.

By contrast, during the summer months of 2007 much of the UK was suffering from significant flooding. The heavy rainfall during a mild, wet summer brought about:

1. Reduced photochemical generation of fine particle aerosol;
2. Increased washout of coarse particles;
3. Reduced re-suspension of coarse dust fractions

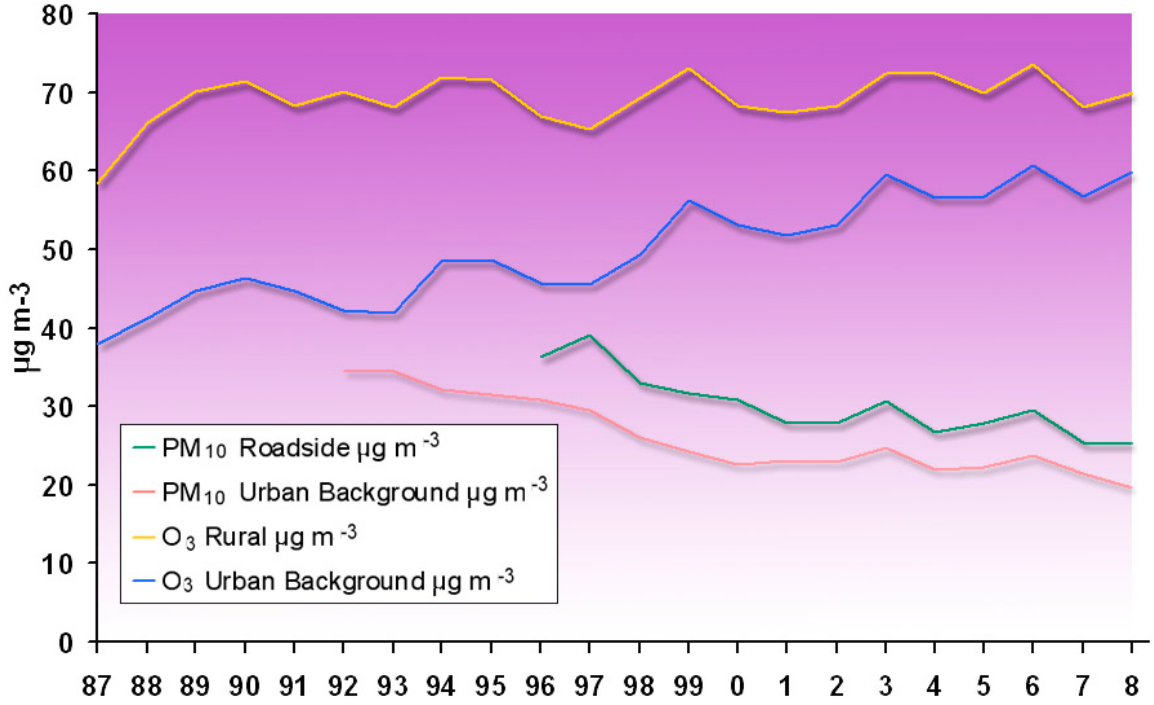


Figure 6.1 – Trends in Air Pollution Indicator 1 from 1987 to 2008: gravimetric PM_{10} annual mean and ozone annual mean of the daily maximum running 8-hr mean

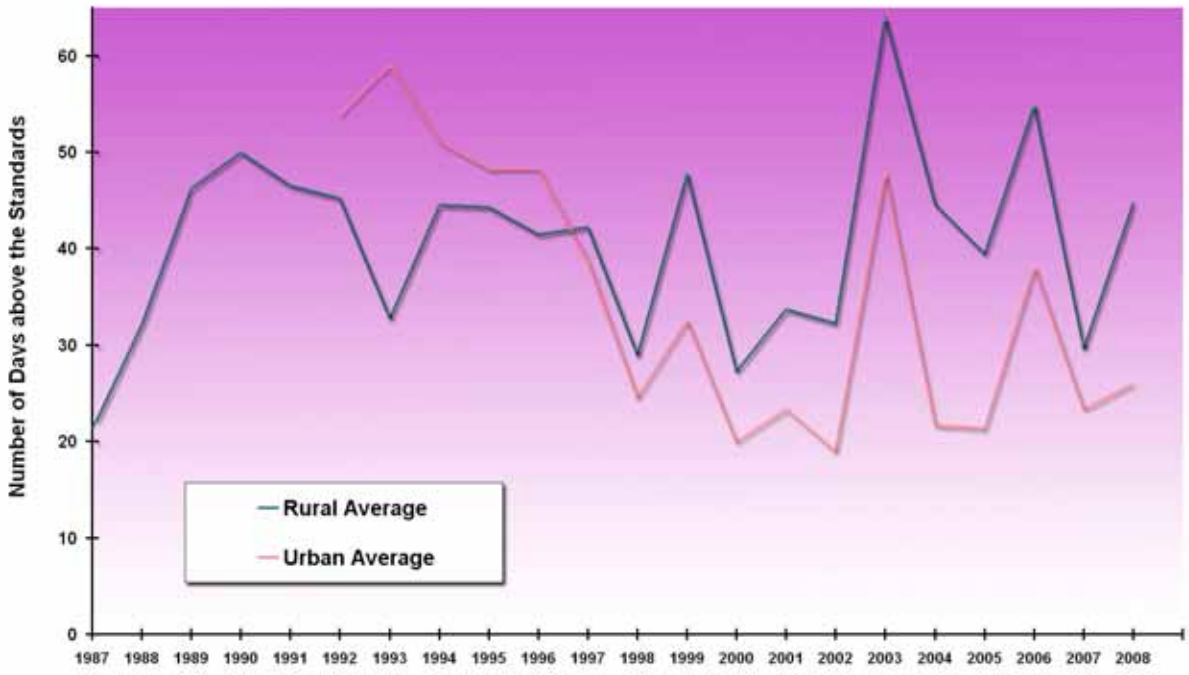


Fig 6.2 Trends in air Pollution Indicator 2 from 1987 to 2008: number of days exceeding 'moderate' air quality band

These factors had a marked impact on pollution concentrations, as shown by the marked decline in the ozone metric in Figure 6.1 from 2006 to 2007, evidenced at both urban and rural locations. Although the subsequent summer of 2008 was not particularly sunny, ozone concentrations were still higher than the previous year.

Corresponding concentrations of PM_{10} at background and roadside sites fell steadily at a similar rate until about 2000, were reasonably stable until 2006 and since 2006 appear to have resumed a gentle downward trend. Again, 2003 and 2006 stand out in these trends and suggest that the heat waves in these years also affected the PM_{10} levels through photochemical secondary aerosol generation. PM_{10} concentrations in the UK in 2006 were also known influenced by biomass burning on the continent, in particular a large forest fire in Russia during May[F1].

6.3 Pollution indicator 2 – number of moderate or high air pollution days

The second of the UK Government's Sustainable Development air quality indicators has been established for several years and analysed in earlier reports in this series. This is based on the average number of days at each monitoring site on which pollution levels were in or above the UK's 'moderate' air quality band. These bands represent defined concentrations associated with different levels of health risk. When pollution is 'moderate', sensitive people may notice mild effects, but these are unlikely to require action. When levels enter the 'high' band, sensitive people may notice significant effects and may need to take action.

Figure 6.2 shows how the number of moderate or higher air pollution days in the UK has changed since 1987. Unlike the first indicator discussed, this indicator is based on data from five different pollutants:

- PM_{10}
- Ozone
- Sulphur dioxide
- Carbon monoxide
- Nitrogen dioxide.

Figure 6.2 exhibits a marked decline in the number of moderate or higher days at urban sites (the red line) until 2000. Since then, the trend appears to have levelled off with the exception of the notable heat wave-related peaks in 2003 and 2006, which have been discussed above.

There is a less obvious trend among the rural sites (the green line), which generally appears to rise gradually across the last two decades, albeit with considerable year-to-year variability. This may be because the dominant pollutant in rural areas is ozone; being a secondary pollutant, this is created by chemical reactions in the atmosphere from precursors. Concentrations of this pollutant are therefore heavily dependent on a range of factors, including the weather and long-range transport.

The transboundary nature of ozone pollution means that the Government is working at an international level to reduce the emissions of precursor pollutant species that react in the atmosphere to form ozone. 2008 has seen at all sites an increase in the number of days with moderate or higher ozone concentration and above, but this rise has been more prominent at rural locations.

6.4 Comparison with UK objectives

Each year, a comprehensive analysis is undertaken of how UK-wide air quality measurements from the national networks compare with the Air Quality Strategy Objectives – both those established in Regulation (summarised in earlier sections) and those not in Regulation. Results from the analysis carried out for 2008 are summarised in Figures 6.3 and 6.4.

As in previous reports, Figure 6.3 is presented as a 'box and whisker' plot showing mean compliance statistics averaged across all measurement sites in the Automatic Urban and Rural Network (AURN), normalised and expressed as a percentage of the relevant Air Quality Strategy Objective. To provide additional information, the maximum site statistic is also shown.

The height of each bar in this figure represents the average statistic across the whole network compared with the relevant national objective, while the t-bar lines above each bar show how the 'worst' site compares with that objective – this is important information, since a single site above the level of the Objective constitutes an exceedence even where the network average falls below the Objective level. The methodology used to produce Figure 6.3 is discussed in greater detail in Appendix A6.

Figure 6.3 shows clearly that some pollutants - notably benzene, carbon monoxide and sulphur dioxide - are largely under control. By contrast, levels of other pollutants – Benzo[a]pyrene (BaP), NO_2, ozone and PM_{10} – currently exceed their respective objectives at some locations. Ratified data for 2008 in this figure show a continuation of the overall pattern seen over recent years – BaP, NO_2, ozone and PM_{10} all exceed the objective at the most highly polluted sites. Of particular concern are BaP and PM_{10} for which not only the highest concentrations measured, but also the network average, exceed objectives.

Please see Appendix 6 (Section A6.3) for further information to help in interpreting and understanding this 'box and whisker' plot, as well as Figure 6.4.

Figure 6.4 summarises time series analyses for four specific examples of trends in compliance against specific pollutant objectives for: (a) BaP, (b) NO_2, (c) ozone and (d) PM_{10}. The average and maximum concentrations are presented in $\mu g\ m^{-3}$, rather than as percentages of the objective value (shown in Figure 6.3). These graphs show how levels are changing over time in relation to each objective.

Figure 6.4a demonstrates that BaP concentrations have, on average, been close to the objective between 2001 and 2007. However, concentrations increased markedly in 2008, both in relation to the network average and the highest concentrations, which were well above the objective value. The trends presented in this plot are as much the result of changes in monitoring locations as in ambient concentrations. For example, several BaP monitoring stations have been specifically located in close proximity to known 'hotspots' close to large-scale industrial emissions such as steelworks.

The reason for the marked increase in maximum (and therefore network average) concentrations in 2008 is that a new monitoring station commenced operation at Scunthorpe Santon monitoring station which is intentionally sited downwind of a major integrated steelworks, in order to assess worst-case impacts of these industrial emissions. The measured BaP annual mean at this location in 2008 was 6.1 ngm^{-3}

Moreover, changes in measurement methodology - including instrument type and change to daily sampling - have also made a contribution to the increasing concentrations measured. It should nevertheless be noted that these trends are representative of localised industrial emissions rather than background concentrations on a regional scale.

Encouragingly, network average NO_2 concentrations (Figure 6.4b) have been steadily declining over the last two decades and have been below the objective value since 2000; this trend looks set to continue. However, by contrast the highest concentrations of NO_2 measured by the network appear to have been increasing over time at several of the busiest roadside monitoring sites. While this increase may have levelled off since 2003, concentrations at the most polluted sites remain well above the objective level.

Both maximum and average ozone concentrations (Figure 6.4c) have risen slightly over the last decade, and it is likely that both these will exceed the objective value in the next few years. Trends in ozone concentrations can be influenced by a number of factors including the weather, baseline background levels, the magnitude of the precursor emissions and reactions with local NO_x emission in urban areas[F2]. Analysis of hemispheric baseline ozone concentrations suggests that concentrations increased over the period from 1995 to a peak in 1999 and subsequently remained roughly constant[F3].

It should be noted that the increase in average ozone concentration measured across the UK network also reflects the corresponding changes observed in urban areas as a result of tighter control of NO_X emissions; a trend that is further illustrated in the urban background and rural ozone lines in Figure 6.1. Measured ozone concentrations have declined from 2006 (a heat wave year) to 2007 but rose again in 2008. This most recent upturn in concentrations was not the result of particularly high concentrations in 2008, but reflects the relatively low concentrations in 2007 associated with cooler and wetter weather over that summer.

Figure 6.4d shows corresponding trends in average and maximum PM_{10} compared against the daily objective. It shows a slight decline in average levels in the long-term, although concentrations in recent years appear to have levelled off. The highest levels remain above the objective and have not decreased significantly in recent years. Like the most recent trend in NO_2, measured PM_{10} concentrations in 2008 illustrates a continuing, gentle decline in recent years as a network average but a steady rise in the highest concentration measured across the network.

Both the time series plots for ozone and PM_{10} (Figures 6.4c and 6.4d) clearly show the elevated concentrations of these pollutants associated with the heat wave summers of 2003 and 2006.

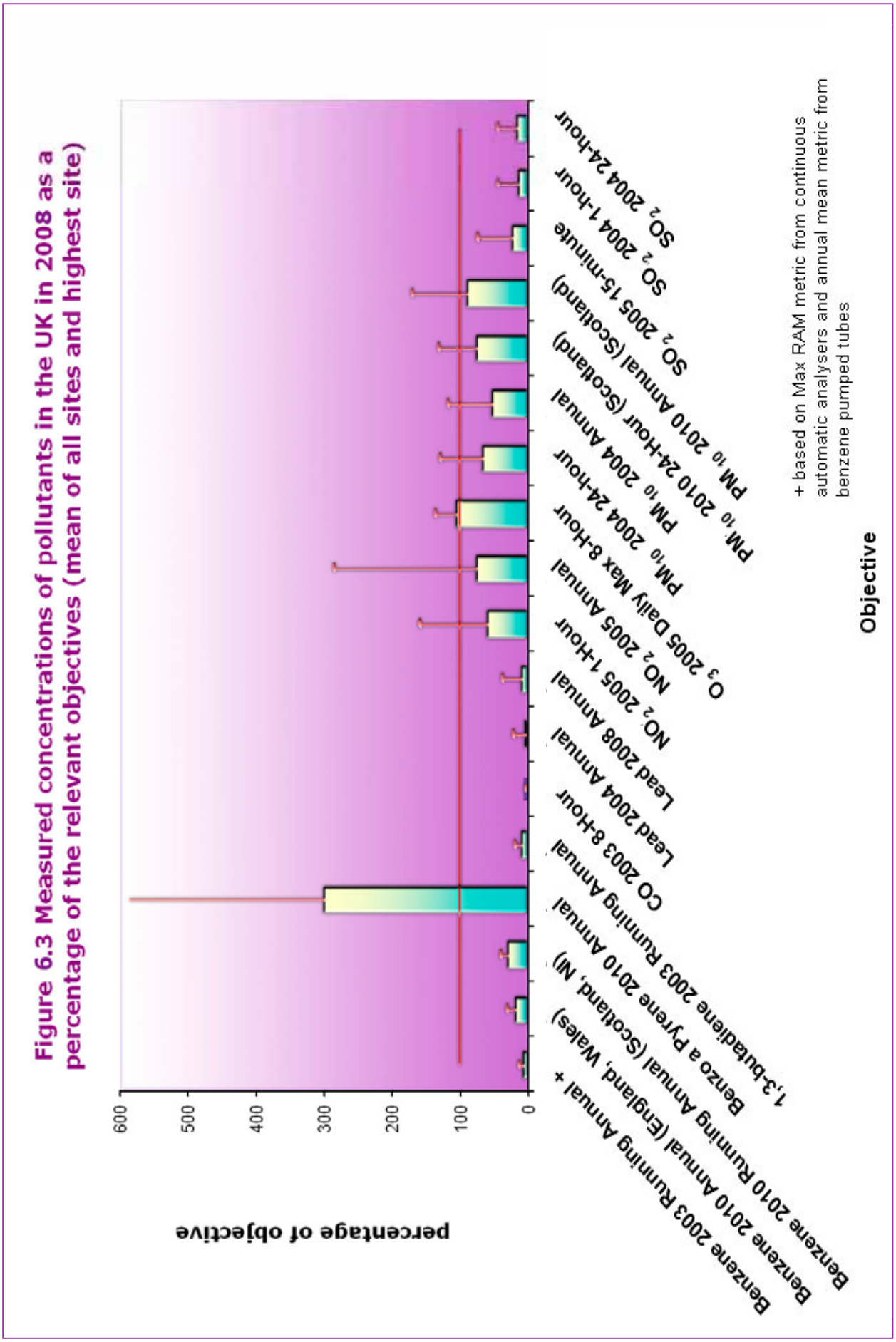


Figure 6.3 Measured concentrations of pollutants in the UK in 2008 as a percentage of the relevant objectives (mean of all sites and highest site)
percentage of objective
600
500
400
300
200
100
0
Benzene 2003 Running Annual (England, Wales) +
Benzene 2010 Annual (Scotland, NI)
Benzene 2010 Running Annual (Scotland, NI)
1,3-butadiene 2003 Running Annual
Benzo a Pyrene 2010 Annual
CO 2003 8-Hour
Lead 2004 Annual
Lead 2008 Annual
NO2 2005 1-Hour
NO2 2005 Annual
O3 2005 Daily Max 8-Hour
PM10 2004 24-Hour
PM10 2004 Annual
PM10 2010 24-Hour (Scotland)
PM10 2010 Annual (Scotland)
SO2 2005 15-minute
SO2 2004 1-hour
SO2 2004 24-hour
+ based on Max RAM metric from continuous automatic analysers and annual mean metric from benzene pumped tubes
Objective

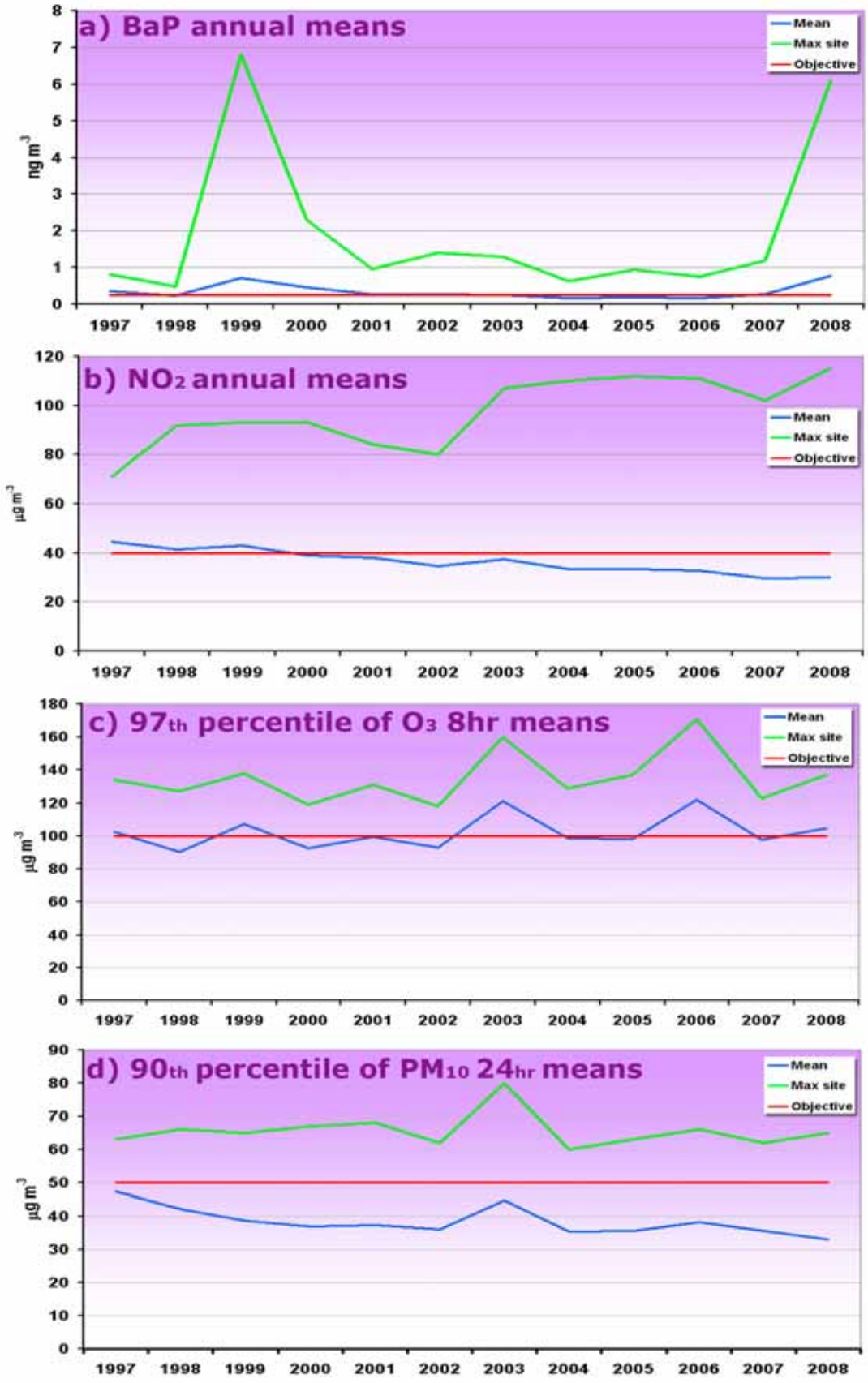


Figure 6.4 a) to d) Trends from 1997 to 2008 in mean and maximum measured concentrations of four selected pollutants against their corresponding UK Air Quality Strategy Objectives

7 What acid rain monitoring networks have taught us

Monitoring networks utilising simple chemical and mass-sampling techniques have been in operation since the 1960s. They have shown how pollution levels, and UK's overall pollution climate, have changed over the decades. This year we examine results from the UK's long-running acid deposition monitoring programmes.

Continuing previous years' reviews of key results and findings from the UK's non-automatic air monitoring programmes, we now focus our attention on one of the longest running sampler-based monitoring networks – the Acid Deposition Network. Over the past quarter of a century, this network has recorded significant changes in the levels of acid deposition and continues to play an important role in the monitoring and understanding of pollutants that can damage UK's precious ecosystems.

7.1 Origins of the Acid Rain Network

During the late 1960's and 1970's there was increasing evidence that increases in lake and river acidity– particularly in some upland areas of the country - were linked to an observed decline in fish population and other fauna and flora. Similar observations were found throughout parts of North America and Europe and, particularly, in Scandinavia.

At the time, the transport of acidifying emissions from high chimneys, such as power stations, was identified as a major problem (Figure 7.1).

Figure 7.1 Emissions from power stations contributed to long-range acidification during the 1960s and 70s. Image © Jon Bower, Apexphotos 2009

Following a review of the science and available data in the early 1980's a comprehensive UK-wide monitoring network was established in 1986. This operated to consistent sampling protocols and aimed to provide a more complete understanding of both precipitation chemistry and the concentration of a number of gases, including sulphur dioxide and nitrogen dioxide, as well as particulate sulphate.

The science…

Rainwater is naturally acidic due to the partially soluble nature of carbon dioxide; rainwater is - after all - dilute carbonic acid. In addition, as rainwater can absorb gases and particulates during its transport through the atmosphere, it can deliver pollutants to the earth's surface that may result in harmful impacts - particularly in some sensitive ecosystems and building materials.

Acid deposition - often described as acid rain - is a term commonly used to describe the combined deposition of sulphur and nitrogen. In addition, the deposition of nitrogen-containing compounds may also contribute to the eutrophication – 'excess nutrient enrichment' of terrestrial and marine ecosystems. This may lead to displacement of existing vegetation by more nitrogen tolerant species- for example, heather in heathlands being displaced by grass.

Monitoring and measurements- a brief history

In the mid 1980's, the United Kingdom government made a major commitment to understanding how rainwater composition and acidifying gases might change in response to international agreements designed to cut pollutant emissions. Its key action was to establish the UK acid rain monitoring network.

Figure 7.2 Assessing impacts on our precious ecosystems: the acid rain monitoring site at Llyn Llydaw, Snowdonia

The acid rain monitoring network has evolved substantially and continuously since its inception in 1986. It has always adapted as policy needs have changed and the science has progressed. For example, in the late 1980's, there were nearly 60 bulk rain water and 9 wet only collectors distributed at rural locations throughout the United Kingdom. As our knowledge of the causes of acidification and eutrophication increased, and to meet the available funding budget, the national network has evolved to include a number of sub-networks.

Perhaps the two most important sub-programmes were the commencement of national-scale monitoring of ammonia and nitric acid (and other acid gases) in 1996 and 1999, respectively. As ambient sulphur dioxide concentrations decreased in the late 1990's to below levels that could be reliably measured with the existing technique, alternative techniques were required; for example filter packs replaced the 'bubbler' technique in the early 2000's. These, in turn, were replaced by low cost denuder samplers in 2005.

A recent review of monitoring networks recommended the discontinuation of the long term monitoring at Eskdalemuir (where acid deposition monitoring had taken place for more than thirty years) and the daily sampling of sulphate aerosol at 5 sites. Monitoring of the atmospheric inputs that lead to acidification and eutrophication is now conducted via the United Kingdom Eutrophication and Acidifying Atmospheric Pollutants (UKEAP) Network. The component sub-networks are summarised in Table 7.1.

Table 7.1 Summary of what is measured in the United Kingdom Eutrophication and Acidifying Atmospheric Pollutants (UKEAP) Network.

Sub network	Components measured	Instrument type	Comment
Rainwater composition	Major ions, including SO_4, NO_3, NH_4, Ca, Mg, Na, Cl, K and pH.	Collection by bulk collector. Analysis of samples by ion chromatography and pH probe	38 bulk sampling sites. Wet only collectors at two EMEP super sites (Auchencorth Moss and Harwell)
Ammonia	NH_3	Mixture of passive samplers and Delta (low volume active denuder) sampler.	Ammonia concentrations measured at about 90 sites throughout UK- but are located predominately in agricultural areas with intensive livestock farming.
Rural NO_2	NO_2	Palmes diffusion tube	24 sites. Provides rural concentrations at locations not covered by rural automatic monitoring
Acid gas ammonia and aerosol components	SO_2, HNO_3, HCl, NH_3, SO_4^{2-}, NO_3^-, Cl^-, Na^+, Ca^{2+}, Mg^{2+}	Delta sampler consisting of denuder and filter pack	30 sites. The Delta* superseded the SO_2 'bubbler' instrument

* *The Delta sampler is a low cost robust monitoring method developed by the Centre for Ecology and Hydrology*

A broader context to the work

It should be recognised that the monitoring of atmospheric acidifying species is only a part of the broader research effort needed to understand and hence combat acidification and eutrophication. Other research work funded by UK Government and the Devolved Administrations aims to:

- Quantify sulphur and nitrogen deposition, both for current case and future scenarios by using long-range transport models;
- Quantify the cost and benefits of various abatement strategies;
- Calculate the exceedence of critical loads;
- Improve UK critical load and dynamic models.

Other reasons for monitoring acid deposition

As well as needing to inform policy makers in the United Kingdom as to the impact that emission controls may have on acid deposition, the transboundary nature of acid deposition means that controlling deposition needs concerted efforts at the international level. The United Kingdom signed the Convention on Long-Range Transboundary Air Pollution (LRTAP) in 1979, agreeing to its commitments to monitor, assess and control acidifying emissions and impacts.

7.2 What the Acid Rain Network has shown us

Changes in emissions

As monitoring continued during the 1980's, 1990's and 2000's emission inventory compilation techniques improved considerably. Figure 7.3 shows a long-term time series of UK national emissions for sulphur dioxide, oxides of nitrogen and ammonia. Such information allows policy makers and scientists to understand how socio-economic and legislative drivers have effected emissions.

It is interesting to note from this figure that sulphur dioxide emissions decreased substantially with:

1. The introduction of gas-fired power stations in the early 1990's and
2. The installation of flue gas desulphurisation abatement to the larger coal-fired power stations.

Figure 7.3 also shows that oxides of nitrogen emissions declined due to:

1. The introduction of catalysts for petrol cars
2. General improvements in engine design
3. Better regulation of industrial plant.

However, the decline in oxides of nitrogen emission has been significantly less than that for sulphur dioxide. Ammonia emissions have decreased slightly compared to the other two pollutants.

Similar large-scale reductions in emissions were observed throughout Europe, reflecting the concerted international effort to control the transboundary nature of acid rain.

How have concentrations changed in response to falling emissions?

Figure 7.4 shows:

- The total annual sulphur dioxide emission from 1986 to 2007
- Network average sulphur dioxide concentration from 1988 to 2007 (please note that the concentration scale has been multiplied by 5 to allow plotting on the same axis as the sulphur in rainwater concentration).

- Network average volume weighted mean sulphur concentration measured in the rain samples.

It is clear from this figure that network-wide UK SO_2 concentration has declined linearly and tracked very closely with emissions; however, corresponding sulphate concentrations in rainwater have fallen more slowly.

This suggests a non-linearity in response to emissions- it is important to understand why this occurred. Possible reasons could include:

- The use of the bulk collector to collect rainwater; these are prone to contamination by dry deposition- this may have masked a reduction in sulphate in rainwater concentration, particularly when the ambient sulphur dioxide concentration was much higher than current concentrations or
- There have been changes in the oxidative capacity of the atmosphere; more oxidant is available to convert available sulphur dioxide to sulphate, hence it is removed faster than previously.

Spatial variability of acidifying species

It should be recognised that the use of network average data may mask variations in trends at the local or regional level. The contour maps presented in Figure 7.5 therefore compare the trends in concentration for the main pollutants contained in rainwater that contribute to acidification and eutrophication. Each map shows the change in concentrations (measured in terms of µeq l^{-1} $year^{-1}$) for those sampling sites where there was long-term monitoring. For example, at Bottesford in the East Midlands (Map 2), the average reduction in sulphate concentration was 3.2 µeq l^{-1} $year^{-1}$, whereas at Lough Navar in western Northern Ireland the sulphate reduction was only 0.5 µeq l^{-1} $year^{-1}$.

The maps for sulphate (SO_4^{2-}, map 2) and hydrogen ion (H^+, map 1) are similar and show that the decline in rainwater concentrations of these species was greatest for sampling sites located close to the major power stations. This is not surprising.

Nitrate (NO_3^-) concentrations (map 3) also fell at sites close to emission sources but, elsewhere, the decrease was even less pronounced that for the non-sea salt sulphate and hydrogen ion. In the far southwest, there is some indication that concentrations have actually increased over the long term – but these trends are not statistically significant

Ammonium (NH_4^+) concentrations in map 4 show significant inter-year variability compared to SO_4^{2-}, NO_3^- and H^+. The rate of decline for ammonium is different compared to the sulphate, nitrate and hydrogen ions; there is no smooth gradation in trends away from the power station region. Ambient ammonia is significant source of contamination in rainwater samples.

7.3 Summary

The acid deposition network was in operation during major advancements in the science and techniques to quantify and control the impact of acid deposition. For example, there were improvements in:

- The science of understanding how acid deposition causes geochemical changes in sensitive soils;
- Emission inventory compilation to allow accurate reporting of emissions;
- Modelling the processes by which the pollutants are transported and transformed and finally deposited to the earth's surface.

In its 23 years of operation, the acid rain network has exploited these advances fully.

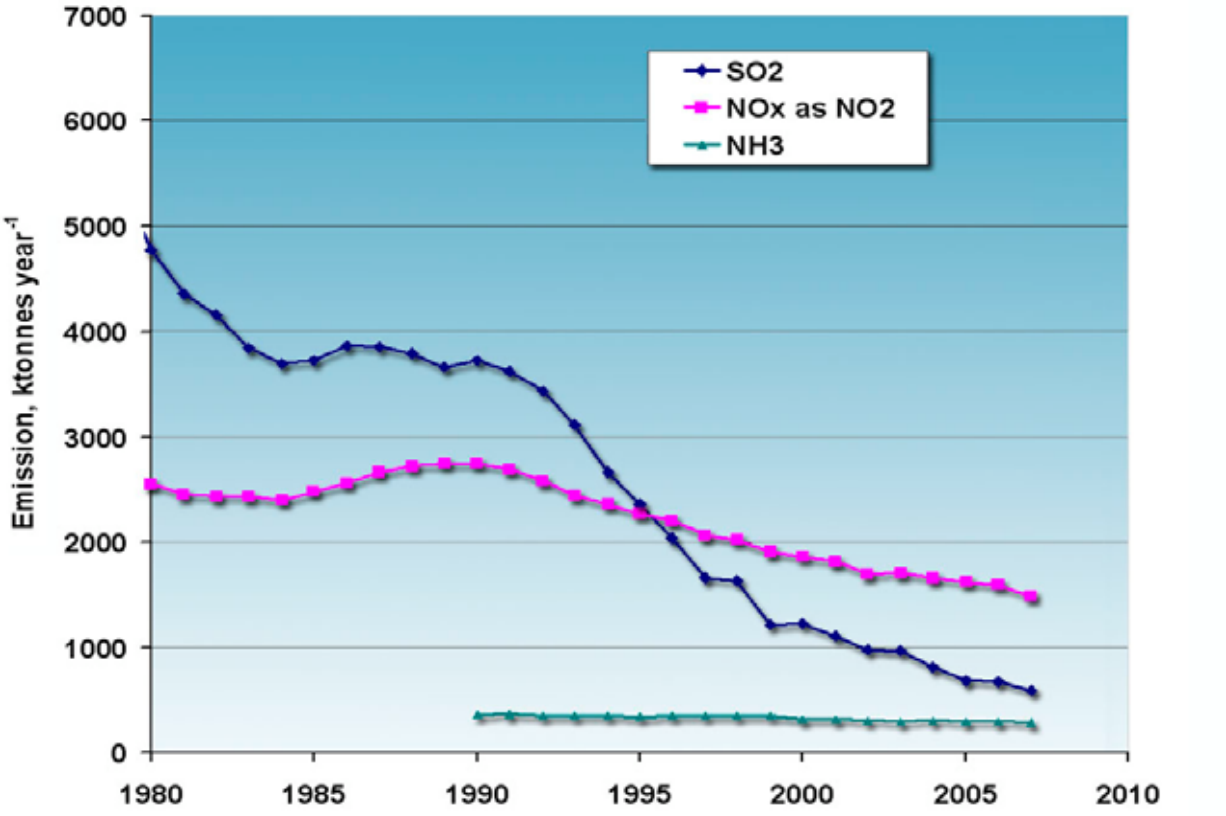


Figure 7.3 Time series of UK SO_2, NO_X and NH_3 emissions

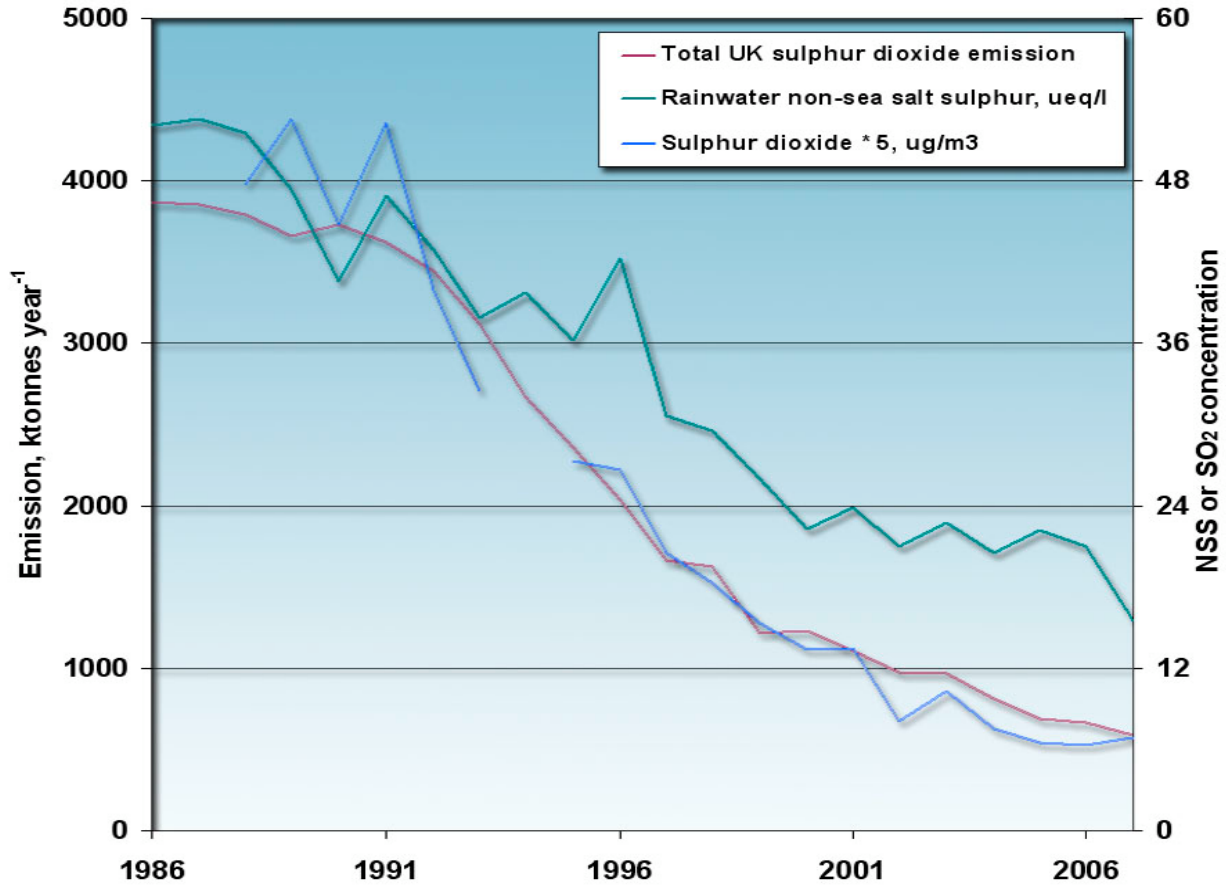


Figure 7.4 Time series showing the decrease in rainwater sulphur concentrations, ambient sulphur dioxide and annual sulphur dioxide emissions during the lifetime of the acid deposition network.

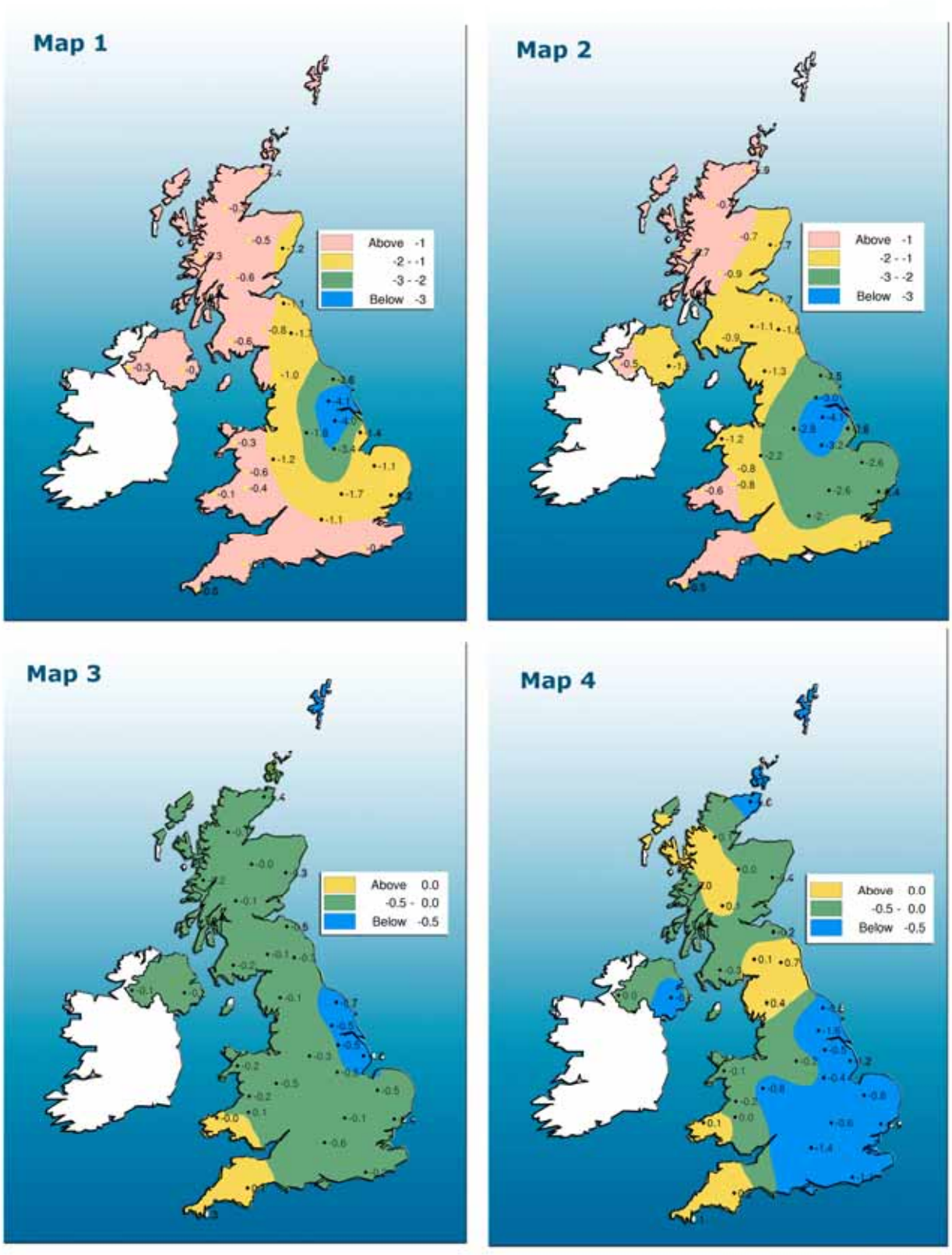


Figure 7.5 How spatial pattern of acidification have changed over time:

Map 1 Changes in H^+ (hydrogen ion) concentrations in rainwater, 1986- 2007
Map 2 Changes in SO_4^{2-} (sulphate) concentrations in rainwater, 1986- 2007
Map 3 Changes in NO_3^- (nitrate) concentrations in rainwater, 1986- 2007
Map 4 Changes in NH_4^{2-} (ammonium) concentrations in rainwater, 1986- 2007

Please note: 1) All data graphed in μeql^{-1} year $^{-1}$ 2) Each figure on the maps is the regression coefficient generated when a regression line is drawn through the annual averages collected at each site

Its achievements and main findings may be summarised as follows:

1. The acid rain monitoring network was initially established to show how rainwater composition, levels of acidifying gases and particulates might change in response to reductions in emissions; however, it has since evolved to include assessing the impact of eutrophying pollutants.
2. The monitoring occurred during a time of significant reductions in emissions from combustion sources – particularly emissions from power stations, large industrial plant and road transport.
3. Rural sulphur dioxide and nitrogen dioxide concentrations have declined markedly, in line with emissions.
4. Sulphate concentrations in rainwater also declined, but it is difficult to assess whether the fall can be considered linear with relation to the decline in emissions.
5. Nitrate concentrations in rainwater have fallen less than the sulphate concentrations; there is evidence that concentrations have increased in the southwest of England.
6. The monitoring programme is part of the United Kingdom's ongoing contribution to the UNECE Convention on Long-range Transboundary Air Pollution.
7. The measurement data have substantially aided the development of long-range transport models, such as the EMEP Unified Model, used for carrying out European-scale impact assessments.
8. There is evidence that recovery is occurring for some sensitive lakes and streams; however, due to other factors such as climate change, ecosystems may not return to pre-industrial conditions.

Figure 7.6 Our target- clean, sustainable ecosystems and fresh water resources throughout the UK (PhotoDisk Stock)

8 A broader perspective on UK Air Pollution

How does air pollution in the UK compare with other parts of the world? This is a topic we examined for the first time in the 2006 report. Here we extend that initial assessment, focussing on our European neighbours.

8.1 Introduction

Previous sections in this report, and previous reports in this long-running series, have focussed exclusively on UK-based air pollution issues and measurements. However, it is a reasonable question to ask how pollution levels here compare with those in other parts of the world- in fact, we get asked this question quite a lot!

This is not altogether a straightforward question to answer, however. There are differences in national climates, measurement techniques, siting criteria and other factors, which all complicate the comparisons.

The best way of obtaining meaningful comparisons is to use data from countries that are broadly comparable in terms of measurement methodology, siting philosophy and measurement quality. Fortunately, the European Union's Air Quality Framework and Daughter Directives (discussed at length in Section 2.1) have substantially improved the degree of harmonisation and comparability between air quality measurements made in different Member States of the European Union.

We have chosen, therefore, in this section to compare current UK levels of key pollutants- PM_{10} particles, ozone, nitrogen dioxide and (for the first time) $PM_{2.5}$ - with corresponding measurements throughout Europe. We also compare UK trends in air quality since 1997 with corresponding changes throughout Europe.

The indicator statistics for these pollutants are precisely those presented and analysed in the previous section:

- Gravimetric PM_{10} annual mean
- Gravimetric $PM_{2.5}$ annual mean
- Ozone annual mean of the daily maximum running 8-hour mean
- NO_2 annual mean

Why have we selected these pollutants in particular? This is primarily because long-term exposure to particles and ozone are now believed to pose the most significant threats to public health in UK and throughout Europe. NO_2 levels are also included; these are strongly connected with those for ozone. Moreover, as we have seen in Section 6, levels of this pollutant appear to be rising steadily at near-road locations, and remain well above objective.

For these comparisons, data have been obtained from AirBase, the public air quality database system of the European Environment Agency; this currently contains air quality information contributed by participating countries throughout Europe, extending up to 2007. Airbase can be found at http://air-climate.eionet.europa.eu/databases/airbase/; data can be freely retrieved using AirView, a web-based system enabling interactive access and download of information from a wide range of EU states and EEA participants: http://air-climate.eionet.europa.eu/databases/airbase/airview/index_html

It is important to note, however, that the datasets for some Member States are more complete than others. Despite the degree of caution necessary in interpreting these early analyses, we hope that you will find the results of interest.

8.2 European particle (PM_{10}, $PM_{2.5}$) levels

Gravimetric PM_{10} annual means have been analysed separately for two key location types: Roadside and Urban and Suburban Background stations- see Figures 8.1 to 8.4.

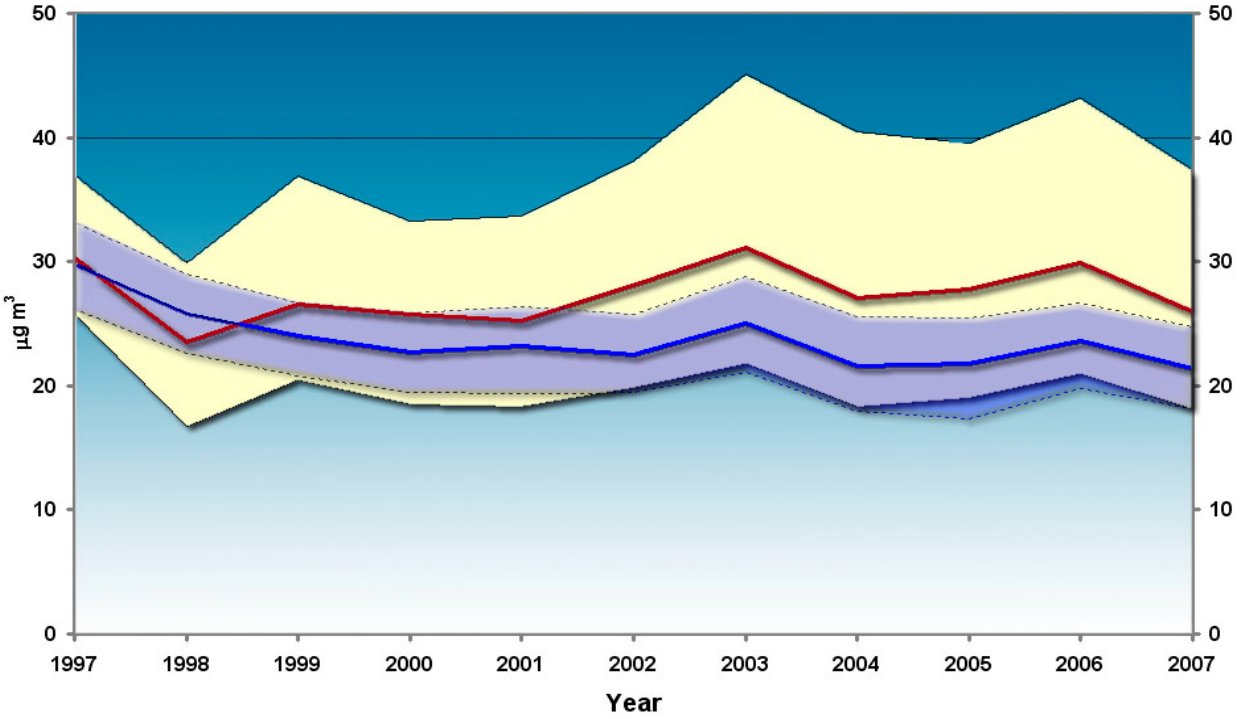


Figure 8.1 Comparison of UK urban and suburban background PM_{10} levels (blue line and blue shaded area) with European averages (yellow, with red line as EU average): 1997 to 2007. Ranges shown from 10th to 90th percentile values.

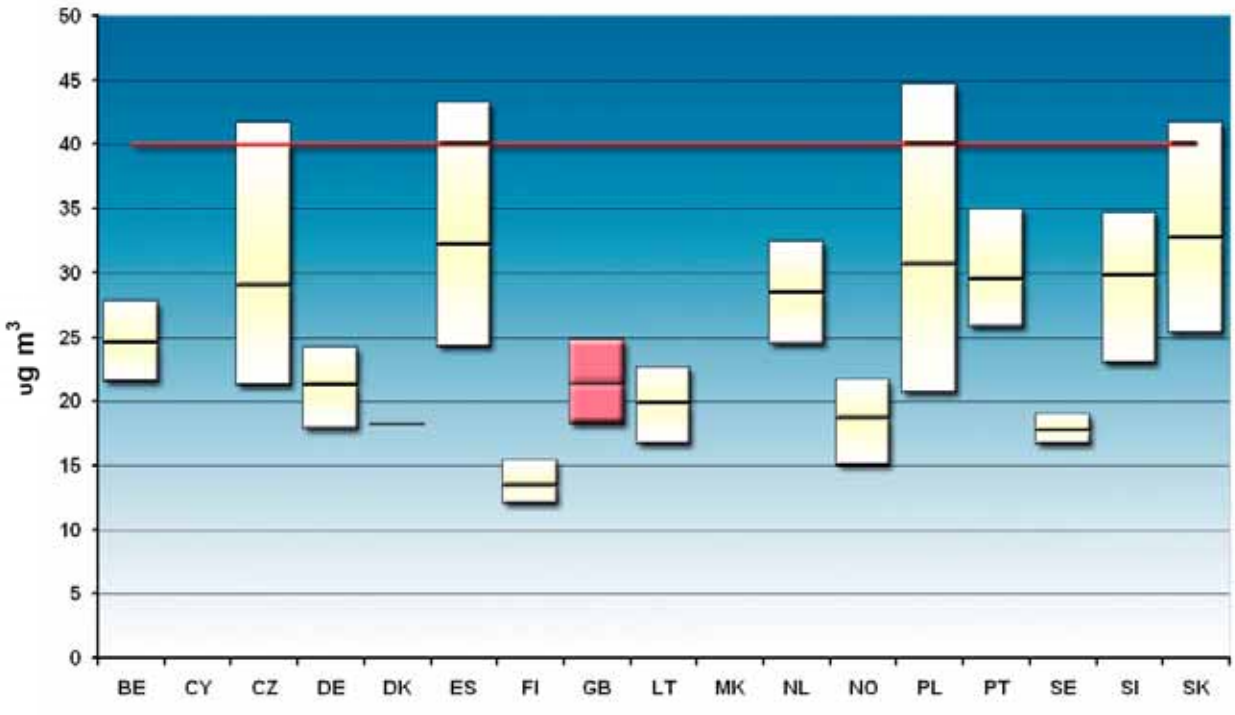


Figure 8.2 Comparison of UK urban background PM_{10} levels (red) with other European Member States (yellow) for 2007. Ranges shown from 10th to 90th percentile values.

Figure 8.1 shows annual mean PM_{10} levels across urban and suburban background stations in the UK from 1997 to 2007: 90th percentile, mean and 10th percentile levels are graphed in blue. By way of comparison, the corresponding EU-wide statistics (15 Member States, 2700 sites) are shown in yellow. The blue and yellow shaded areas therefore broadly represent the range of measured PM_{10} annual average levels in urban background areas across the UK and throughout Europe (in the Member States analysed) over the last eleven years.

Figure 8.1 clearly shows that current annual means for PM_{10} across urban and suburban background stations in the UK tend to lie well below the EU average. It was not always so: in 1997 and 1998, UK and EU levels appeared broadly similar. Since then, however, the 90th percentile of UK measurements (that is, the level exceeded by only the top 10% of measurements) has been around or below the mean of corresponding EU data. This is consistent with the analysis carried out in previous years.

Note also from Fig 8.1 the similarities in background trends across Europe. As well as the peaks in all data in 2003 and 2006 (due to unusual 'heat waves' experienced in those summers, as highlighted in previous reports) trends are similar for the rest of the years.

Figure 8.2 compares UK background PM_{10} concentrations with those of individual EU countries for the latest year of measurements available in AirBase- 2007. UK data are shown in red, with upper and lower ranges denoting the 10th and 90th percentile measurements respectively, and the middle line showing the mean.

This figure reinforces the observations summarised in Figure 8.1. It shows that the UK PM_{10} levels in 2007 were broadly similar to those in other northern countries like Germany, Lithuania, Sweden and Norway, but markedly lower than those in most of other states including the Netherlands, Czech Republic, Poland, Portugal Slovakia and Spain.

How can this be explained? A number of factors may be involved:

- Differing particle measurement techniques in UK and Member States of the European Union.
- Our milder, wetter climate; this tends to lead to less dusty conditions and less re-suspension of particles than in the relatively hotter and drier southern and Mediterranean countries.
- The fact that UK urban background measurements are often made in relatively green city park areas; such urban background environments are relatively less common in some EU states.

The corresponding PM_{10} data for roadside environments, shown in Figures 8.3 and 8.4, show interesting differences from those for urban and suburban background sites. This might be expected; after all, roadside environments are more homogeneous throughout Europe than corresponding urban background areas.

Figure 8.3 shows very little systematic long-term trend over time in levels throughout UK or Europe (15 states, 1500 sites). More significantly, however, UK and EU-wide mean PM_{10} measurements at roadside sites are similar – this is markedly different from corresponding observations for background locations. This lends support to the possibility that UK urban and suburban background measurement sites may be representative of different generic location types from those in other EU Member States.

Figure 8.4 tells a similar story; UK roadside PM_{10} levels in 2007 are broadly similar to those in many European countries. Clear differences are apparent for some Central/Eastern states however - Poland in particular – where older, comparatively 'dirtier' vehicle fleets and industrial emissions from older plants appear responsible for the markedly higher particle measurements. These results are similar to previous years.

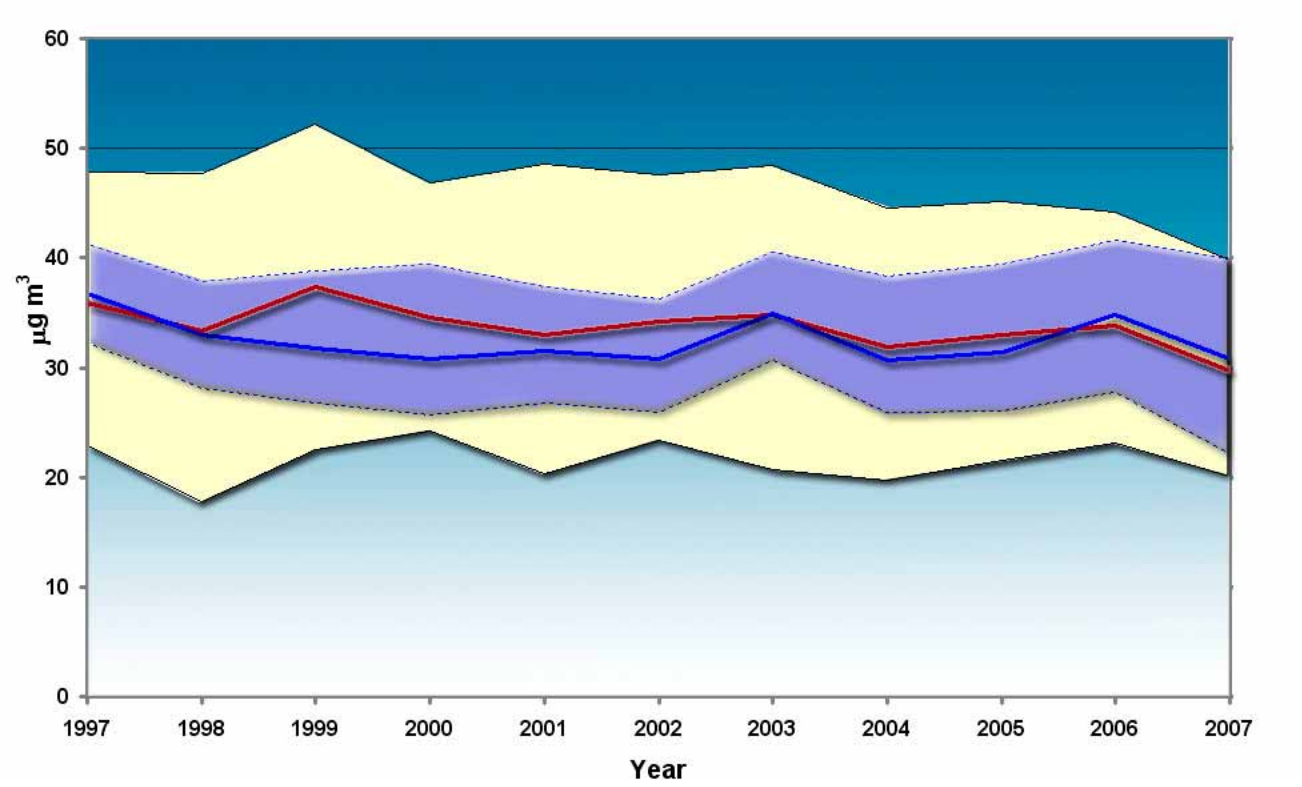


Figure 8.3 Comparison of UK roadside PM_{10} levels (blue line and shaded area) with European Averages (yellow, with red as EU average): 1997 to 2007

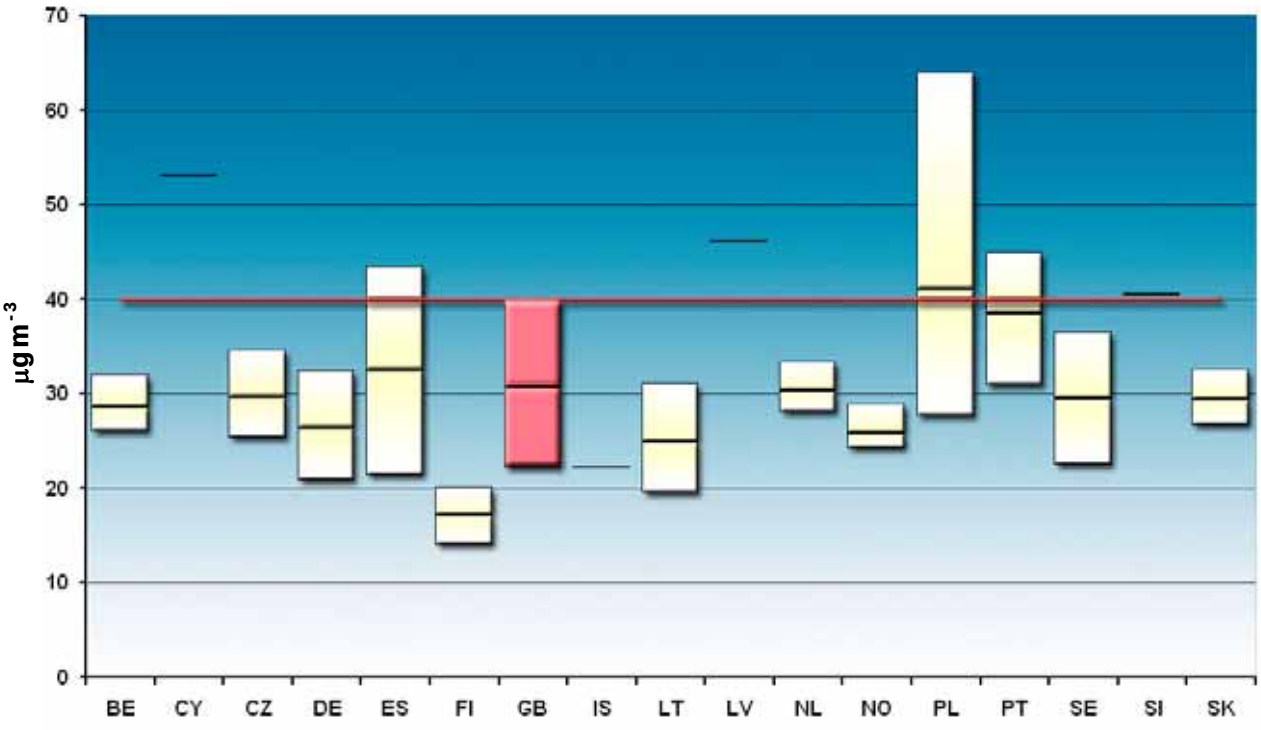


Figure 8.4 Comparison of UK roadside PM_{10} levels (red) with other European Member States (yellow) for 2007

This year, due an increase of data availability and the new EU legislation regarding $PM_{2.5}$, we have introduced a new analysis comparing $PM_{2.5}$ levels across different member states. Comparison for 2006 and 2007 (Figures 8.5, 8.6) show that $PM_{2.5}$ levels in UK are somewhere in the middle of the range measured in Europe. The UK's annual mean urban background concentrations are lower than those of Belgium, Czech Republic, Germany, Spain and Slovakia, but higher than those of Denmark, Finland, Norway, Portugal and Sweden. No trend analysis for this newly measured pollutant is possible, of course.

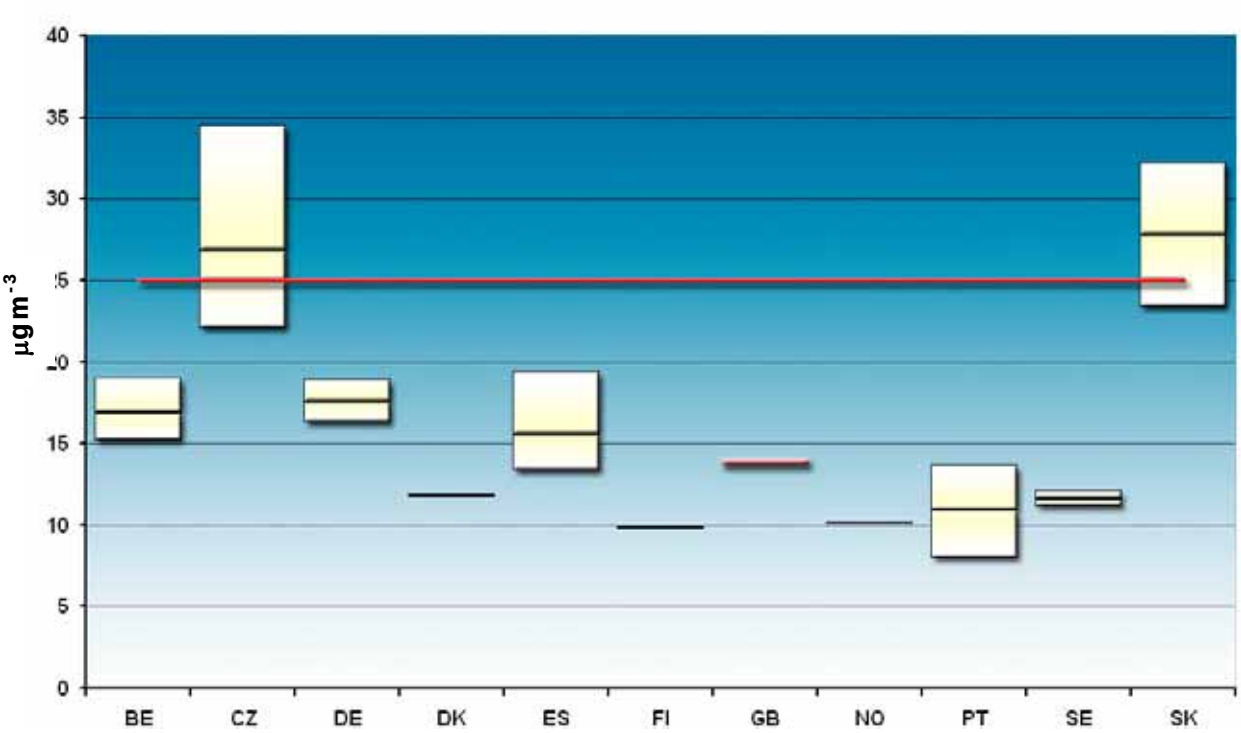


Figure 8.5 Comparison of UK urban and suburban background $PM_{2.5}$ levels (red) with other European Member States (yellow) for 2006

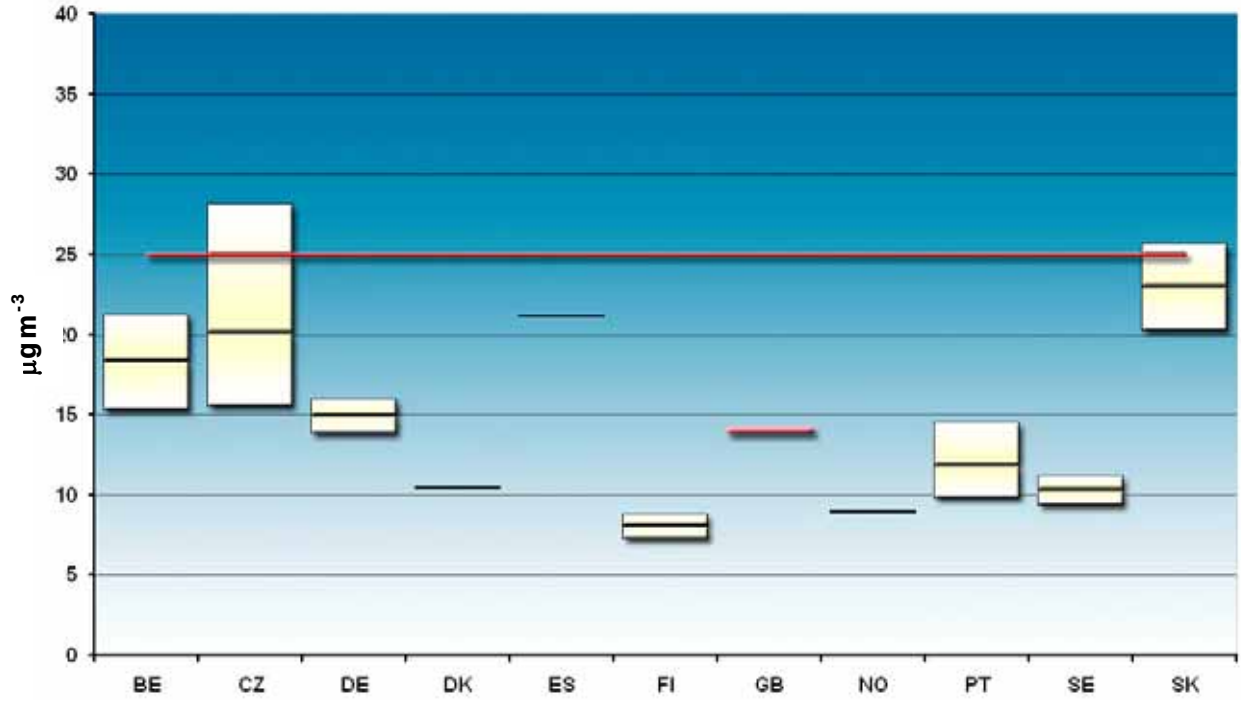


Figure 8.6 Comparison of UK urban and suburban background $PM_{2.5}$ levels (red) with other European Member States (yellow) for 2007

8.3 European ozone (O_3) levels

We have repeated the analyses of the previous section for another key pollutant – ozone. O_3 levels have been examined for both urban background and rural environment types. The annual mean of the daily maximum running 8-hour mean is used here as indicator.

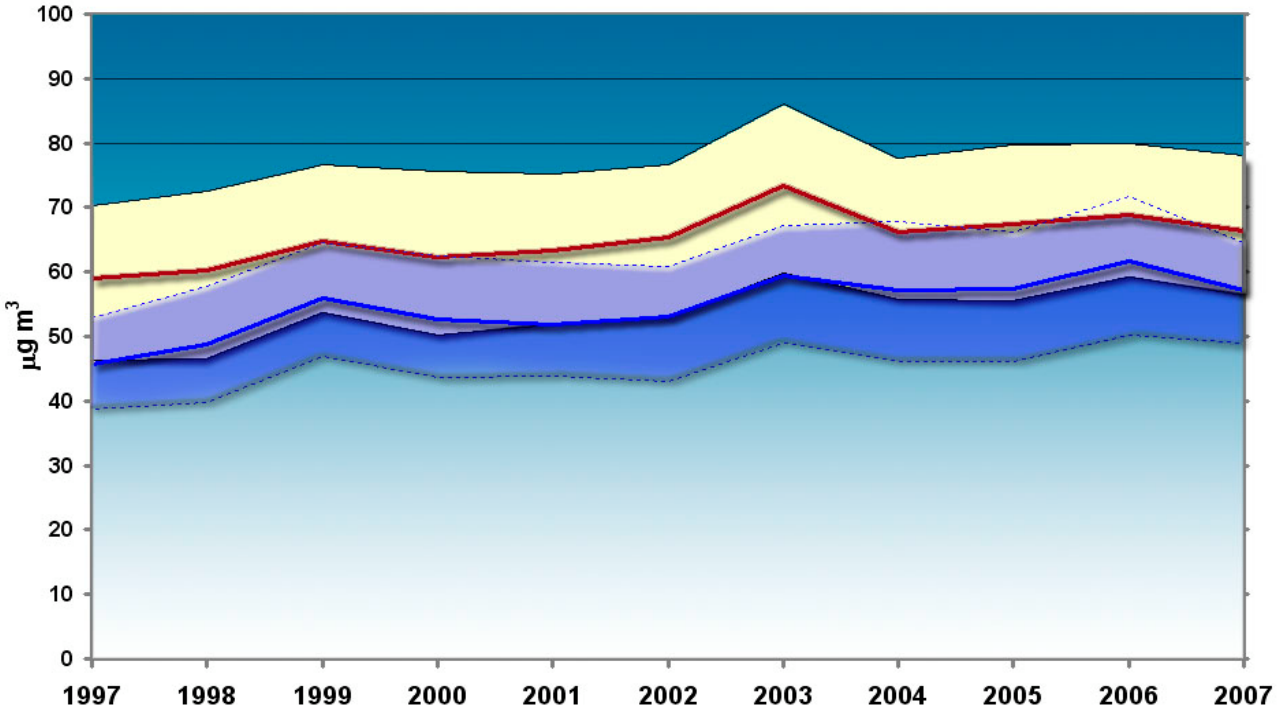


Figure 8.7 Comparison of UK urban and suburban background O_3 levels (blue line and blue shaded area) with European Averages (yellow, red line as EU average): 1997 to 2007

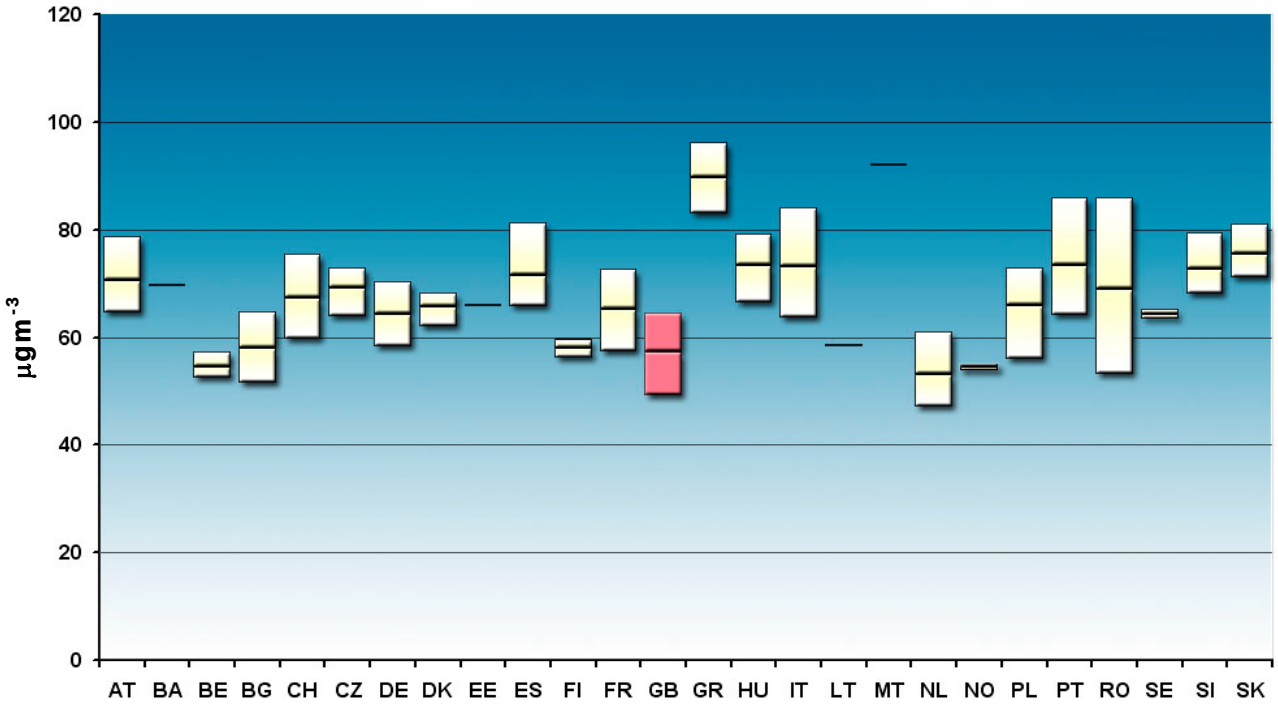


Figure 8.8 Comparison of UK urban and suburban background O_3 (red) with other European Member States (yellow) for 2007

Figure 8.7 shows 10th percentile, mean and 90th percentile 0_3 levels at UK urban and suburban background monitoring stations to be consistently below those throughout Europe. There is also evidence of a rising trend in levels at all locations from 1997. Not surprisingly, the 2003 and 2006 'heat wave' summer peaks are strongly evidenced again.

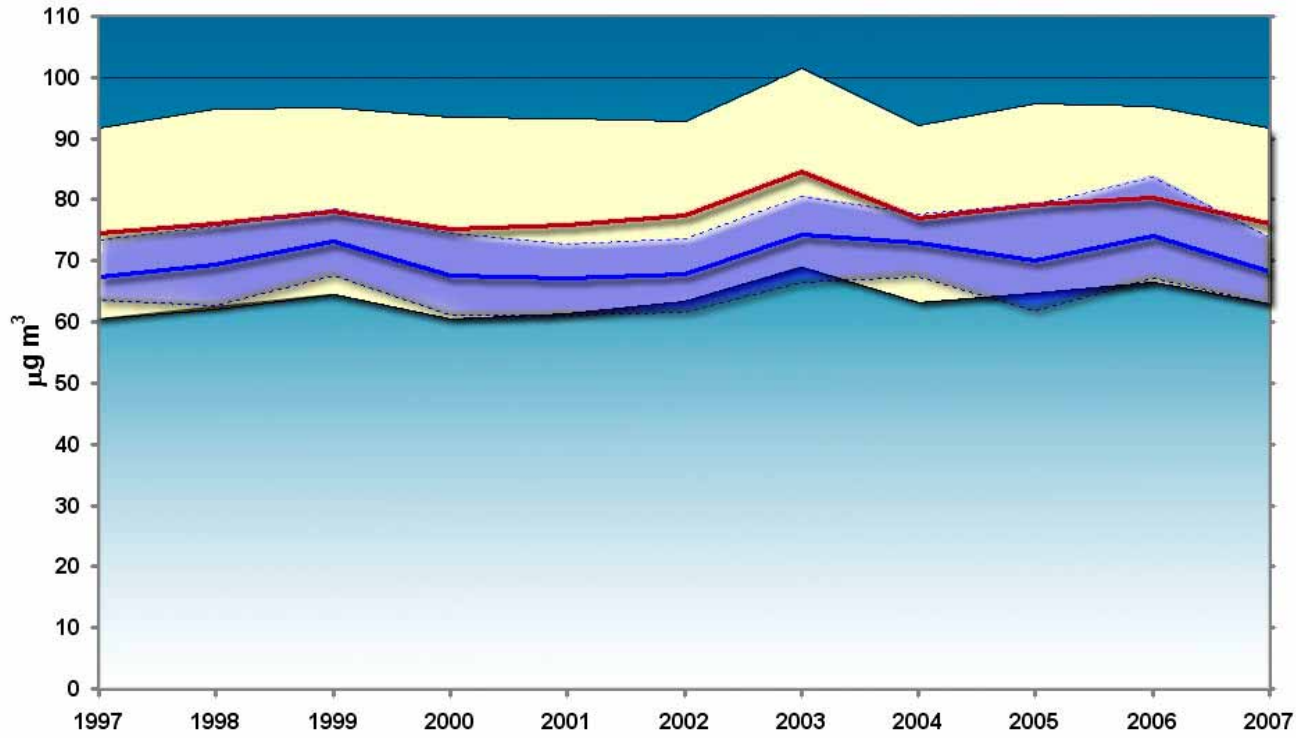


Figure 8.9 Comparison of UK rural O_3 levels (blue line and shaded area) with European Averages (yellow, with red as EU average): 1997 to 2007

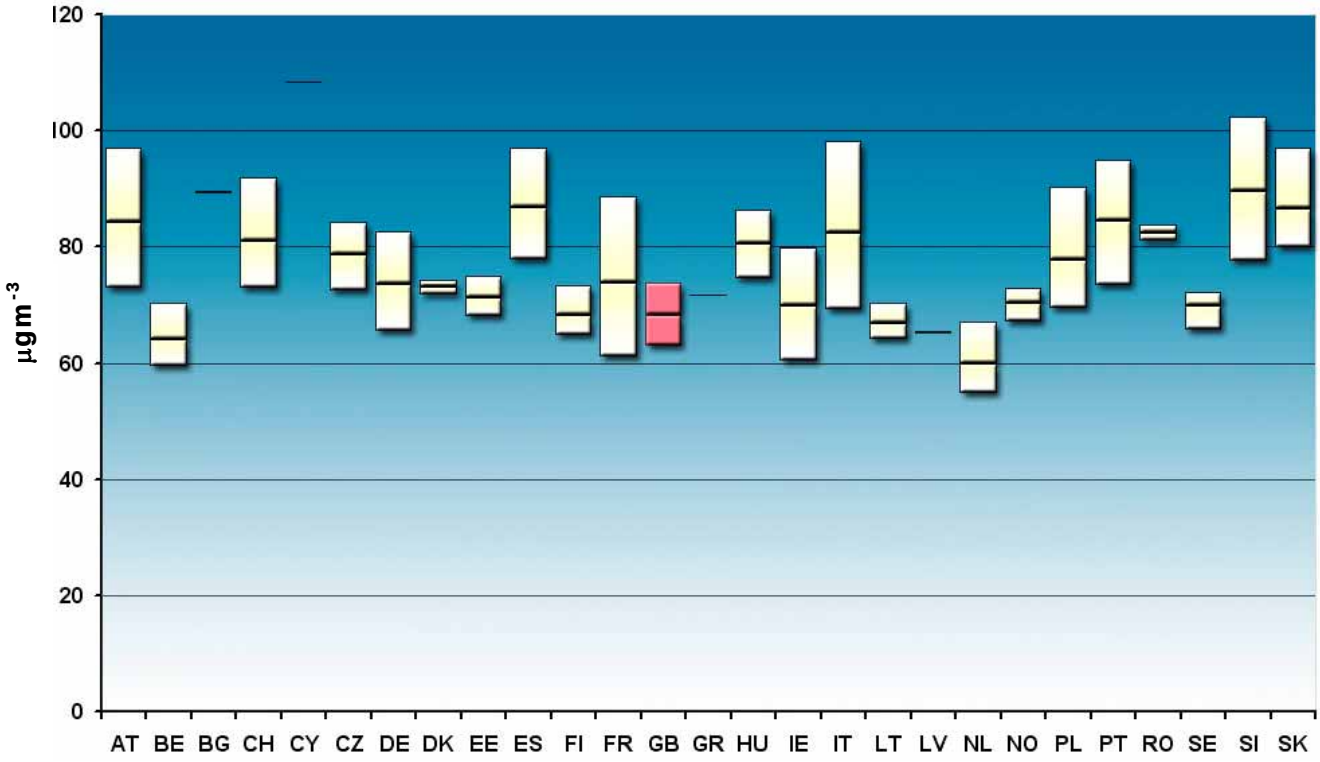


Figure 8.10 Comparison of UK rural O_3 (red) with other European Member States (yellow) for 2007

Examining 2007 measurements in greater detail (Figure 8.8) shows UK urban ozone levels to be similar to those European states such as the Belgium, Bulgaria, the Netherlands, Norway and Latvia, but considerably lower than in most EU countries including Austria, Spain, France, Greece, Hungary, Italy, Portugal and Slovakia.

Geographical location, climate (sunshine and temperature in particular) and altitude can all have a significant impact on ozone levels. In this context, it is interesting to note the similarities between the UK and neighbouring countries such as Belgium and the Netherlands. Conversely, it is not really surprising to see the highest urban ozone levels in hot Mediterranean countries such as Greece, Italy, Malta, Spain and Portugal.

When it comes to rural ozone levels (Figures 8.9 and 8.10), we again see UK levels to be consistently lower than the EU average. Comparing Figures 8.9 (rural) and 8.7 (urban background) shows an interesting difference however; urban and suburban background ozone levels in UK and throughout Europe are rising, whilst corresponding rural levels of this pollutant are broadly stable. In other words, the gap between rural and urban ozone levels is closing throughout Europe.

In fact, this is readily understandable. The ozone statistics analysed here are not strongly affected by peak episodes, but more a measure of baseline average tendency. Background urban ozone levels are rising throughout Europe. This is because corresponding NO_x emissions from traffic are being increasingly effectively controlled by a range of EU-wide directives and initiatives, bringing about enforced changes to vehicle engines, fuels and control technologies.

NO_x has a chemical scavenging effect on ozone, reducing overall concentrations: therefore lower NO_x emissions from road vehicles now make conditions in urban areas closer to those in the countryside.

8.4 European nitrogen dioxide (NO_2) levels

We examine here another key pollutant- nitrogen dioxide; NO_2 levels have been analysed for both urban background and rural environment types. The annual mean of the 1-hour mean is used here as an indicator.

Figures 8.11 to 8.16 show a comparison of NO_2 levels at rural background, urban and suburban background and roadside sites. In general, rural NO_2 levels across the UK are lower than average in Europe, while urban and suburban background and roadside levels are higher than the European average.

Figure 8.11 shows a long, slow decline in NO_2 levels across Europe. Up until around 2003, rural NO_2 levels across the UK were very similar to the European average. However, in recent years (2004 – 2007, they appear to have been lower than the EU average, remaining so in 2007 (Figure 8.12).

However, this is not the case for NO_2 concentrations at urban and suburban background and roadside sites. NO_2 levels across these sites have been and are in average higher in the UK compared to EU. As shown in Figures 8.13 and 8.14, at urban and background sites the UK, mean NO_2 concentrations are *higher* than the EU averages, by approximately 5 μgm^{-3}. Similarly, at roadside sites, mean UK NO_2 concentrations are higher than the EU roadside averages, by approximately 10 μgm^{-3} (Figures 8.15 and 8.16).

As was the case for the corresponding PM_{10} analyses (Section 8.1), it is possible that the differences observed here between UK and European NO_2 long-term concentrations may be explicable- at least in part – by the fact that UK urban background measurements are often made in relatively green city park areas; such urban background environments are relatively less common in some of the EU Member States examined here.

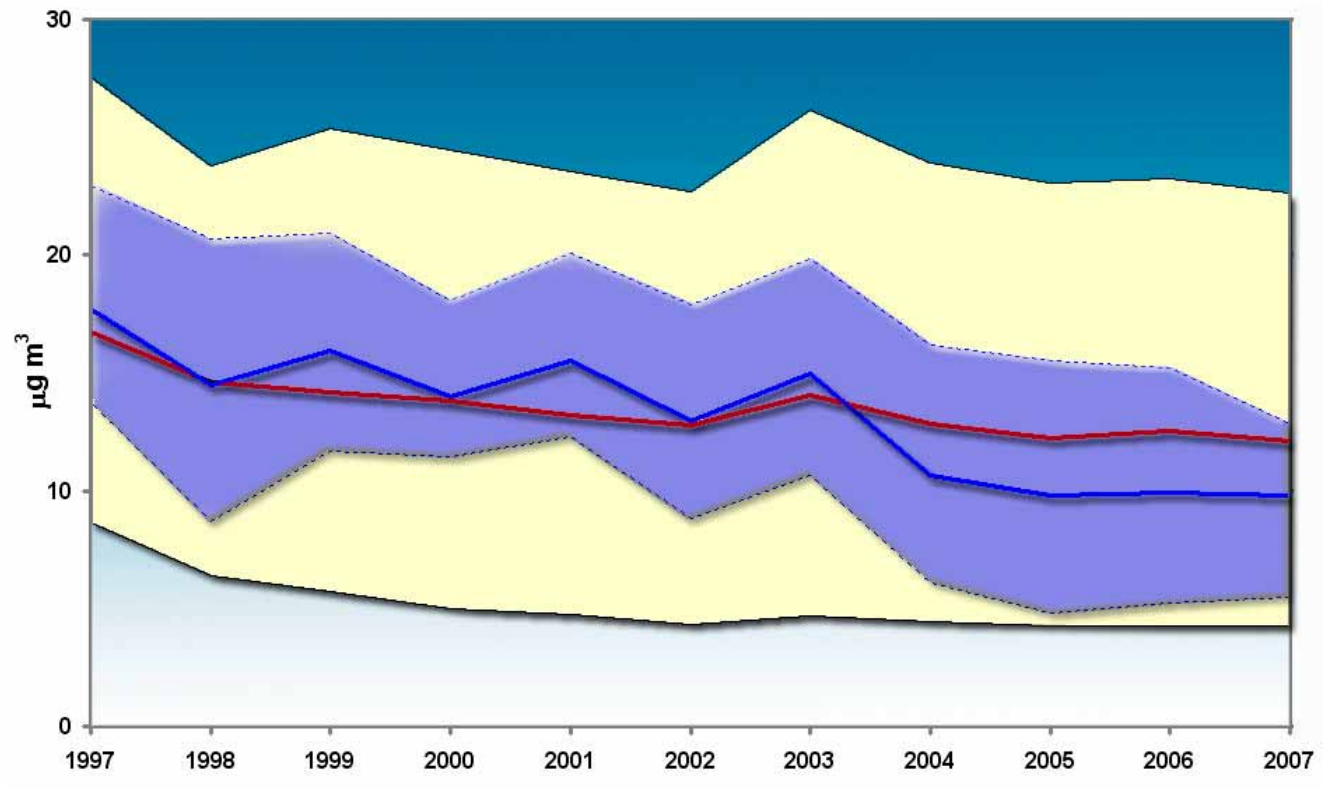


Figure 8.11 Comparison of UK rural NO_2 levels (blue line and blue shaded area) with European averages (yellow, red as EU average): 1997 to 2007

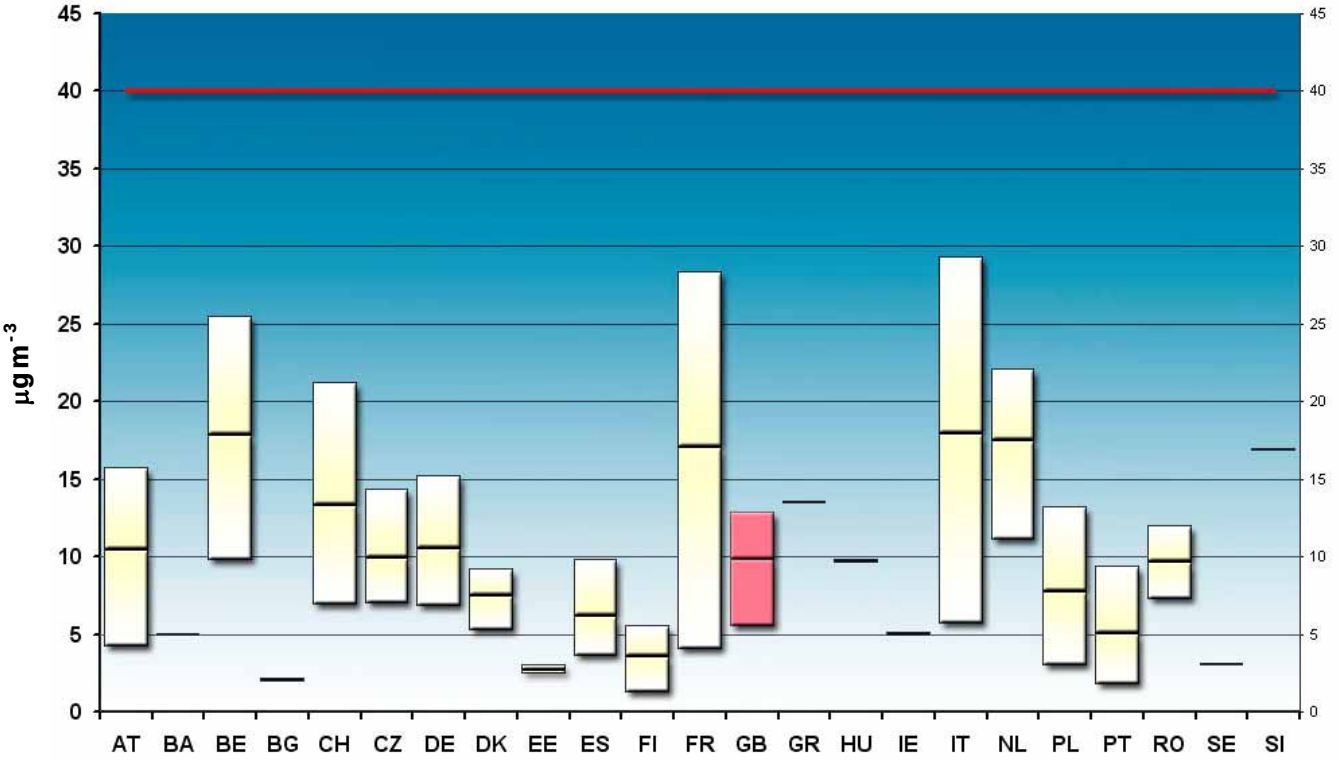


Figure 8.12 Comparison of UK rural NO_2 (blue) with other European Member States (yellow) for 2007

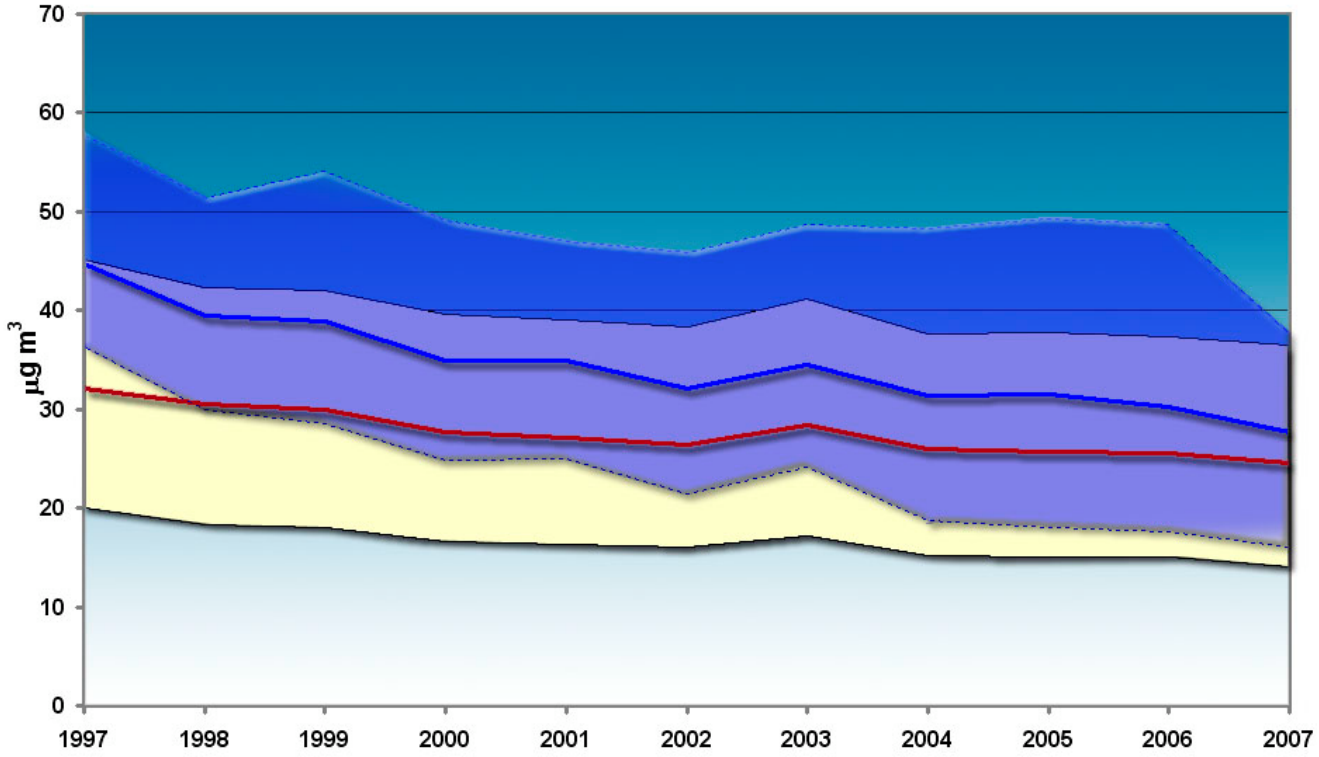


Figure 8.13 Comparison of UK urban and suburban background NO_2 levels (blue line and blue shaded area) with European averages (yellow, red as EU average): 1997 to 2007

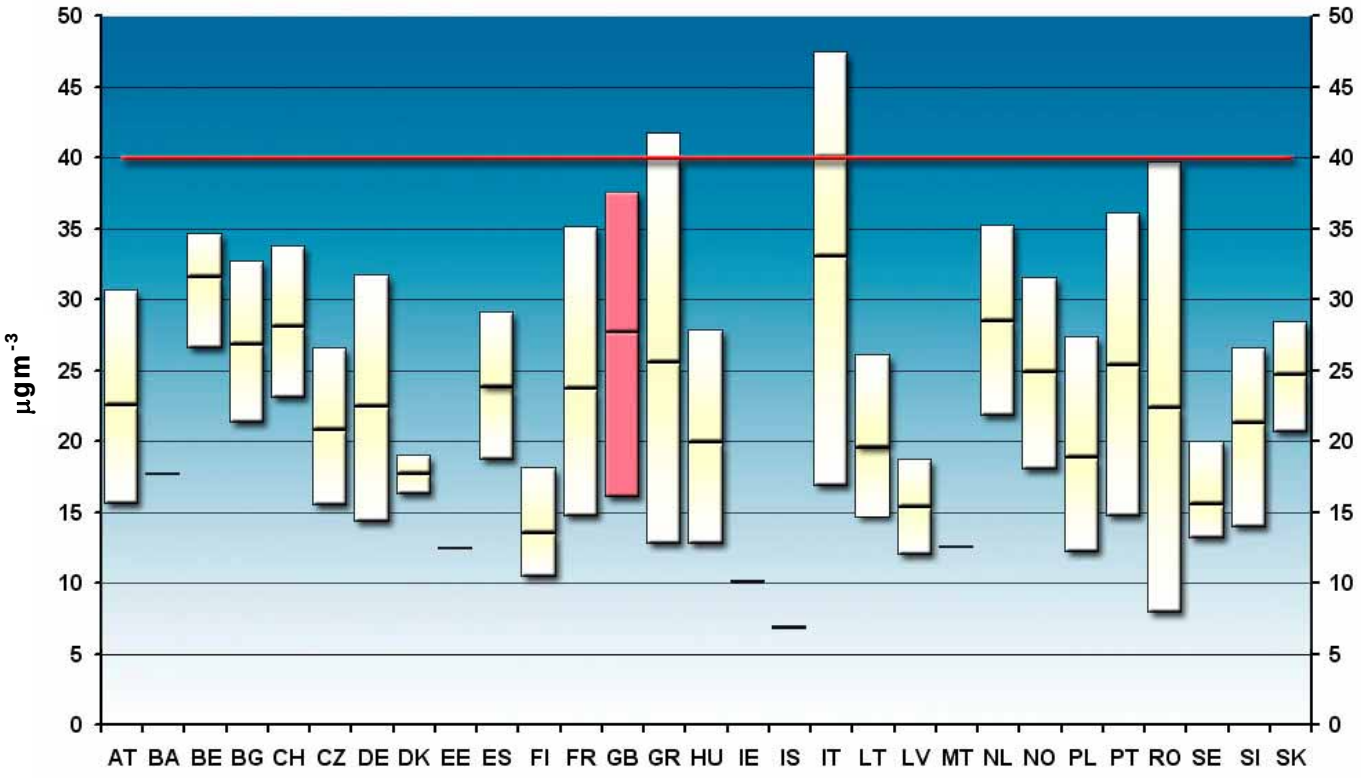


Figure 8.14 Comparison of UK urban and suburban background NO_2 (red) with other European Member States (yellow) for 2007

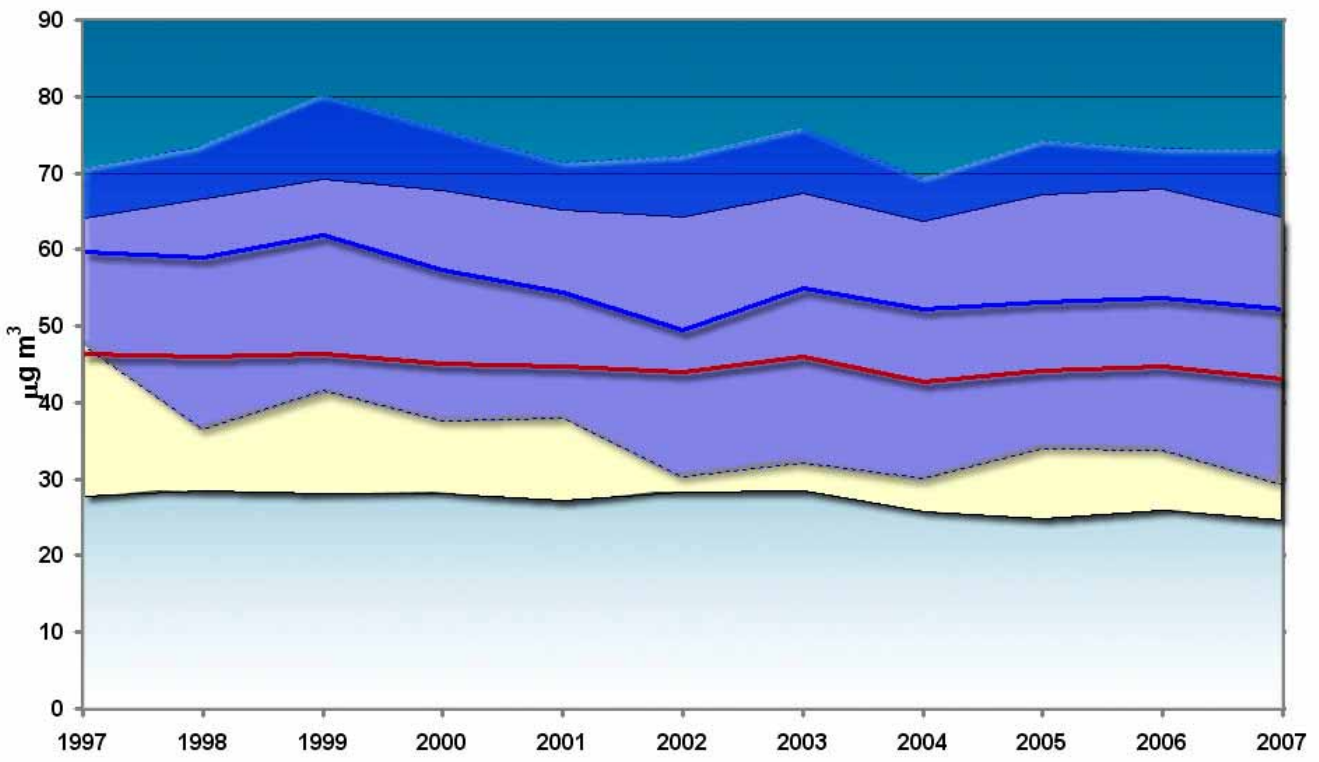


Figure 8.15 Comparison of UK roadside NO_2 levels (blue line and shaded area) with European averages (yellow, red as EU average): 1997 to 2007

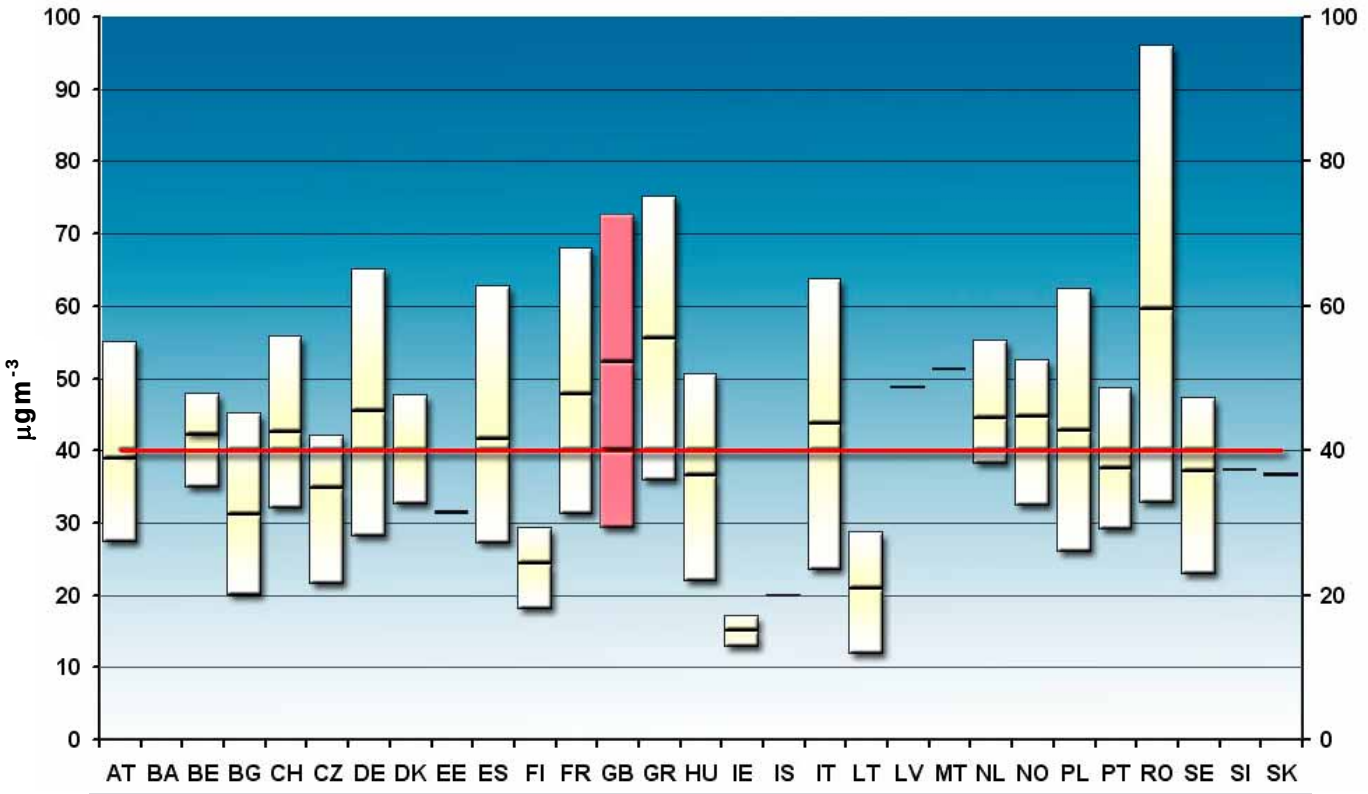


Figure 8.16 Comparison of UK roadside NO_2 (blue) with other European Member States (yellow) for 2006

9 How do I find out more?

Here we provide details of a wide range of sources of further information on the UK's air quality, including media and web-based resources. Presentation and visualisation technologies for air quality data are developing very rapidly, so we also provide details of new and emerging ways of examining and reporting UK's air pollution levels.

9.1 Current UK air quality reporting systems

As we have seen in previous sections, the UK's air monitoring programmes produce very large amounts of data. However, in isolation, these raw data are of very limited utility. We first need to ensure that the data are accurate and reliable; this is a major quality control task, as highlighted earlier in Section 3.5. Once this key activity has been completed, the validated data are archived; useful information can then be derived and communicated to government, technical, local authority and public users in timescales and formats meeting their needs. This high-level process of turning raw data into useful information, depicted in Figure 9.1, is vital to the success of the UK monitoring networks.

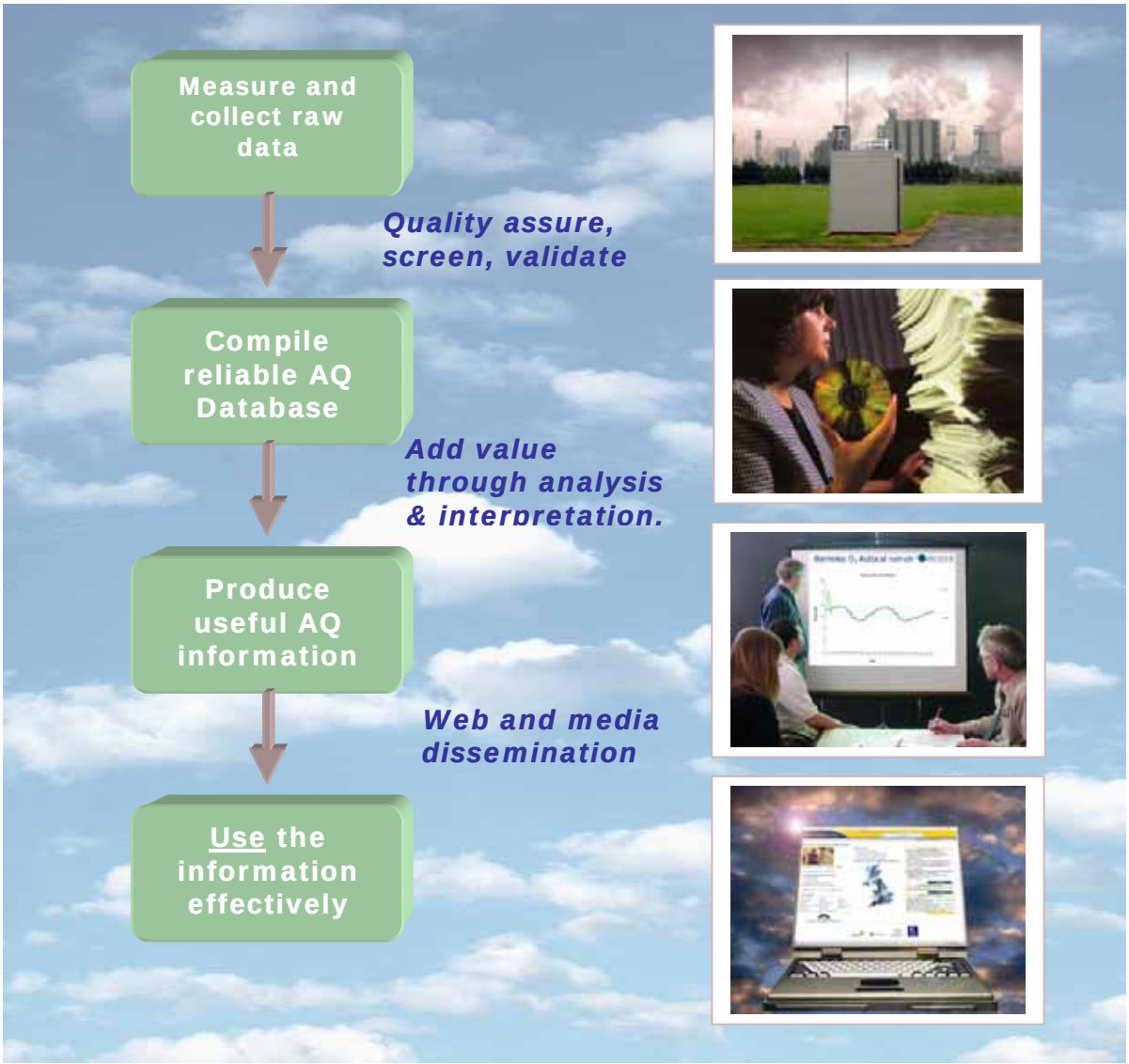


Figure 9.1 This report, as well as the UK Air Quality websites, is a key end-product of the process of turning large quantities of raw air quality data into accurate and user-friendly information

The UK's **Air Quality Archives** and **Air Quality Information Service** are our key tools enabling the widest access and use of air quality information in the UK.

The main functions of these systems are:

1. To inform citizens about the quality of the air we all breathe
2. To provide information to Local Government, for the purpose of planning and Local Air Quality Management (see Section 2.3)
3. To provide public warnings in the event of extreme conditions, as required by a number of EC Directives and Decisions
4. To raise awareness, inform and educate
5. To provide a comprehensive data and information resource to scientists, doctors and epidemiologists, both in UK and worldwide.

The UK's air quality archives and associated information services have evolved over many years to serve this wide diversity of end-user communities and objectives.

As noted in the introduction to this report, a primary objective of the UK's air quality monitoring networks is to provide rapid and reliable air quality information to the public. The Air Quality Information Services provide the main link between the networks and the public at large (see Box 9.1 at the end of this section). Data from all the UK's automatic monitoring stations are automatically collected every hour and uploaded to the UK's Air Quality Archive. Corresponding data from sampler measurements programmes are also collected and merged with the archive. The resulting archive contains over 200 million measurement and statistical records, making it one of the largest publicly accessible online environmental databases in the world.

The UK's Air Quality Archive is also the national repository for historical ambient air quality measurements and emissions data. It contains measurements from automatic measurement programmes dating back to 1972, together with sampler measurements dating back to the 1960s. The Archive brings together into one coherent database both data and information from all the UK's measurement networks, as well as corresponding detailed emission data from the National Atmospheric Emissions Inventory (NAEI).

All data and information stored in the UK's Air Quality Archive are freely available at www.airquality.co.uk The website provides user-friendly but comprehensive access to information on all air pollutant concentrations and emissions, together with up-to-date bulletins and measurements from the UK national monitoring networks. It also provides a twice-daily air quality forecast, which is further disseminated via TV, Teletext, newspapers and a free telephone service on 0800 556677 (Figure 9.2). Finally, the website offers many pages of background information and advice on air quality, together with links to other UK and international information resources. See Box 9.2 for further details of information available from the website. Three areas of this website provide more detailed access to additional information for both public and technical end-users:

1) The external links page at www.airquality.co.uk/archive/related_sites.php
2) The UK air quality research reports database at - www.airquality.co.uk/archive/reports/list.php
3) Access to downloadable previous UK annual reports at - www.airquality.co.uk/archive/annualreport/

Box 9.3 provides details of a matching information resource that was introduced last year, and is specifically designed to meet the needs of Local Government at www.laqmsupport.org.uk. This resource provides advice and good practice guides covering all aspects of local air monitoring, emission inventories, modeling and management. It also offers downloadable tools and data to assist with the entire Local Air Quality Management process.

The UK's national air quality web site currently records over 4,000 hits each day and over 1.5 million every year. It also responds rapidly in providing data and reassurance during

major pollution events. The Archive has become a key resource for education and research. It has received wide praise, both within the UK and internationally. Major re-designs over recent years made further improvements to the navigation, user-friendliness and overall usability of the site, as well as enhancing its accessibility to all user communities.

Fig 9.2 The UK Air Quality Information Service

This utilises a wide variety of media, web and electronic resources to disseminate the latest air quality data and forecasts:

TV Weather Bulletins

TV Teletext

The UK and DA Air Quality Websites

Twice daily web forecasts

A series of brochures & reports

Freephone 0800 556677

The success of the UK Archive has led to the development of similar national archives for Scotland, Wales and Northern Ireland. Following the development of the Welsh Archive in 2004, www.welshairquality.org.uk, the Northern Ireland Archive www.airqualityni.co.uk going live in 2006 and the Scottish Archive www.scottishairquality.co.uk early in 2007, the family of UK Air Quality websites is now complete.

Together, these four national websites provide an unparalleled and comprehensive resource for data and analyses covering all aspects of air quality throughout the UK and all its regions.

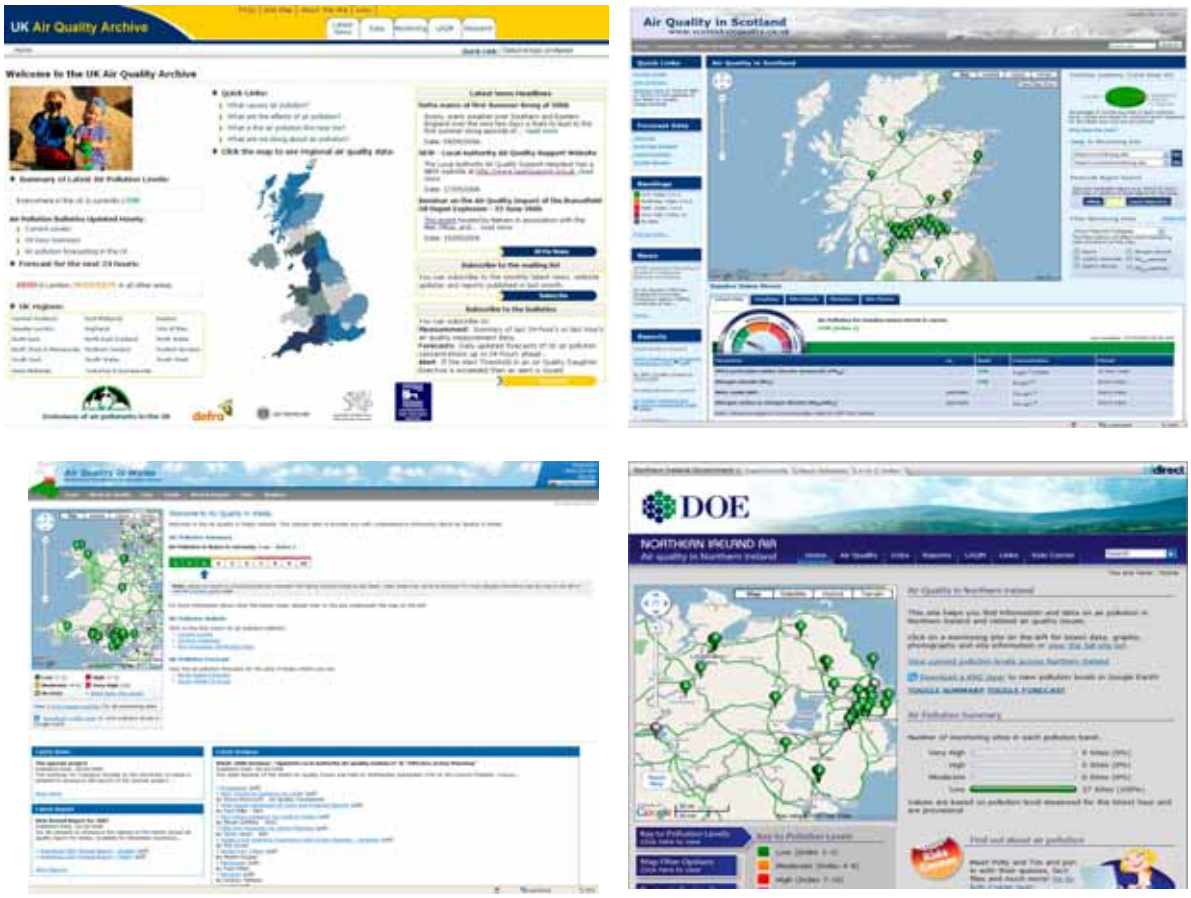


Figure 9.3 The family of UK, Scottish, Welsh and Northern Ireland websites was completed in 2007. The Devolved Administration websites are now developing very rapidly and increasingly serving local needs and aspirations.

Although providing many of the same core services as the UK Archive, the Devolved Administration websites vary in terms of design, features and functionalities.

The Scottish, Northern Ireland and Welsh websites (Figure 9.3) now offer a range of new services including:

- Access to many locally operated monitoring stations not included in the UK national archive; these are subject to QA/QC review comparable to that employed in the national networks.
- Advanced data visualisation and reporting systems based on Google Maps™ (now operational in Scotland, Northern Ireland and Wales)
- New services and functionalities, such as:

- Dedicated educational services for schoolchildren, such as the Northern Ireland Kids' Corner (discussed in last year's report- please see Figure 9.4)
- Interactive on-line discussion forum - Welsh Archive
- New reporting systems under development, including customised websites for PDA/mobile browsing (Scotland)
- SMS text alert system under development for Scotland
- Content management systems allowing site administrators to upload information to, and modify the site content, directly- Northern Ireland
- Postcode search for local air quality- Wales, Scotland, Northern Ireland

These ongoing developments, many of which are discussed later in this section, serve to ensure that these websites are fully customised to meet local needs and aspirations within the Devolved Administrations, as well as providing citizens with the most complete locally-based air quality information and forecasts.

Figure 9.4. The updated Northern Ireland 'Kid's Corner'. Educational web content targeted at schoolchildren is an excellent way of raising awareness in tomorrow's citizens.

9.2 New approaches to air quality reporting

1) Google Earth™ and Google Maps™

The UK and Devolved Administration air quality websites are designed to disseminate information in a direct, user-friendly and intuitive manner. Recent developments to web data presentation and visualisation techniques are now providing ever more powerful ways of doing this.

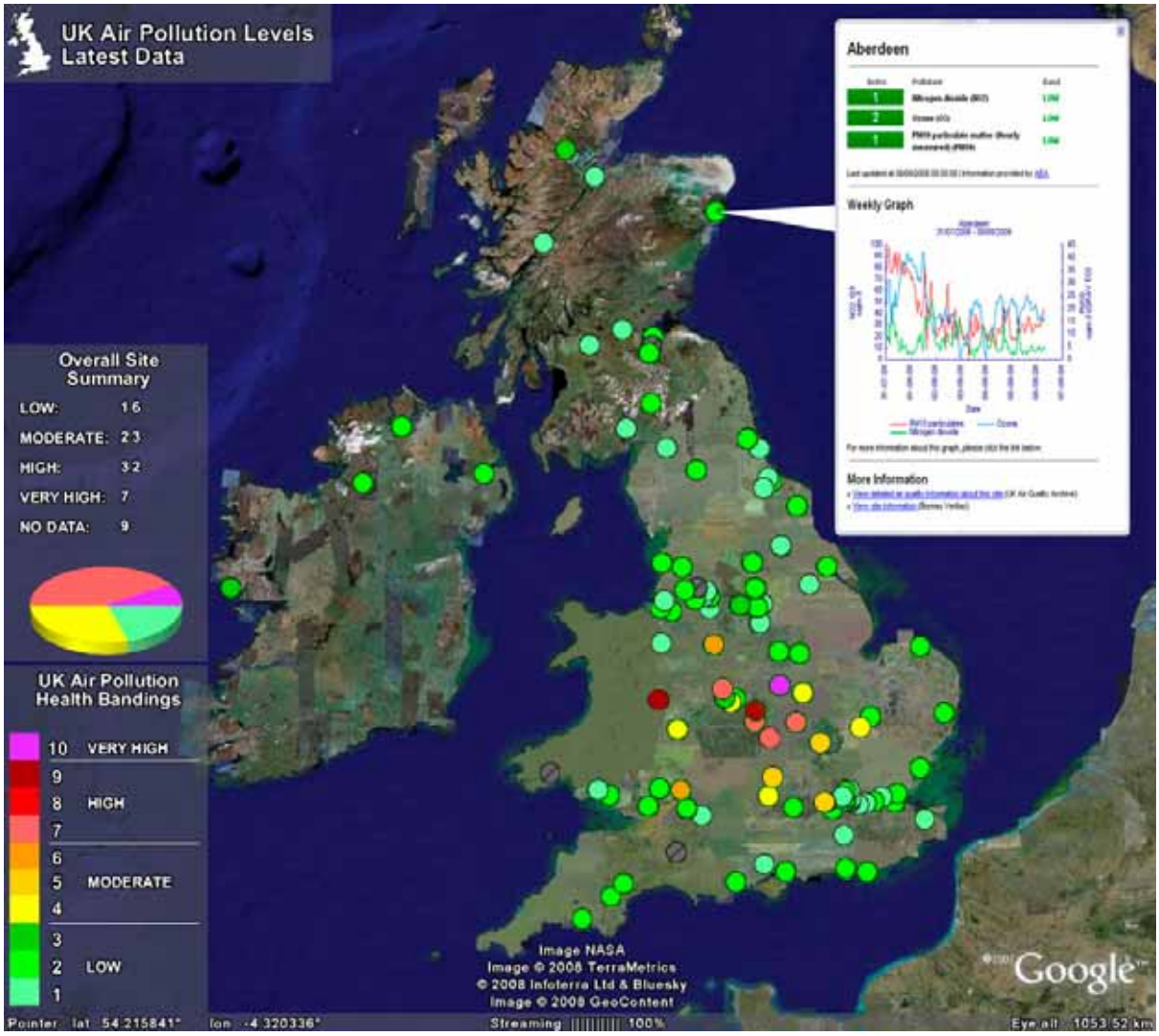


Figure 9.5 Google Earth™ and similar GIS technologies now feature on all UK and Devolved Administration national websites; they make possible more powerful, user-friendly and immersive ways of presenting air quality data

A real time Google Earth™ interface was developed and implemented for the UK Archive in 2007. This allows users, after downloading and installing Google Earth and a simple data file – to directly access a real-time map of UK-wide pollution levels, as well as detailed information from over 130 automatic monitoring stations throughout the UK. Web users can simply click on any site icon to obtain graphs, current pollution levels, site pictures and other useful information (see Figure 9.5).

As noted in last year's report, similar systems have been under development for other Devolved Administration and Local Government websites. In fact, the Welsh, Northern Ireland and Scotland air quality websites are now all equipped with even more advanced

Google Map™ interfaces. Unlike Google Earth, these do not require users to download data files or software. Instead, users see a seamless interface that can be accessed through their normal browser. In addition, Google Maps enable 'live' maps of air quality; users can click directly on these to see more about local air quality; moreover, they can also type in their postcode to access additional locally-based information.

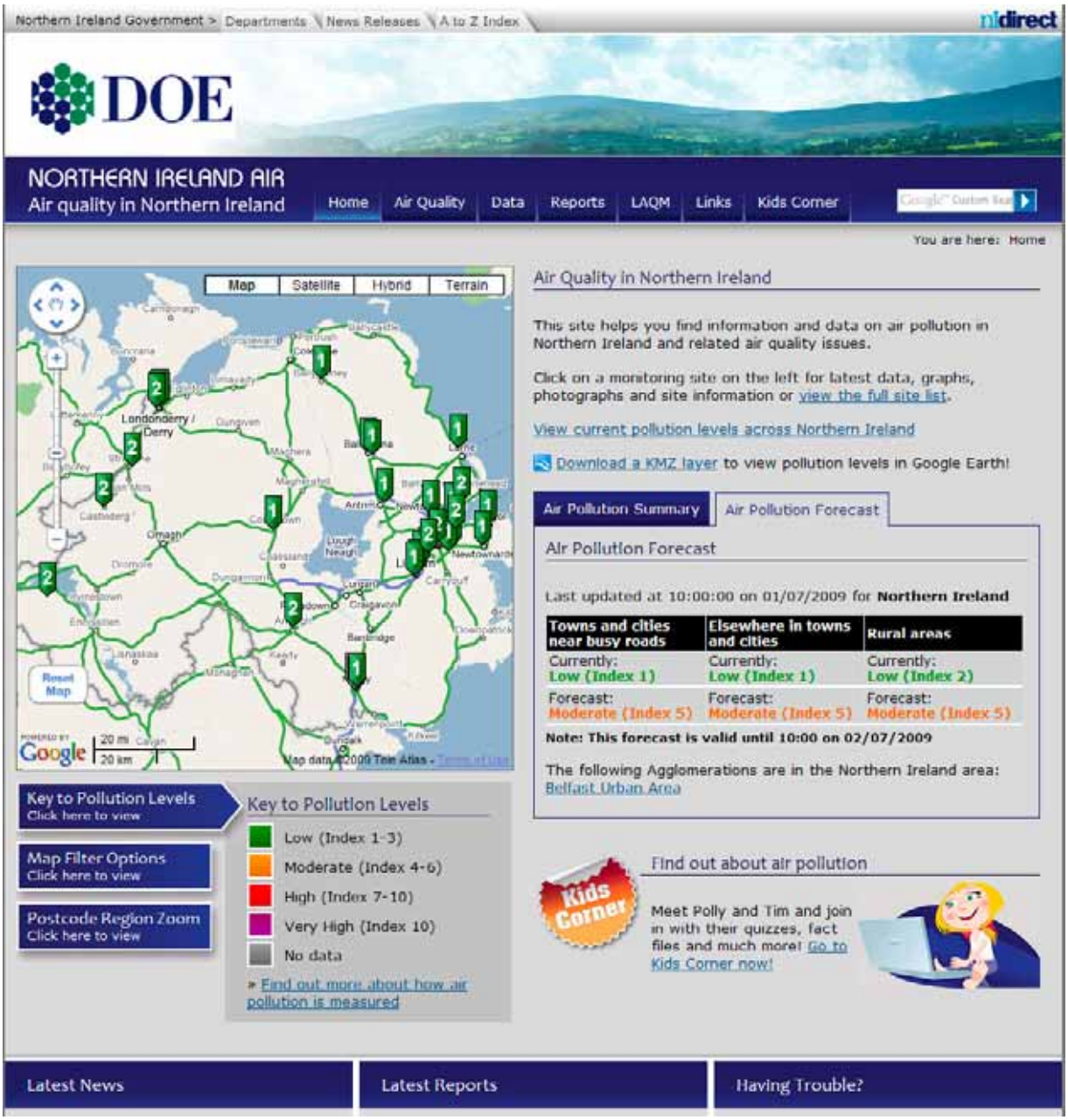


Figure 9.6 The Northern Ireland websites offers many new map-based services, including one-click access to local air quality information

The most recently refreshed website for Northern Ireland (Figure 9.6) shows these new features and services particularly clearly.

Google Maps are fully zoom-able and interactive. Like Google Earth, they include colour-coded spots for all sites. Clicking on any spot will produce a pop-up display showing:

1. Colour coded and numeric value of each pollutant measured at site
2. Link to site information
3. Link to stacked time series graph for site and pollutants

However, Google Maps offer a number of key advantages:

- They enable a very clean and clearly delineated interactive home page design
- Unlike the Google Earth-based system, the Map-based services integrate seamlessly with the existing website, and require no download of software or data files.
- The services can be introduced with minimal disruption to home page or other page layouts.
- Google Maps enable a fully active home-page map, colour coded according to current pollution levels- this will be ideal for users wishing synoptic 'at a glance' information on current UK-wide pollution levels.
- Clicking on the map will lead directly to an interactive Google Maps page of the region.
- The ability to high-level search for sites and data by UK postcode. This is typically provided in a central position on the homepage, just beneath the active map. Users are therefore able to immediately access high-level information on air quality in their neighbourhood.

Google-enabled air quality archives are transforming the way many people interact with the Archive. They make more information available to more users, in a more direct, intuitive and user-friendly way than ever before.

We saw in Section 2.1 how new European legislatory drivers such as the INSPIRE Directive will in future require all European Member States to transform the way that they archive and report all environmental data. In the UK, we are well abreast of these emerging requirements, and participate in several European pilot schemes to examine the impacts of new data visualisation and reporting technologies.

Google Earth and Maps are likely to be only the first of many developments to the UK national air quality archives and websites, exploiting new Geographical Information Systems (GIS) and mapping technologies in order to more effectively convey information to our many public and technical end-users. We aim to report on further developments in future reports in this series. In subsequent sections, we examine some new approaches to air quality reporting that are already under development.

2) Mobile access to air quality websites

Increasing numbers of people are accessing web content on the move, through mobile phones or PDAs. Conventional websites, including the UK's national air quality websites, are extremely content-rich and therefore not, in their present form, optimal for browsing on small-screen mobile devices.

It is important, therefore, that web content be customised for use on mobile platforms. This process is currently underway for the Scottish Air Quality website. This will allow users anywhere to access core air quality information and data for Scotland. The modified web content will convey the core information and data from the existing website, except that the data will be packaged and formatted specifically for access through small-screen mobile handsets.

In essence, this will include:

- Summary of current pollution levels
- Ability to view pollution levels where you are
- Links to forecasts
- Links to additional information

Users will be able to personalise their experience of the mobile pages through the use of cookies.

When the user enters a postcode region to personalise the air quality information, a cookie will be stored on the user's mobile handset to store this setting. This will allow the mobile pages to "remember" this setting for future visits by each individual user, allowing them direct and immediate access to local data.

The system will provide a summary forecast of local air quality. If the forecast is for moderate or high pollution, an alert will be issued to each user automatically via their chosen method of communication. The message content will be agreed between customer and AEA. Alerts by SMS, voicemail or email will only be issued once agreed criteria have been reached.

The look and feel of the mobile website will reflect the existing website where applicable, although use of complex graphics-based information will- of necessity – be limited.

The existing website at www.scottishairquality.co.uk will also have additional pages incorporated to inform potential users of the mobile website, and how this can be accessed.

Figure 9.7. Data and forecasts from the Scottish Air Quality website will soon be available on mobile platforms

3) SMS/voicemail systems

Know and Respond™ – and similar systems such as airAlert – are new text-based mobile systems that, again, emphasises the use of targeted and highly customisable platforms for reporting air quality data and alerts to individuals.

We will focus on Know and Respond™. This service sends registered users an text or voicemail alert message if air pollution is forecast to be moderate, high or very high. People who are susceptible to the effects of elevated air pollution, typically the very young, elderly and those with heart and lung diseases, can then take action if necessary to minimise the effects.

Like web gadgets and mobile platform websites discussed earlier, the use of SMS text-based mobile technologies can be specifically targeted to the needs of individual users and user communities such as:

- Local or regional government
- Medical and health workers
- Asthmatics and other potentially susceptible population subgroups
- Local or national communities

Such a system is currently being implemented for the Scottish Government and for a number of local authorities including Liverpool; this is discussed further in section 6.

There are a number of main building blocks to such systems. The key components the web interface, forecasting system, service subscription system, alert content generation and interface to external SMS or voicemail service (Figure 9.8).

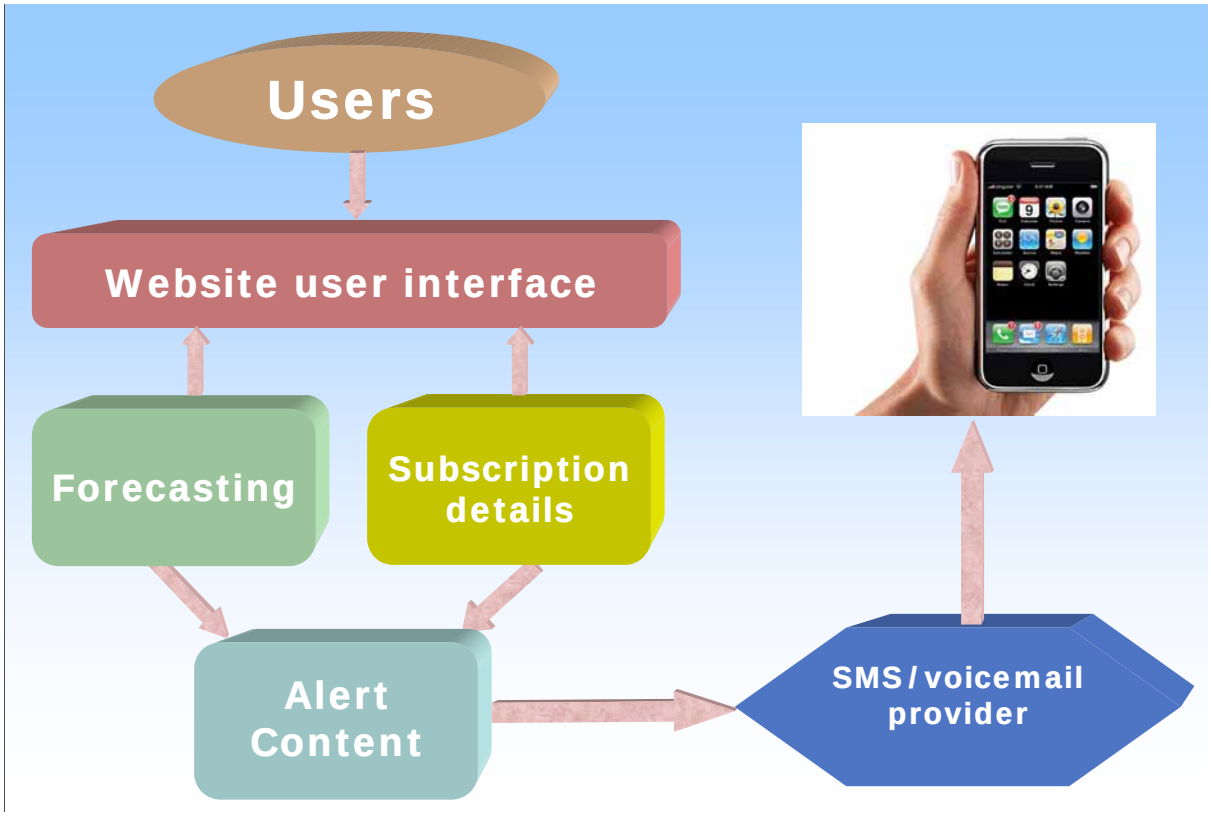


Figure 9.8. Basic architecture of the SMS-based air quality information system being developed for Scottish government and other users

The web interface

A dedicated Know and Respond web page is being developed and this will integrate seamlessly into the current Air Quality in Scotland website www.scottishairquality.co.uk

Accompanying web content will describe the service and take potential users through a simple step-by-step process for anyone to subscribe, free of charge, to the service

Forecasting system

Every day at 4pm (by default), air quality forecasters at AEA will issue an air pollution forecast for the following 24 hours. The forecasting areas will be Highlands, North East Scotland, Central Scotland, and Scottish Borders. The proven forecasting systems and models utilised are described fully elsewhere.

Service subscription

Registration to the scheme and further information will be made available via the Know and Respond website. When users register for this free service, their details will be held in a database table. The personal information will not be used for any other purpose, and will be never disclosed to third parties.

Alert content

This is highly customisable. A typical example of SMS alert content might be:

Glasgow Air Pollution Nov 3rd at 2pm
Roadside areas- INDEX 6, forecast rising to 7 (HIGH) tomorrow
Background urban areas- INDEX 4, forecast rising to 6 (MODERATE) tomorrow
Rural areas- INDEX 3, forecast rising to 7 (HIGH) tomorrow

Regional SMS Alerts will be sent automatically to all users that have registered to receive those alerts within the Scottish region in question.

4) Local authority information systems

Part of the overall trend towards, specialised and targeted air quality reporting systems identified here is an increased focus on local authority air quality websites and alert platforms.

These systems are typically designed to meet a variety of functions, including enabling individual local authorities – or groups of authorities - to meet statutory requirements under Local Air Quality Management (LAQM) and Freedom of Information, as well as providing sophisticated platforms for reporting the results of local monitoring programmes.

Such Local Authority websites are becoming increasingly sophisticated, often offering similar advanced functionalities to those available on the national and devolved administration discussed earlier.

The Kent & Medway Air Quality Monitoring Network (KMAQMN), for example, is a large and sophisticated 28-site regional air monitoring programme. The network is funded by the districts and boroughs within the county, with an additional contribution from Kent County Council. The aims of the network are to promote the improvement of air quality within the region, help local authorities to meet their obligations under Environmental Regulations and maintain an accessible database of robust measurements for public reporting, research and development.

The website for this network at www.kentair.org.uk (see Figure 9.9) enables these objectives to be fully met; it offers a wide range of functionalities designed to meeting the diverse needs of public, technical and local government end-users and stakeholders in the Kent and Medway area, in a way that is both user-friendly and cost-effective.

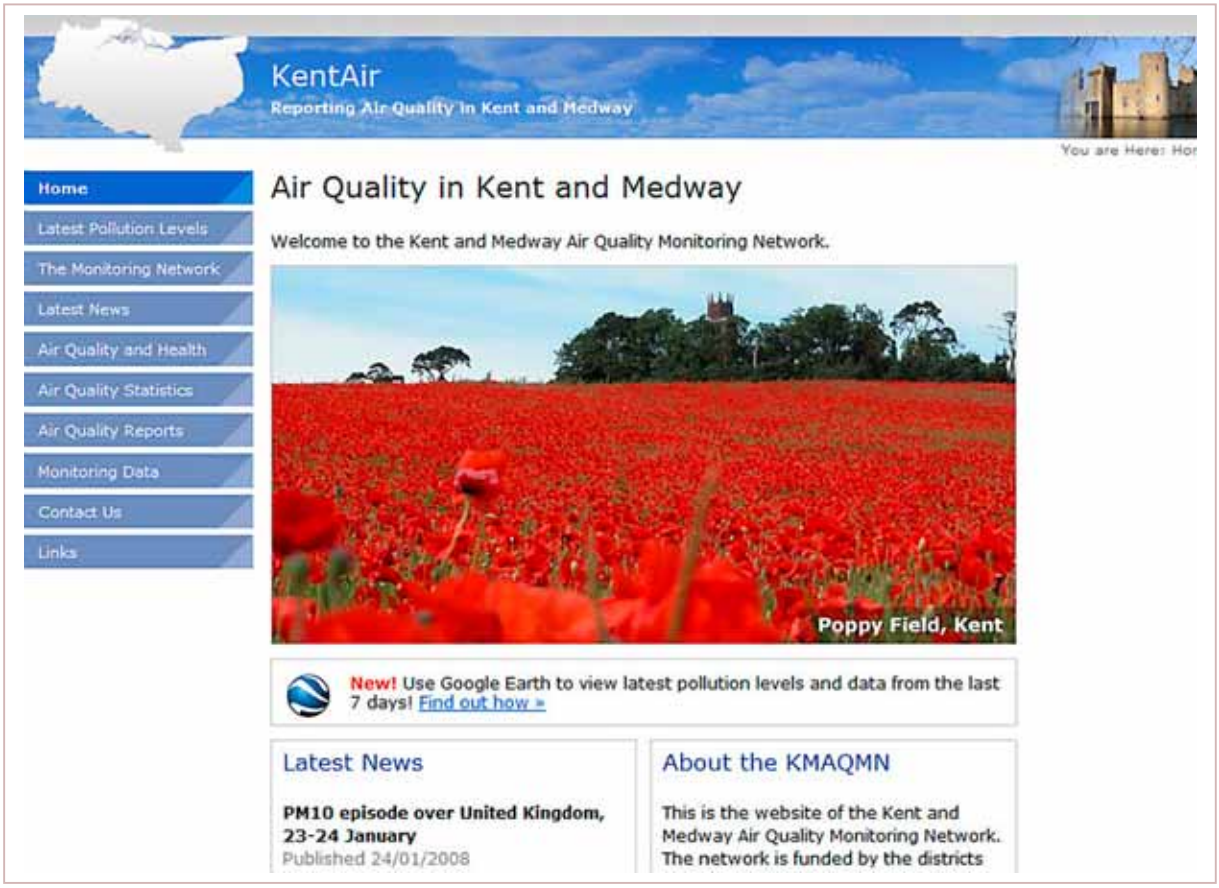


Figure 9.9. An advanced Google-equipped Local Government website for the Kent and Medway Air Monitoring Network – www.kentair.org.uk

Box 9.1 Key Online and Media Information Resources on UK Air Pollution

1) How to obtain up-to date air quality information and forecasts for your area

- The Air Pollution Information Service on freephone 0800 556677
- The UK Air Quality Archive on www.airquality.co.uk
- The Welsh Air Quality Archive at www.welshairquality.org.uk
- The Northern Ireland Archive at www.airqualityni.co.uk
- The Scottish Air quality Archive at www.scottishairquality.co.uk
- Latest forecasts, issued twice daily, at http://www.airquality.co.uk/archive/uk_forecasting/apfuk_home.php
- The National Atmospheric Emissions Inventory on www.naei.org.uk
- The Defra air quality information web resource on http://www.defra.gov.uk/environment/airquality/index.htm
- The Scottish Government Air Quality pages on http://www.scotland.gov.uk/Topics/Environment/Pollution/16215/4561
- The Welsh Assembly Government Environment link at http://www.wales.gov.uk/subienvironment/index.htm
- The Northern Ireland DoE Environmental Policy Division website at http://www.doeni.gov.uk/epd
- Teletext page 156

2) Useful Sources of Background Information

A colourful brochure 'Air Pollution in the UK', suitable for educational or public use, is available from Defra Publications at: defra@cambertown.com or 08459 556000. This can also be downloaded from the UK Archive website.

A corresponding brochure 'Air Pollution in Wales' may be downloaded from the Welsh Archive website, as detailed above.

A brochure and report on Air Pollution in Northern Ireland is available from the DoE NI website at http://www.doeni.gov.uk/foi/search/

A comprehensive range of air quality research reports is available from http://www.airquality.co.uk/archive/reports/list.php

3) Health Effects of Air Pollution

A concise brochure entitled ***'Air Pollution, what it means for your health'*** is available to download from the Defra air quality information web resource listed above or free of charge from Defra publications or via Freephone.

4) Local Air Quality Issues

For further information on air quality issues in your area, please contact the Environmental Health Department at your local Council office.

Further information on Local Air Quality Management may also be found at:
http://www.defra.gov.uk/environment/airquality/laqm.htm and
http://www.airquality.co.uk/archive/laqm/laqm.php
http://www.scotland.gov.uk
http://www.airqualityni.co.uk/laqm_sca.php

Box 9.2 Information Available from the UK Air Quality Archive at www.airquality.co.uk (and corresponding URLs)

- Historic measurements from all national sampler and automatic air monitoring programmes
- A one-stop-shop describing the UK's air monitoring programmes and linking to many websites for the different networks
- Current measurements from automatic networks, speedily available for all UK countries, regions and urban areas
- Detailed air pollution statistics derived from all current and historic data and available via interactive selections
- Twice-daily regional forecasts of air quality
- Maps, photographs and descriptions of all automatic network stations
- Information on causes and effects of the major air pollutants
- Details of UK and international efforts taken to tackle air pollution
- A database of Frequently Asked Questions (FAQs) and answers related to air pollution
- Search-driven information and access to reports covering a wide range of Air Pollution issues
- Background information on a range of Local Air Quality Management (LAQM) issues including:
  - Air Quality Management Areas
  - LAQM tools
  - Helplines
  - Reports and FAQs
- Links to the National Atmospheric Emissions Inventory (NAEI) site which offers:
  - Information on how the inventory has been prepared
  - A data warehouse of emission factors and inventory tools
  - UK–wide maps of emissions of the major pollutants (1km resolution)
  - Mapped emissions for different source types - industrial, transport etc
  - A powerful search facility for finding local emissions by postcode input
  - Information on a broad range of climate change issues
- A range of useful links to air pollution data resources, organisations and information in the UK, Europe and worldwide

Box 9.3 Information for Local Government at www.laqmsupport.org.uk

This new site, provided on behalf of Defra and the Devolved Administrations, provides Local Authorities with access to advice and information on air quality monitoring, air quality modelling, and emissions inventories. It offers:

- Downloadable tools and guidance to assist with the entire Local Air Quality Management process
- The latest updates to Defra's Technical Guidance
- Guidance on use of NO_2 diffusion tubes, and a link to the NO_2 Web-Based Data Entry System, which provides Local Authorities with a convenient and reliable way of storing and sharing their diffusion tube data.
- Frequently Asked Questions
- Links to other useful websites, such as the Action Plan Appraisal Helpdesk and the Review and Assessment Helpdesk.

The Local Authority Air Quality Support Helpdesk can also be contacted by telephone on 0870 190 6050 and by e-mail on lasupport@aeat.co.uk.

Air pollution in the UK: 2008

Part 2

In this statistical part of the report, we provide a detailed summary of the measurements made for each pollutant at every monitoring site in the Automatic Urban and Rural Network (AURN) and Automatic Hydrocarbon Network. We also present information on measurement techniques, site locations and relevant UK, European and WHO pollutant criteria.

We then provide for each pollutant a table summarising measurements and exceedences of the UK Air Quality objectives during 2008. Finally, we include graphs to show variations in pollutant concentrations throughout the day and over the year as a whole, as well as time series showing long-term changes in concentrations over many years.

10. Benzene- measurement sites, instrumentation and statistics

10.1 Measurement method

Benzene is measured using automated Gas Chromatograph or BTEX monitors; these measure concentrations of benzene, toluene, ethylbenzene and xylene isomers as well as 1,3-butadiene. This type of instrument uses an adsorption tube for sample collection.

10.2 Instrumentation

The following instrument types* are currently deployed in the AURN:

- Environnement VOC 71M
- Perkin Elmer OPA

** Here and elsewhere in this report, references to commercial names of equipment or products does not constitute a recommendation or endorsement by Defra, the DAs or the report authors.*

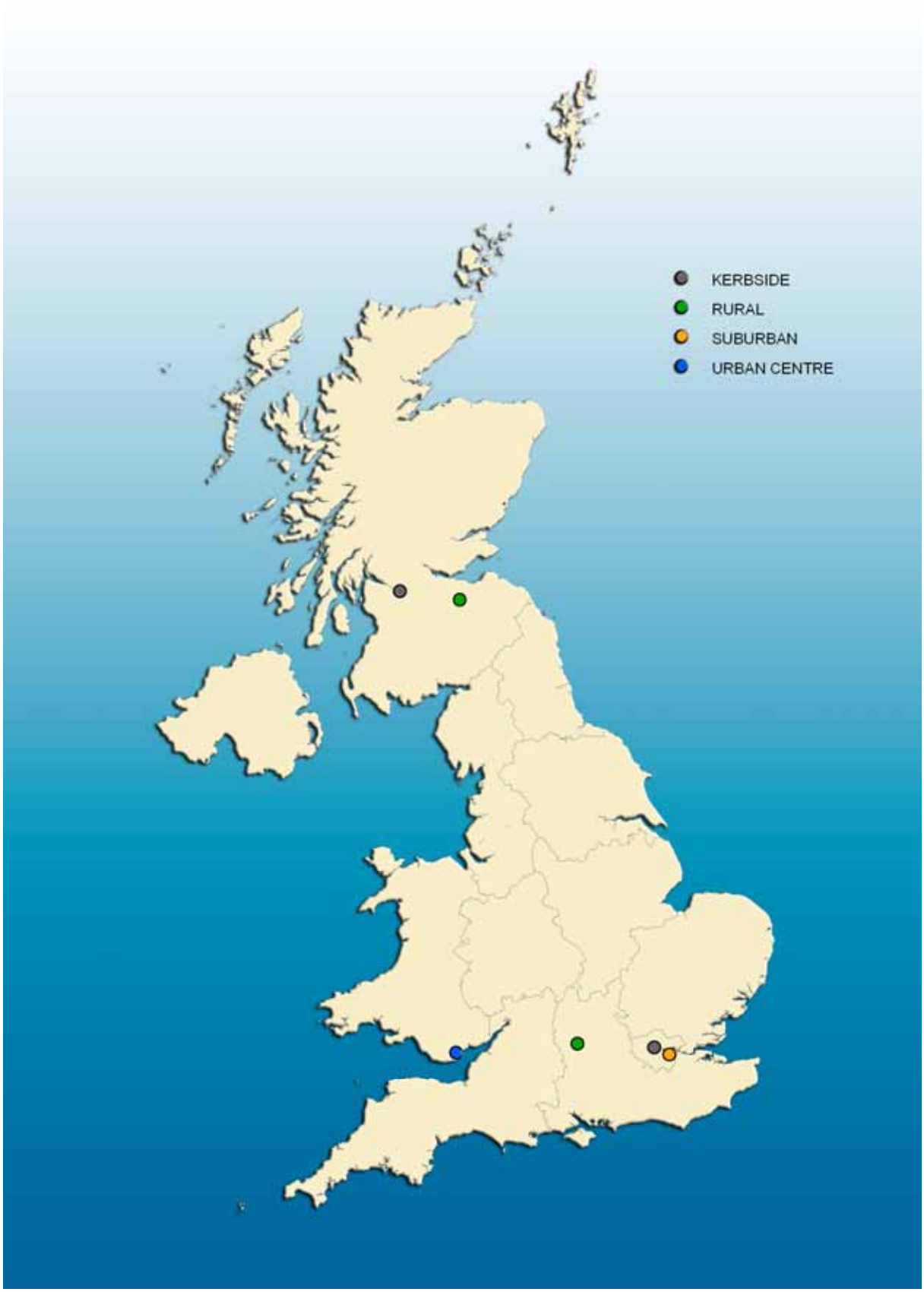
10.3 Data quality requirements of EC Directive 2008/50/EC for benzene

Uncertainty 15%
Minimum data capture 90%

10.4 Objectives and bandings

Summary of objectives of Air Quality Strategy			
	Objective	**Measured as**	**To be achieved by**
Benzene	16.25 µg m^3	Running Annual Mean	31 December 2003
England and Wales only	5 µg m^{-3}	Annual Mean	31 December 2010
Scotland and Northern Ireland only	3.25 µg m^{-3}	Maximum Running Annual Mean	31 December 2010

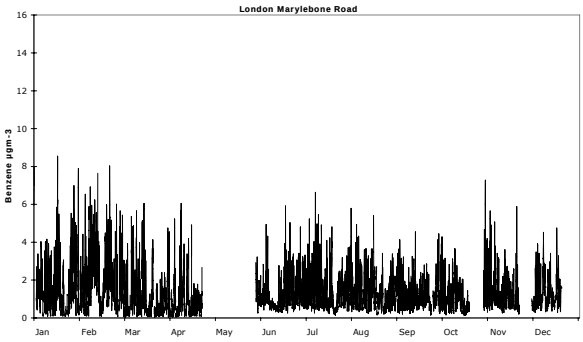
No bandings are set for benzene, as there are no known short-term health effects for this pollutant.



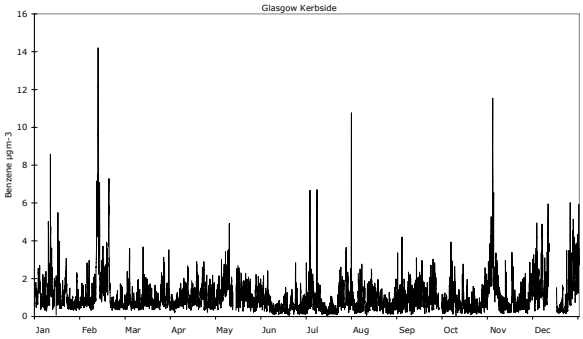
UK automatic benzene monitoring sites 2008

10.5 Hourly average concentrations

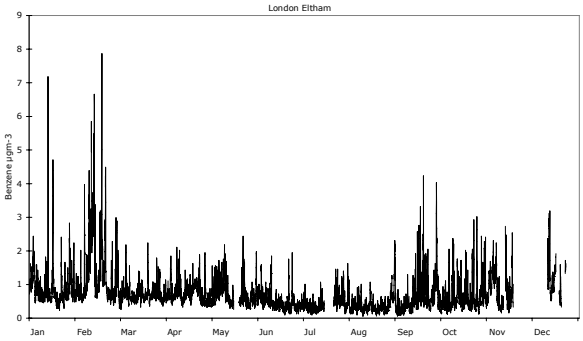
These figures show time series graphs of hourly average benzene concentrations at four monitoring sites of different types for 2008.



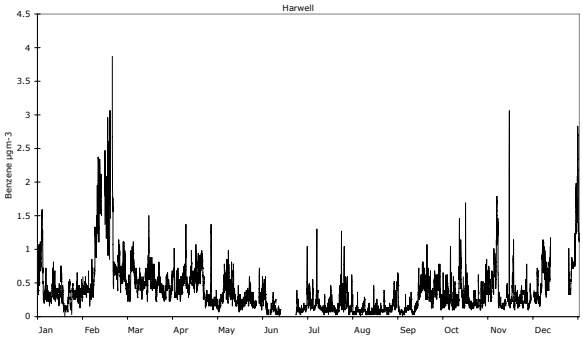
Kerbside Site
(London Marylebone Road)



Kerbside Site
(Glasgow Kerbside)



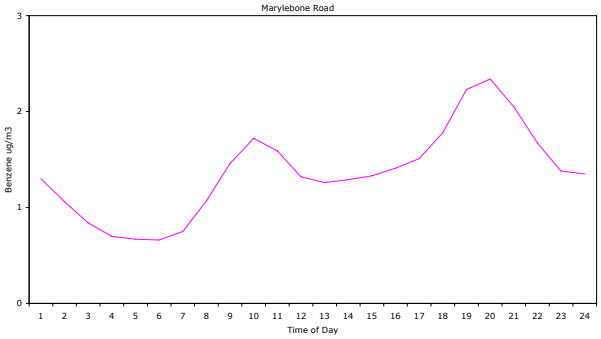
Suburban Site
(*London Eltham*)



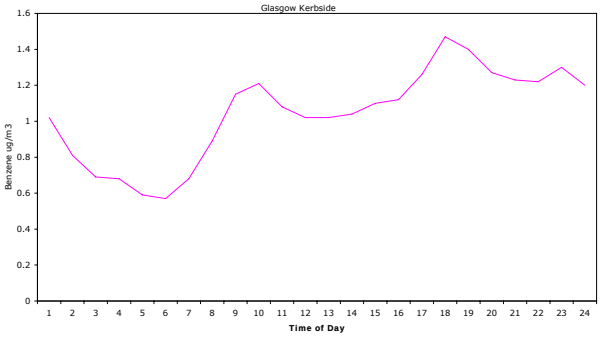
Rural Site
(*Harwell)*

10.6 Diurnal variations

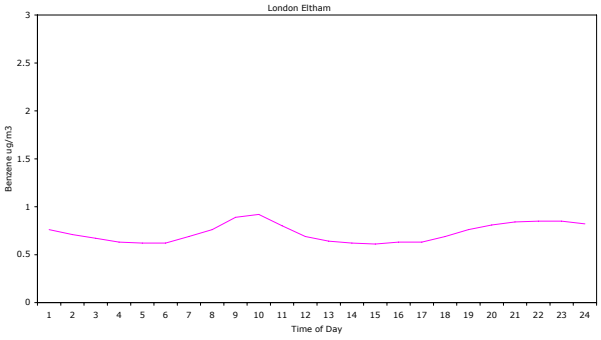
These figures show how benzene concentrations varied on average for each hour of day during 2008, at the same four monitoring sites. Local time is used, rather than GMT, to more closely reflect the daily cycle of man-made emissions.



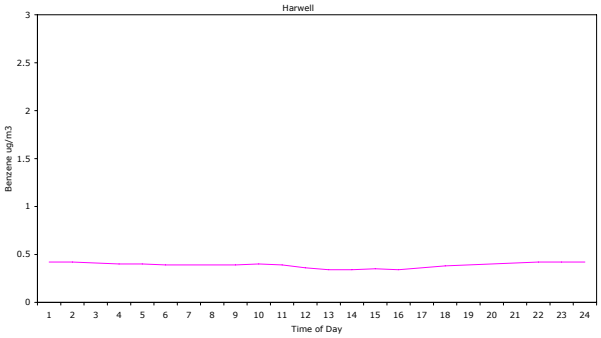
Kerbside Site
(London Marylebone Road)



Kerbside Site
(Glasgow Kerbside)



Suburban Site
(*London Eltham*)

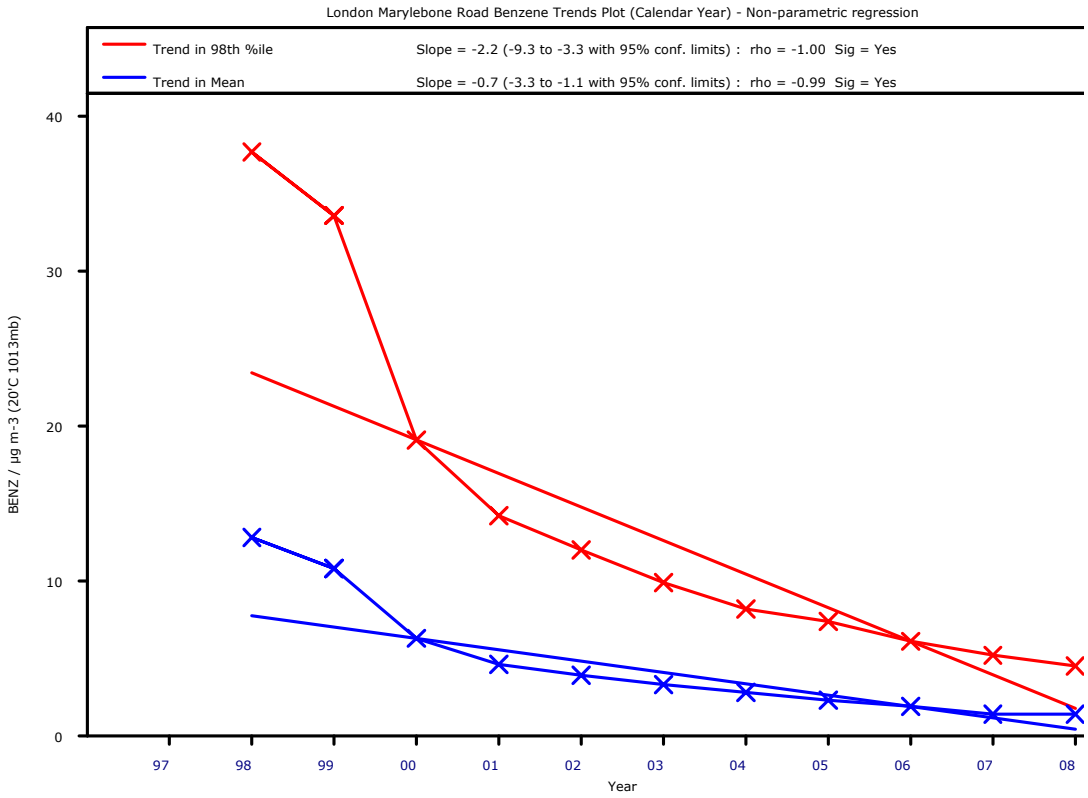


Rural Site
(*Harwell)*

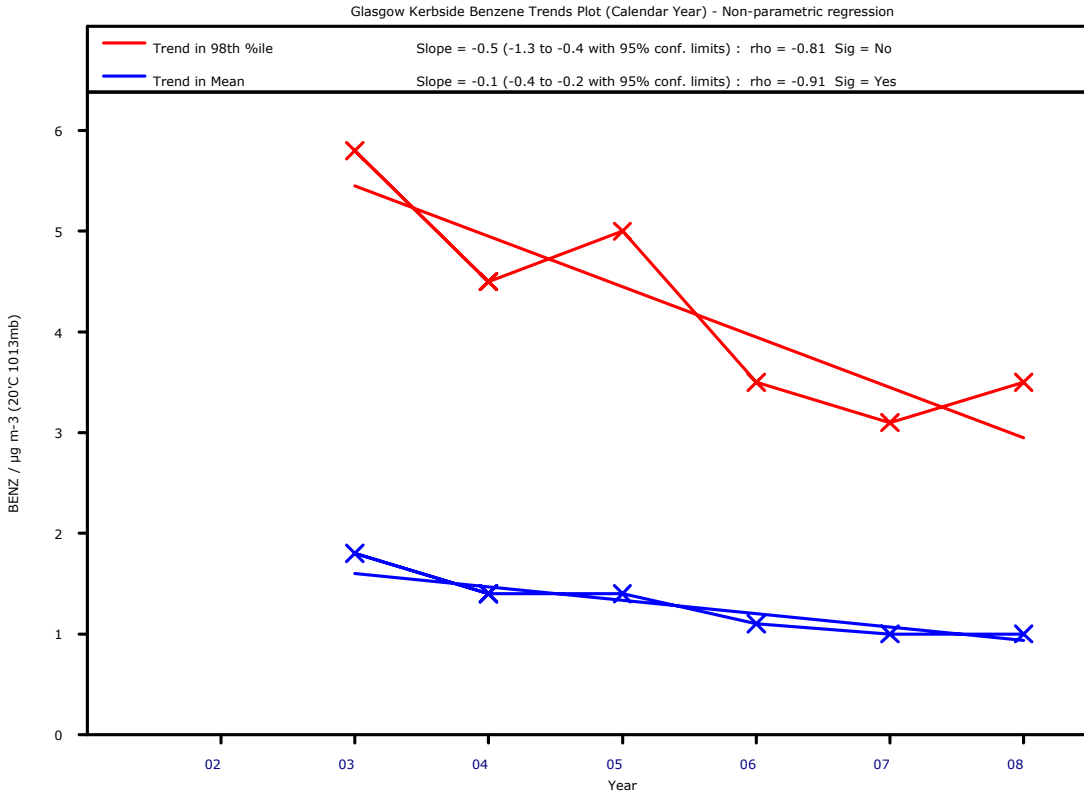
10.7 Trends in annual concentrations

Trends in concentrations are shown for sites with at least 5 years of measurement.

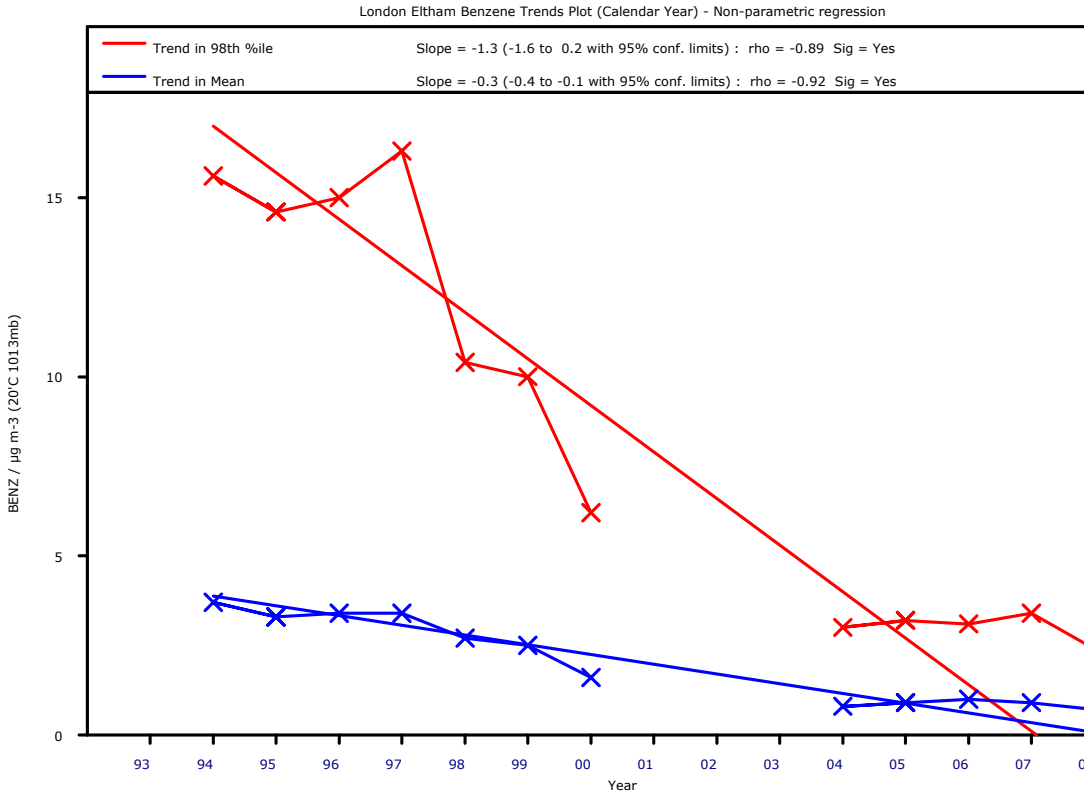
London Marylebone Road Benzene Trends – Non-parametric regression



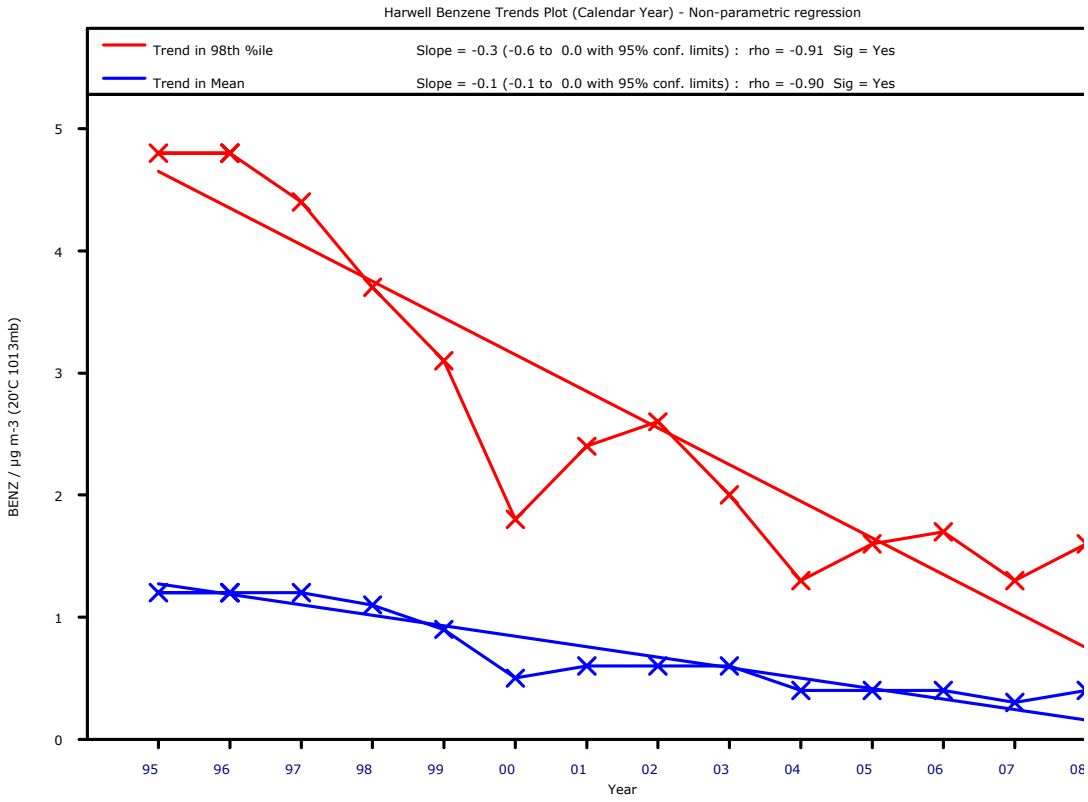
Glasgow Kerbside Benzene Trends – Non-parametric regression



London Eltham Benzene Trends – Non-parametric regression



Harwell Benzene Trends – Non-parametric regression



10.8 Benzene statistical summary 2008

i) Benzene annual statistics

Site	Site Type	Annual average of hourly means µg m^{-3}	Annual data capture of hourly means %	Maximum hourly mean µg m^{-3}
England				
Harwell	RU	0.39	89.2	3.87
London Eltham	S	0.73	85.6	7.87
London Marylebone Road	KS	1.36	76.5	8.55
Scotland				
Glasgow Kerbside	KS	1.04	96.3	14.20
Wales				
Cardiff Centre	UC	---	0.0	---

ii) Benzene exceedence statistics

Site	Air Quality Standard > 16.3 µg m^{-3}	Days	EC Directive and Air Quality Standard (England and Wales) > 5 µg m^{-3}	Annual Mean Standard (Scotland) > 3.3 µg m^{-3}
England				
Harwell	0	0	0	0
London Eltham	0	0	0	0
London Marylebone Road	0	0	0	**0**
Scotland				
Glasgow Kerbside	0	0	0	0
Wales				
Cardiff Centre	0	0	0	0

11. 1,3-butadiene - measurement sites, instrumentation and statistics

11.1 Measurement method

1,3-Butadiene is measured using automated GC or BTEX monitors; these measure concentrations of benzene, toluene, ethylbenzene and xylene isomers as well as 1,3-butadiene. This type of instrument uses an adsorption tube for sample collection.

11.2 Instrumentation

The following instrument types* are currently deployed in the AURN:

- Environnement VOC 71M
- Perkin Elmer OPA

** Here and elsewhere in this report, references to commercial names of equipment or products does not constitute a recommendation or endorsement by Defra, the DAs or the report authors.*

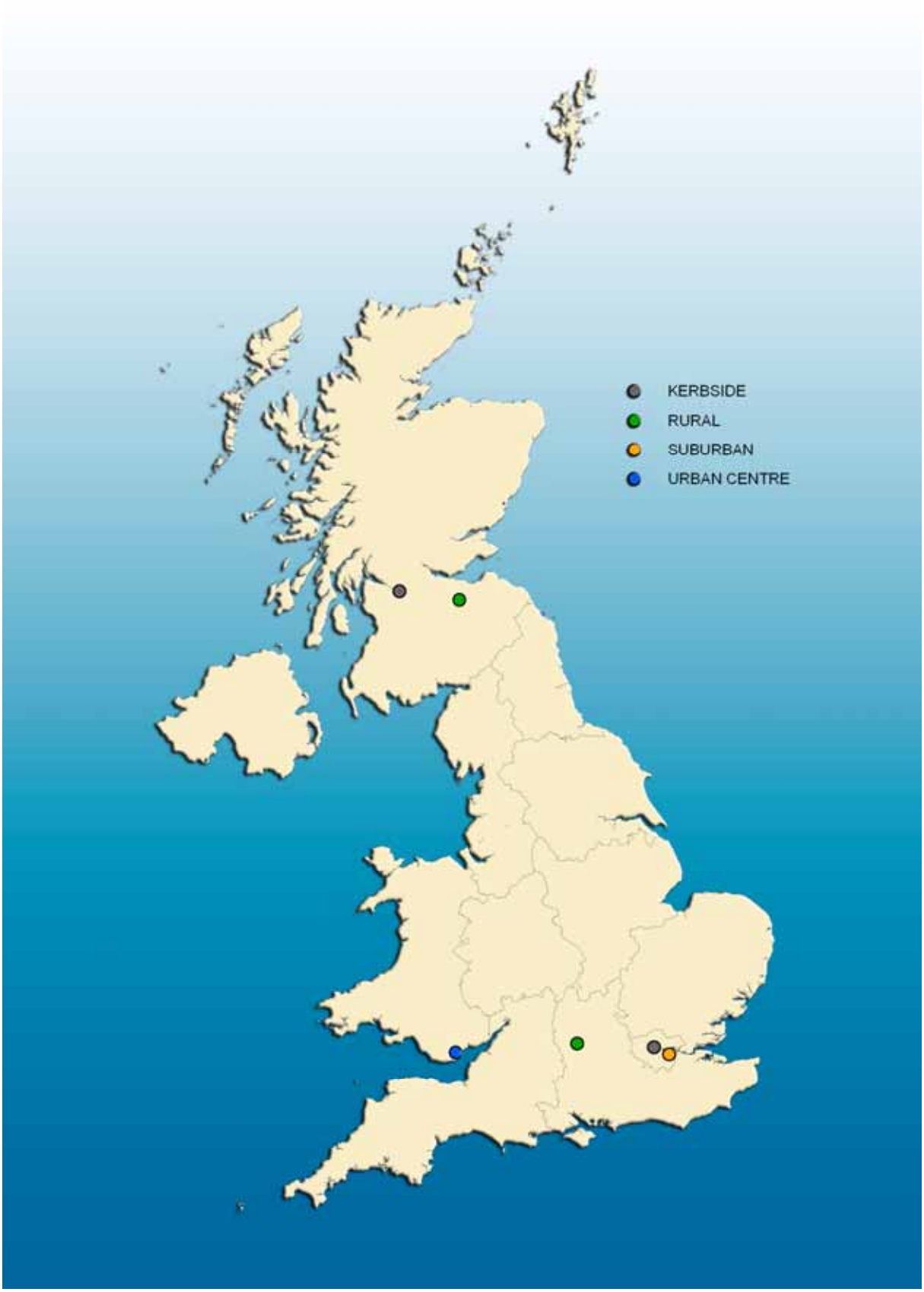
11.3 Data quality requirements of EC Directive 2008/50/EC for 1,3-butadiene

Uncertainty 15%
Minimum data capture 90%

11.4 Objectives and bandings

Summary of objectives of the Air Quality Strategy			
	Objective	**Measured as**	**To be achieved by**
1,3-Butadiene	2.25 µg m^{-3}	Maximum Running Annual Mean	31 December 2003

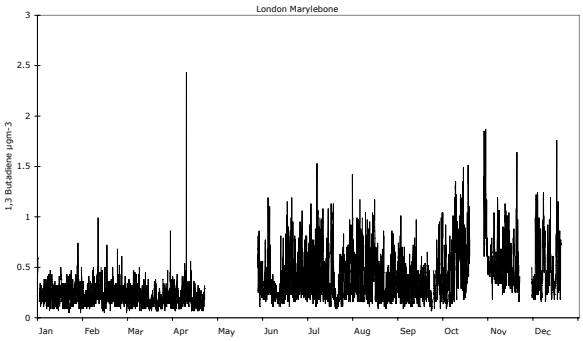
No bandings are set for 1,3-Butadiene, as there are no known short-term effects of this pollutant.



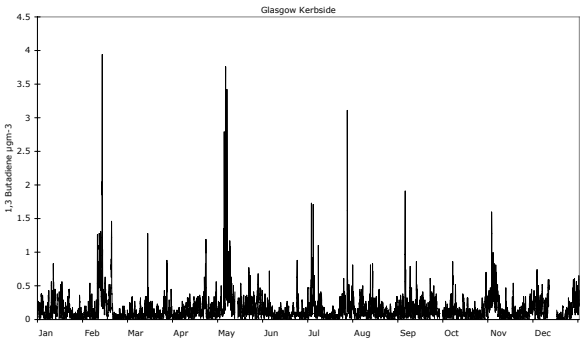
UK automatic 1,3-butadiene monitoring sites 2008

11.5 Hourly average concentrations

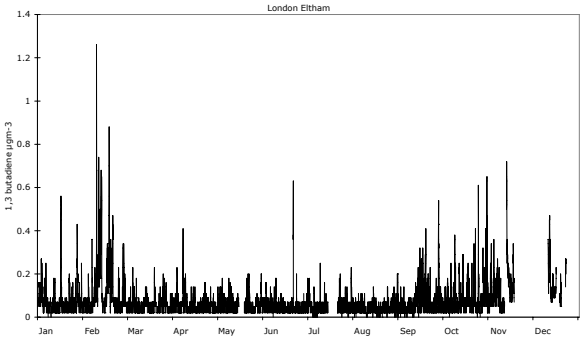
These figures show time series graphs of hourly average 1,3-Butadiene concentrations at four monitoring sites of different types for 2008.



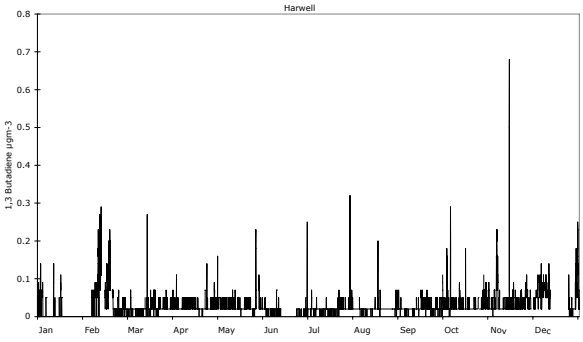
Kerbside Site
(London Marylebone Road)



Kerbside Site
(Glasgow Kerbside)



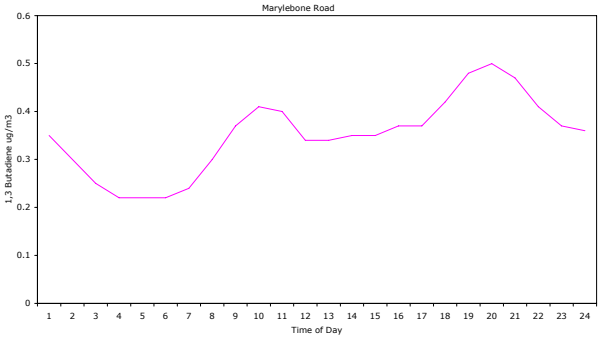
Suburban Site
(*London Eltham*)



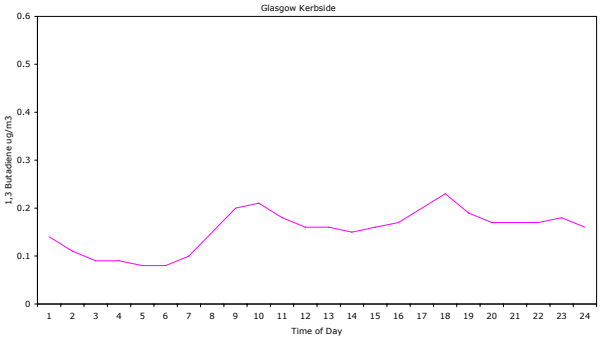
Rural Site
(*Harwell)*

11.6 Diurnal variations

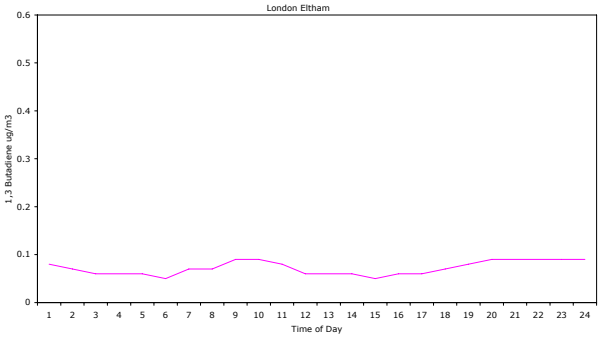
These figures show how 1,3-Butadiene concentrations varied on average for each hour of day during 2008, at the same four monitoring sites. Local time is used, rather than GMT, to more closely reflect the daily cycle of man-made emissions.



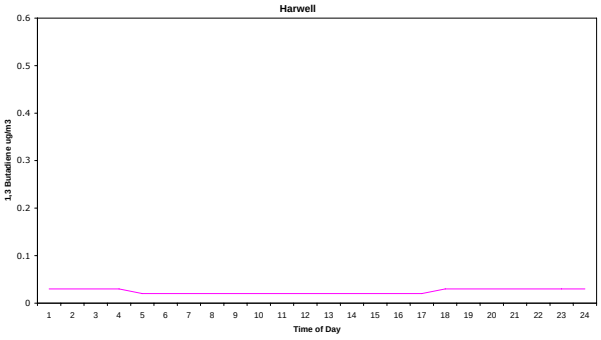
Kerbside Site
(London Marylebone Road)



Kerbside Site
(Glasgow Kerbside)



Suburban Site
(*London Eltham*)

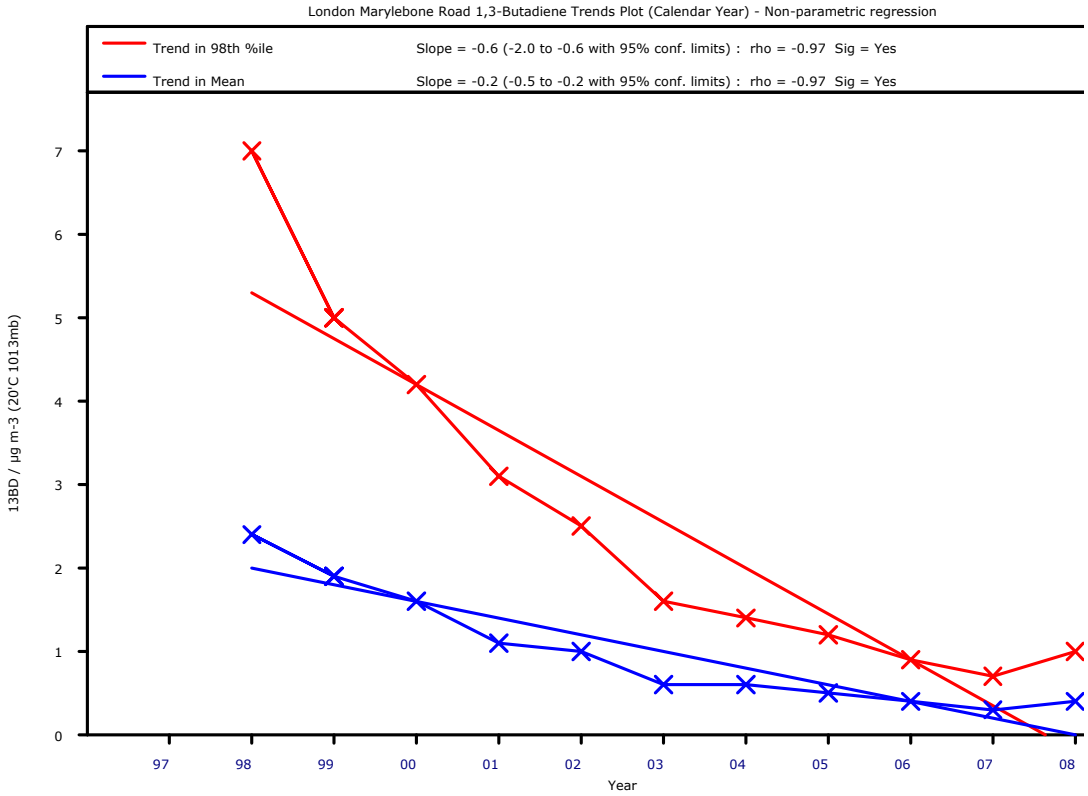


Rural Site
(*Harwell)*

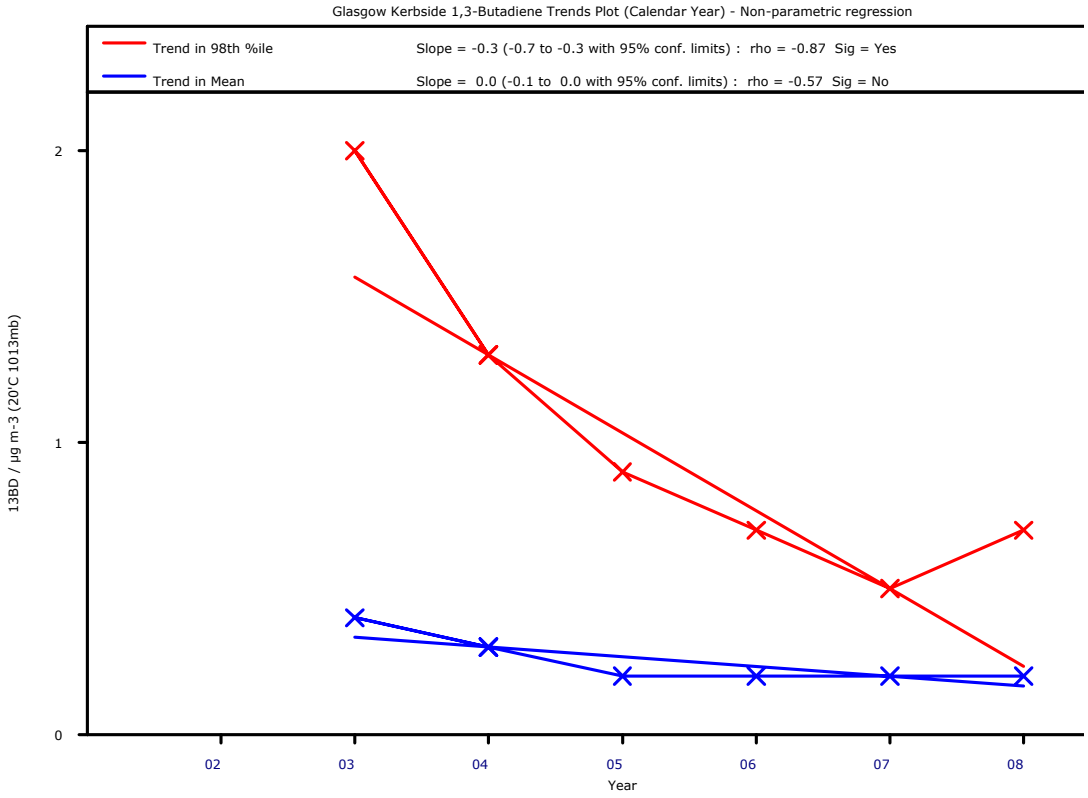
11.7 Trends in annual concentrations

Trends in concentrations are shown for sites with at least 5 years of measurement.

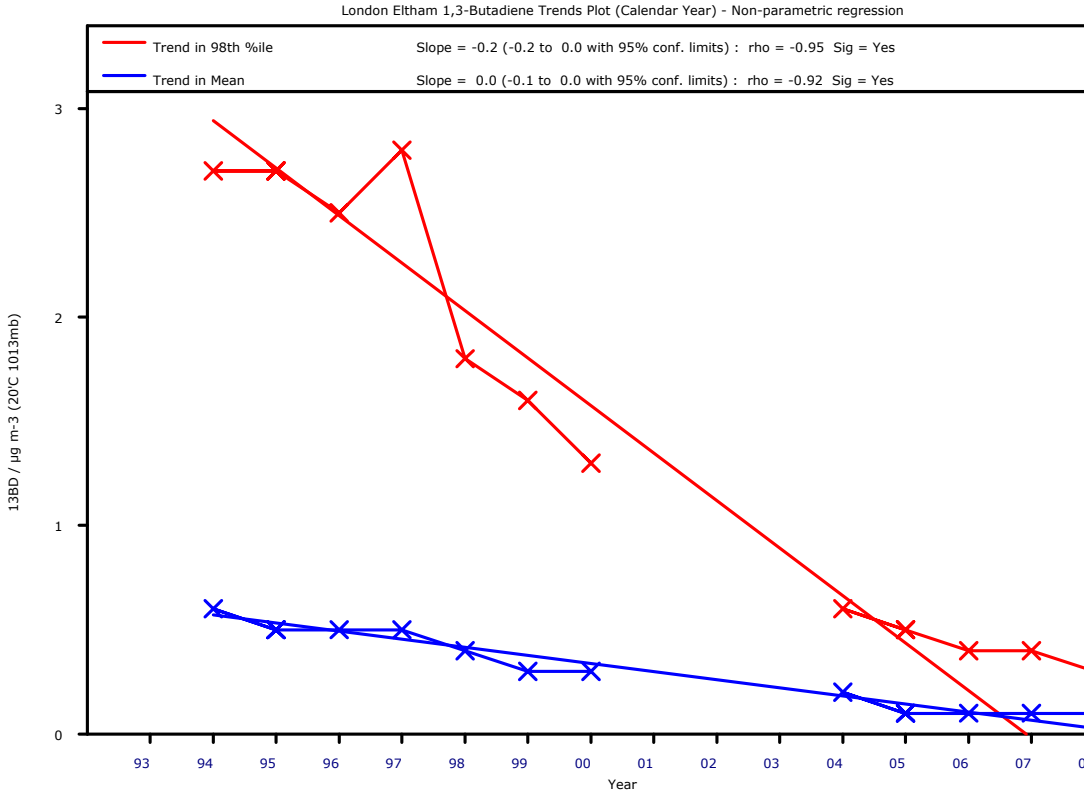
London Marylebone Rd. 1,3-Butadiene Trends – Non-parametric regression



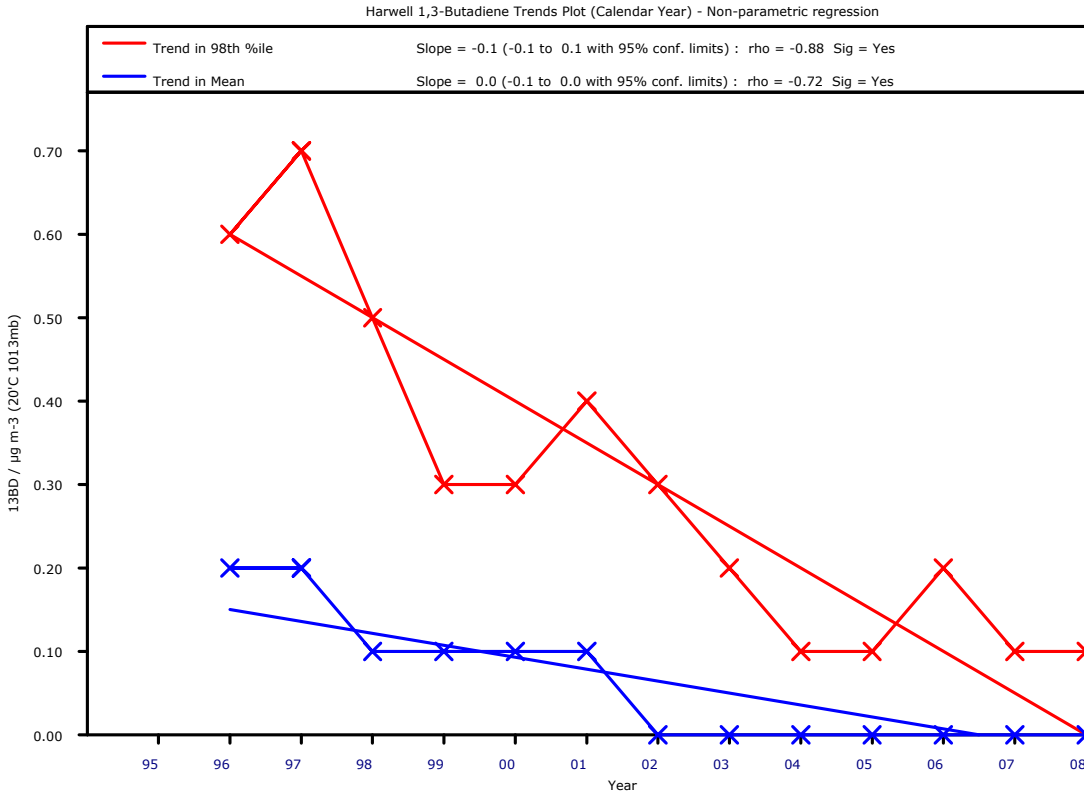
Glasgow Kerbside 1,3-Butadiene Trends – Non-parametric regression



London Eltham 1,3-Butadiene Trends – Non-parametric regression



Harwell 1,3-Butadiene Trends - Non-parametric regression



11.8 1,3-Butadiene statistical summary 2008

i) 1,3-Butadiene annual statistics

Site	Site Type	Annual Average of hourly means	Annual data capture of hourly means %	Maximum hourly mean
England				
Harwell	RU	0.03	89.8	0.68
London Eltham	S	0.07	82.4	1.26
London Marylebone Road	KS	0.35	79.9	2.43
Scotland				
Auchencorth Moss	RU	---	28.6	3.35
Glasgow Kerbside	KS	0.15	96.3	3.94
Wales				
Cardiff Centre	UC	---	0.0	---

ii) 1,3-Butadiene exceedence statistics

Site	Air Quality Standard > 2.25 µg m^{-3}	Days
England		
Harwell	0	0
London Eltham	0	0
London Marylebone Road	0	0
Scotland		
Auchencorth Moss	0	0
Glasgow Kerbside	0	0
Wales		
Cardiff Centre	---	---

12. CO - measurement sites, instrumentation and statistics

12.1 Measurement method

CO concentrations in ambient air are measured by the absorption of infrared radiation at 4.5 to 4.9 µm wavelength. A reference detection system is used to alternately measure absorption due to CO in the sampled air stream and absorption by interfering species. An infrared detector and amplification system produces output voltages proportional to the CO concentration.

12.2 Instrumentation

The following instrument types* are currently deployed in the AURN:

- Ambirak CO
- API M300
- Environnement SA 11M
- Horiba APMA 350E
- Horiba APMA 360
- Monitor Labs 9830
- Rotork 416
- Thermo Electron 48

** Here and elsewhere in this report, references to commercial names of equipment or products does not constitute a recommendation or endorsement by Defra, the DAs or the report authors.*

12.3 Data quality requirements of EC Directive 2008/50/EC for CO

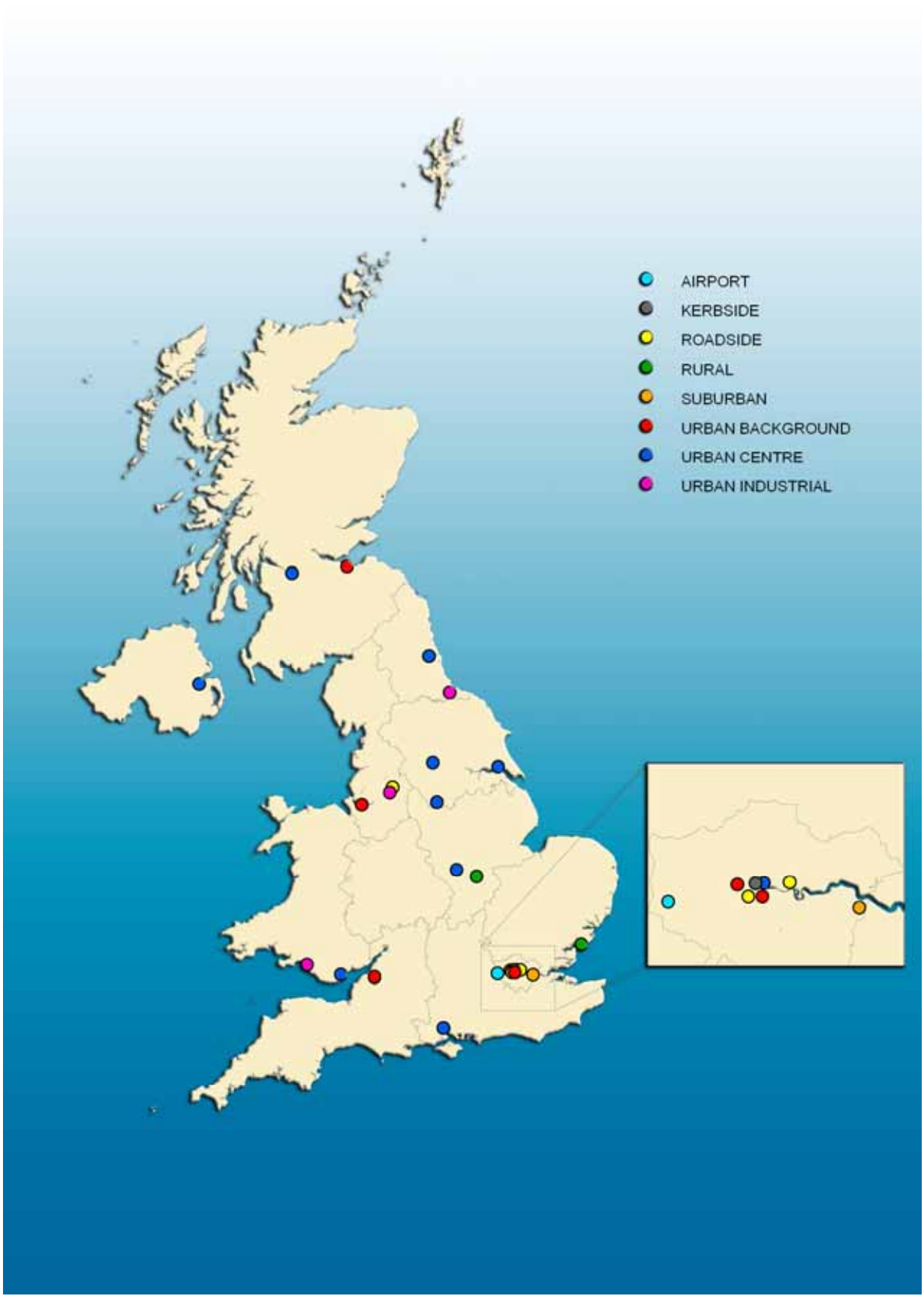
Uncertainty 15%
Minimum data capture 90%

12.4 Objectives and bandings

Summary of objectives of the Air Quality Strategy			
	Objective	**Measured as**	**To be achieved by**
Carbon Monoxide England and Wales	10.0 mg m^{-3}	Maximum daily running 8 Hour Mean	31 December 2003
Scotland only	10.0 mg m^{-3}	Running 8 Hour Mean[a]	31 December 2003
Northern Ireland only	10.0 mg m^{-3}	Maximum daily running 8 Hour Mean	1 January 2005

a. The Quality Objective in Scotland has been defined in Regulations as the running 8-hour mean, in practice this is equivalent to the maximum daily running 8-hour mean

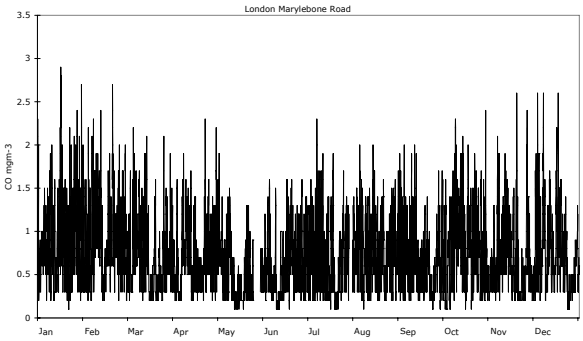
Air Quality Bands and Index Values		
Band	**Index**	**Carbon Monoxide mg m^{-3}**
Low	1	0-3.8
	2	3.9-7.6
	3	7.7-11.5
Moderate	4	11.6-13.4
	5	13.5-15.4
	6	15.5-17.3
High	7	17.4-19.2
	8	19.3-21.2
	9	21.3-23.1
Very High	10	23.2 or more



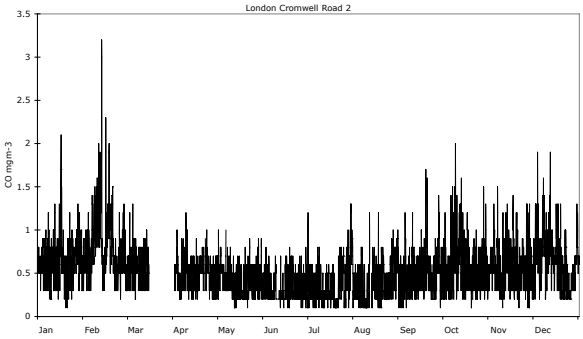
UK automatic carbon monoxide monitoring sites 2008

12.5 Hourly average concentrations

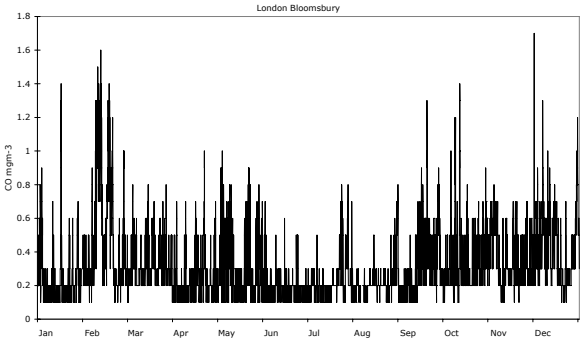
These figures show time series graphs of hourly average carbon monoxide concentrations at four monitoring sites of different types for 2008.



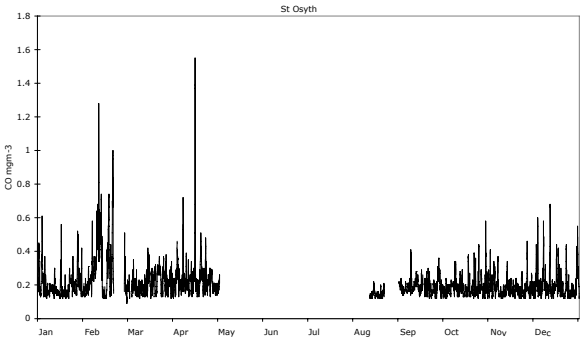
Kerbside Site
(London Marylebone Road)



Roadside Site
(London Cromwell Road 2)



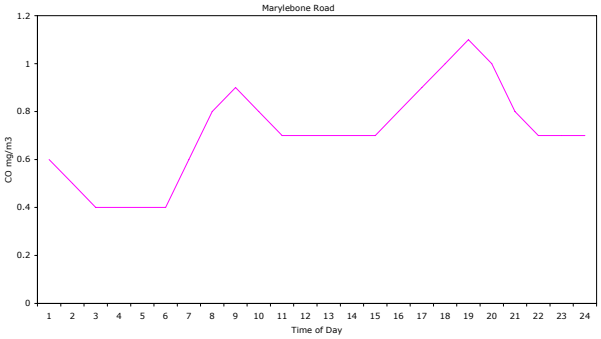
Urban Background Site
(London Bloomsbury)



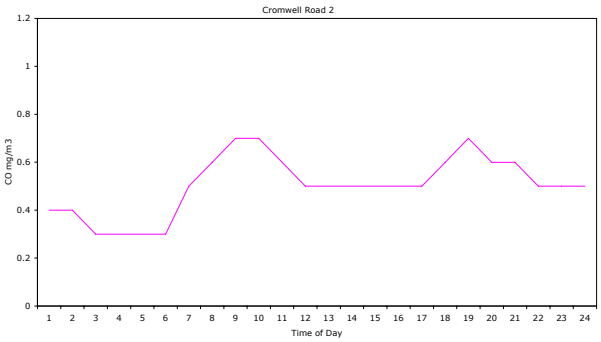
Rural Site
(St.Osyth)

12.6 Diurnal variations

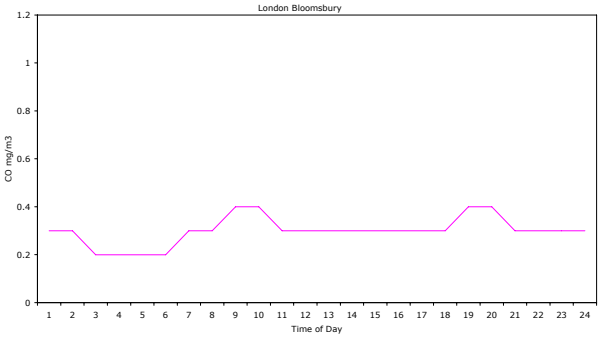
These figures show how carbon monoxide concentrations varied on average for each hour of day during 2008, at the same four monitoring sites. Local time is used, rather than GMT, to more closely reflect the daily cycle of man-made emissions.



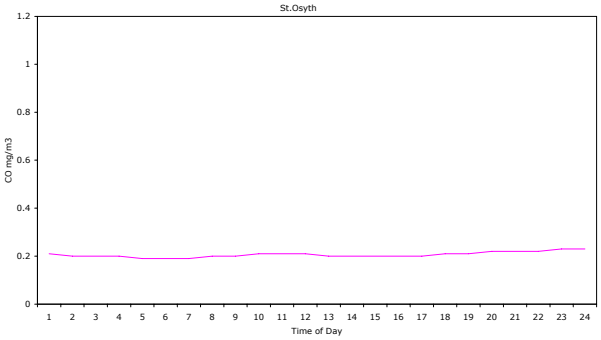
Kerbside Site
(London Marylebone Road)



Roadside Site
(London Cromwell Road 2)



Urban Background Site
(Aberdeen)

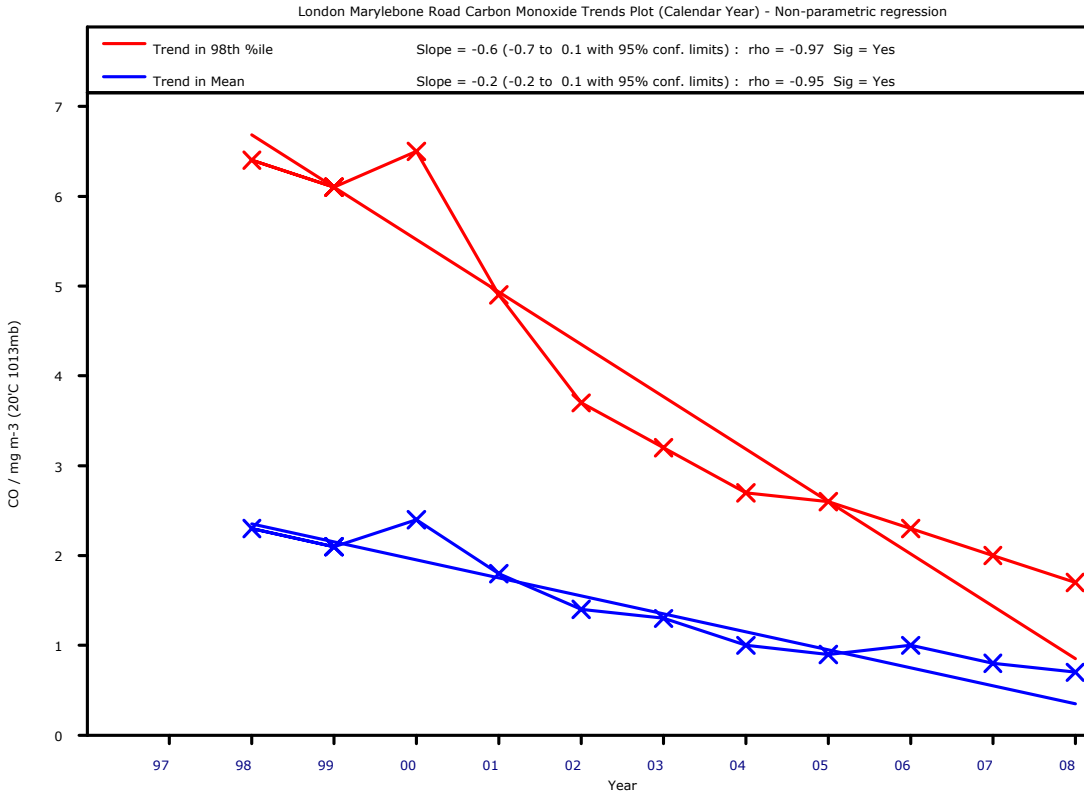


Rural Site
(St.Osyth)

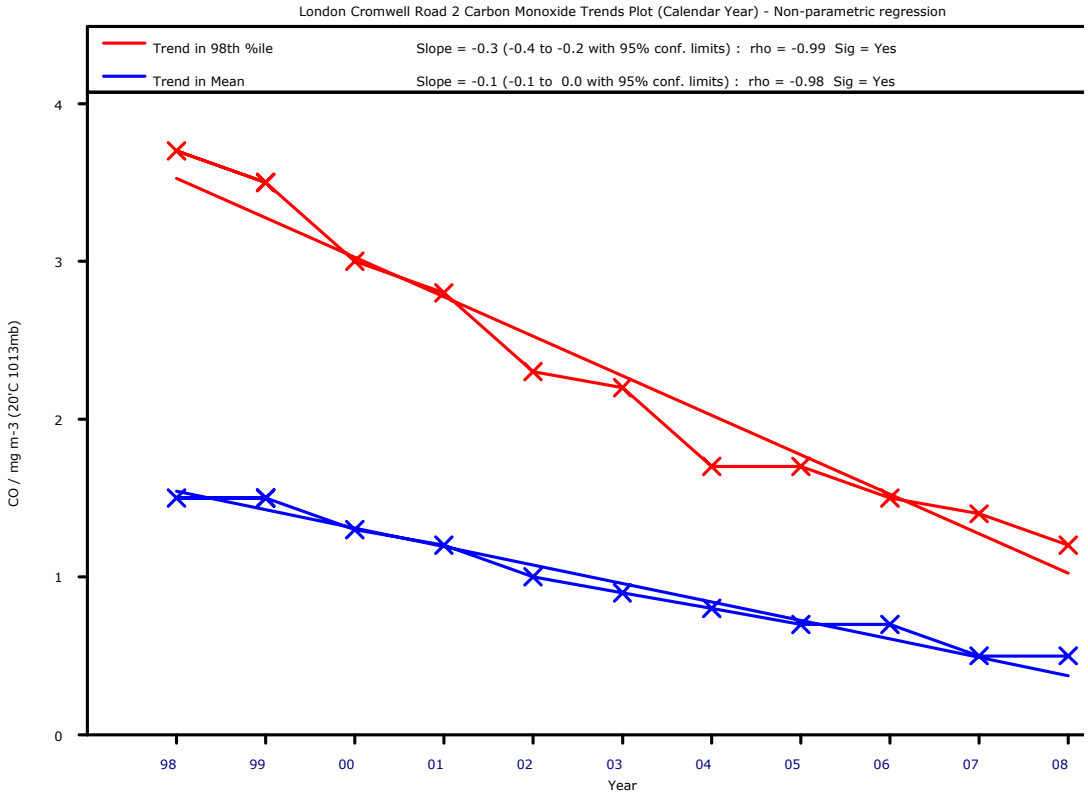
12.7 Trends in annual concentrations

Trends in concentrations are shown for sites with at least 5 years of measurement.

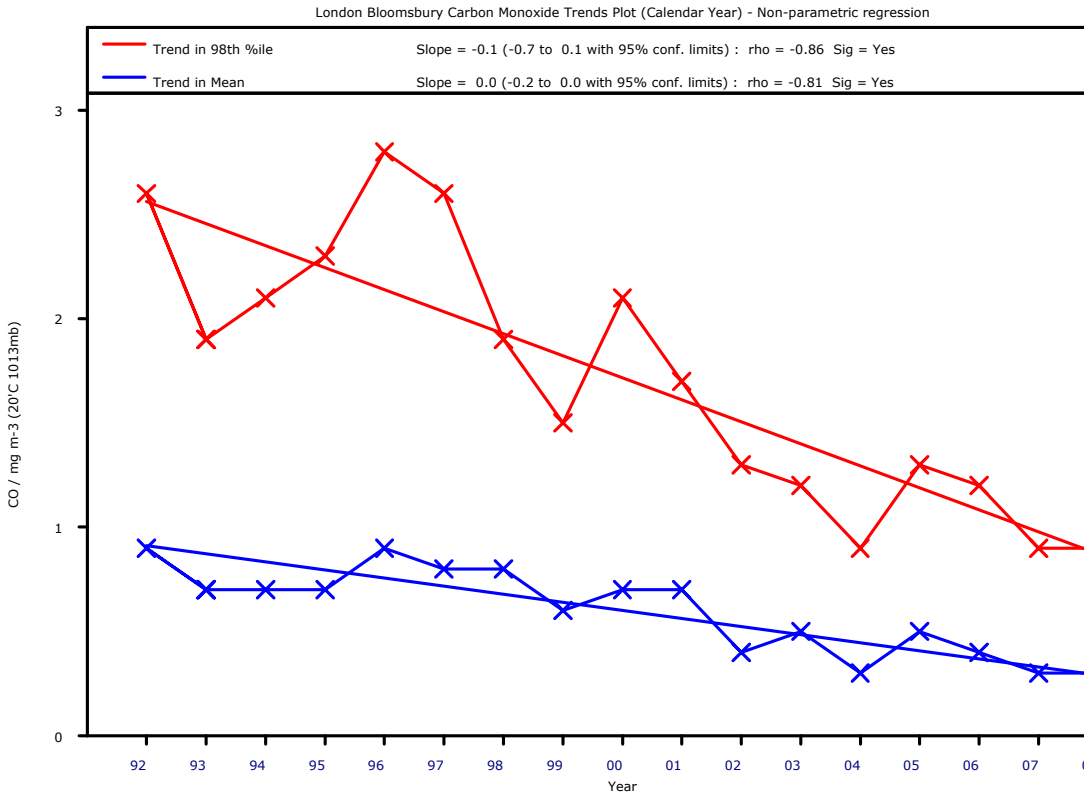
London Marylebone Road CO Trends – Non-parametric regression



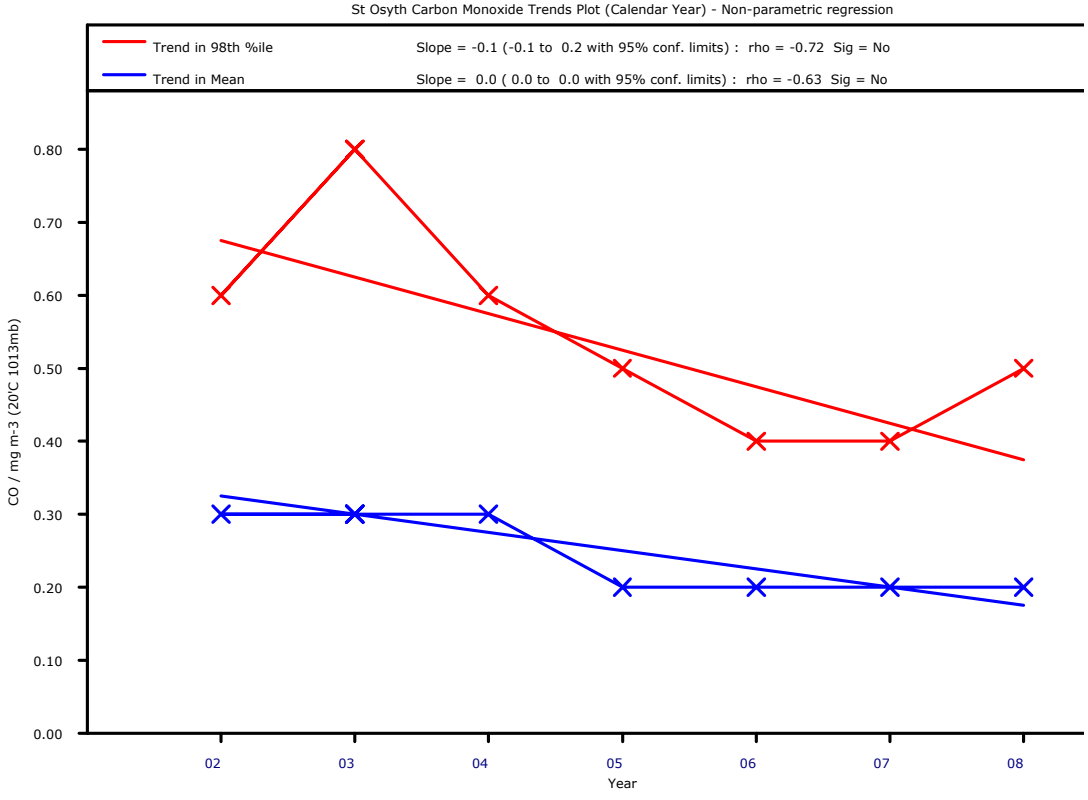
London Cromwell Road 2 CO Trends – Non-parametric regression



London Bloomsbury CO Trends – Non-parametric regression



St Osyth CO Trends – Non-parametric regression



12.8 Carbon monoxide statistical summary 2008

i) CO annual statistics

Site	Site Type	Annual average of hourly means mg m^{-3}	Annual data capture of hourly means %	Maximum hourly mean mg m^{-3}	Maximum running 8-hour mean mg m^{-3}	Date of maximum running 8-hour mean
England						
Bristol Old Market	RS	0.4	97.6	4.1	3.3	07/12/2008
Bristol St Paul's	UB	0.3	93.6	5.8	3.3	05/07/2008
Bury Roadside	RS	0.3	71.6	2.7	2.1	10/02/2008
Hull Freetown	UC	0.2	95.9	2.3	1.5	18/02/2008
Leeds Centre	UC	0.2	99.6	5.6	3.1	12/02/2008
Leicester Centre	UC	0.2	99.2	3.1	2.4	13/02/2008
Liverpool Speke	UB	0.1	93.5	1.6	0.9	06/12/2008
London Bexley	S	0.2	97.1	2.6	1.6	13/02/2008
London Bloomsbury	UC	0.3	99.2	1.7	1.3	12/02/2008
London Cromwell Road 2	RS	0.5	93.3	3.2	2.3	13/02/2008
London Harlington	A	---	17.0	2.8	2.3	13/02/2008
London Marylebone Road	KS	0.7	97.7	2.9	2.5	16/01/2008
London N. Kensington	UB	0.3	98.0	2.2	1.7	17/01/2008
London Westminster	UB	0.2	95.2	2.2	1.7	13/02/2008
Market Harborough	RU	0.2	94.5	0.7	0.5	11/02/2008
Middlesbrough	UI	0.2	87.9	3.0	1.5	26/12/2008
Newcastle Centre	UC	0.1	98.4	2.2	0.9	12/02/2008
Salford Eccles	UI	0.1	90.0	2.7	1.9	07/12/2008
Sheffield Centre	UC	0.3	98.5	2.0	1.3	11/12/2008
Southampton Centre	UC	0.3	91.2	3.5	2.9	11/02/2008
St Osyth	RU	0.21	66.8	1.55	0.90	21/02/2008
Tower Hamlets Roadside	RS	0.5	84.7	2.7	1.8	08/10/2008
N Ireland						
Belfast Centre	UC	---	48.9	2.9	2.7	13/02/2008
Scotland						
Edinburgh St Leonards	UB	0.2	89.7	1.9	1.5	03/11/2008
Glasgow Centre	UC	0.3	82.9	3.9	2.8	12/02/2008
Wales						
Cardiff Centre	UC	0.3	97.0	2.1	1.5	10/02/2008
Port Talbot Margam	UI	0.4	89.4	8.7	5.4	23/02/2008

ii) CO exceedence statistics

Site	Mod. band	Days	High band	Days	Very High band	Days	EC LV & AQS Obj.	Days	AQS Obj. (Scotland)	Days
England										
Bristol Old Market	0	0	0	0	0	0	0	0	0	0
Bristol St Paul's	0	0	0	0	0	0	0	0	0	0
Bury Roadside	0	0	0	0	0	0	0	0	0	0
Hull Freetown	0	0	0	0	0	0	0	0	0	0
Leeds Centre	0	0	0	0	0	0	0	0	0	0
Leicester Centre	0	0	0	0	0	0	0	0	0	0
Liverpool Speke	0	0	0	0	0	0	0	0	0	0
London Bexley	0	0	0	0	0	0	0	0	0	0
London Bloomsbury	0	0	0	0	0	0	0	0	0	0
London Cromwell Road 2	0	0	0	0	0	0	0	0	0	0
London Harlington	0	0	0	0	0	0	0	0	0	0
London Marylebone Road	0	0	0	0	0	0	0	0	0	0
London N. Kensington	0	0	0	0	0	0	0	0	0	0
London Westminster	0	0	0	0	0	0	0	0	0	0
Market Harborough	0	0	0	0	0	0	0	0	0	0
Middlesbrough	0	0	0	0	0	0	0	0	0	0
Newcastle Centre	0	0	0	0	0	0	0	0	0	0
Salford Eccles	0	0	0	0	0	0	0	0	0	0
Sheffield Centre	0	0	0	0	0	0	0	0	0	0
Southampton Centre	0	0	0	0	0	0	0	0	0	0
St Osyth	0	0	0	0	0	0	0	0	0	0
Tower Hamlets Roadside	0	0	0	0	0	0	0	0	0	0
N Ireland										
Belfast Centre	0	0	0	0	0	0	0	0	0	0
Scotland										
Edinburgh St Leonards	0	0	0	0	0	0	0	0	0	0
Glasgow Centre	0	0	0	0	0	0	0	0	0	0
Wales										
Cardiff Centre	0	0	0	0	0	0	0	0	0	0
Port Talbot Margam	0	0	0	0	0	0	0	0	0	0

13. NO_2 - measurement sites, instrumentation and statistics

13.1 Measurement method

The determination of oxides of nitrogen is based on the chemiluminescent energy emitted when nitric oxide (NO) is reacted with ozone (O_3) in an evacuated chamber to form chemiluminescent nitrogen dioxide (NO_2).

13.2 Instrumentation

The following instrument types* are currently deployed in the AURN:

- Ambirak NO_2
- API M200
- Environnement AC 31M
- Horiba APNA 360
- Monitor Labs 9841
- Rotork 447
- Thermo Electron 42

** Here and elsewhere in this report, references to commercial names of equipment or products does not constitute a recommendation or endorsement by Defra, the DAs or the report authors.*

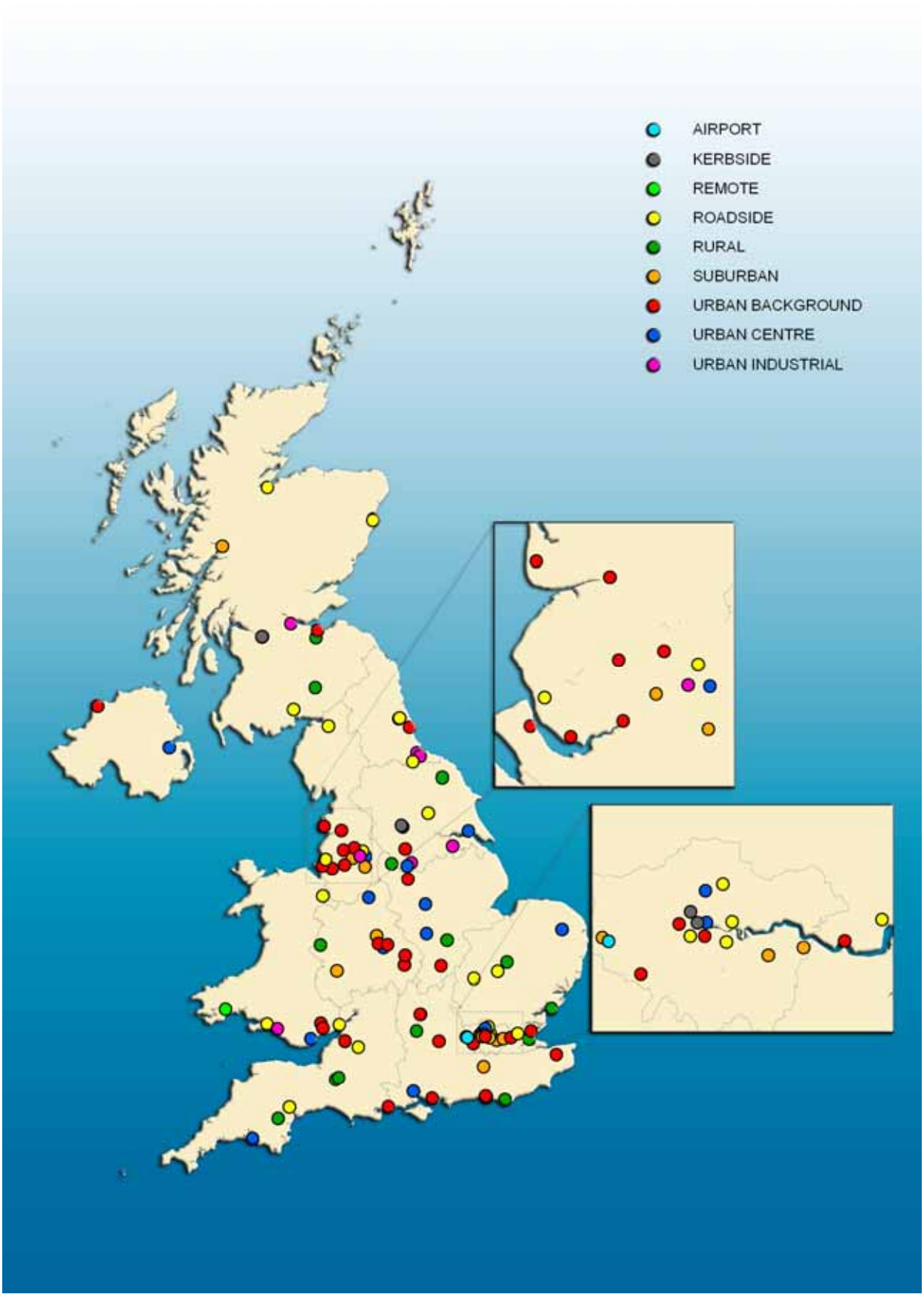
13.3 Data quality requirements of EC Directive 2008/50/EC

Uncertainty 15%
Minimum data capture 90%

13.4 Objectives and bandings

Summary of objectives of the Air Quality Strategy			
	Objective	**Measured as**	**To be achieved by**
Nitrogen Dioxide	200 µg m^{-3} Not to be exceeded more than 18 times per year	1 Hour Mean	31 December 2005
	40 µg m^{-3}	Annual Mean	31 December 2005

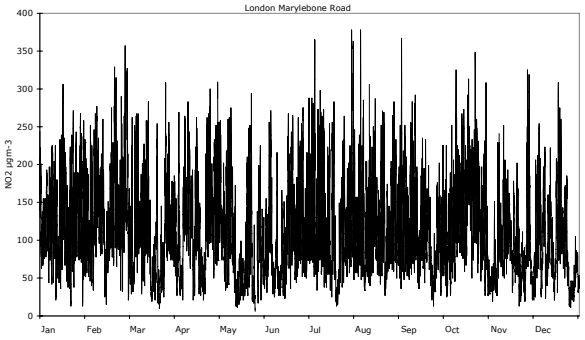
Air Quality Bands and Index Values		
Band	**Index**	**Nitrogen Dioxide µg m^{-3}**
Low	1	0-95
	2	96-190
	3	191-286
Moderate	4	287-381
	5	382-477
	6	478-572
High	7	573-635
	8	363-700
	9	701-763
Very High	10	764 or more



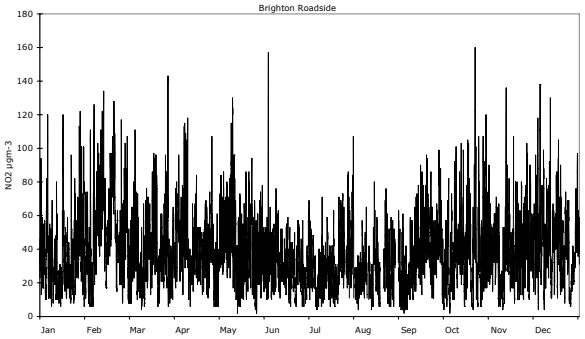
UK automatic nitrogen dioxide monitoring sites 2008

13.5 Hourly average concentrations

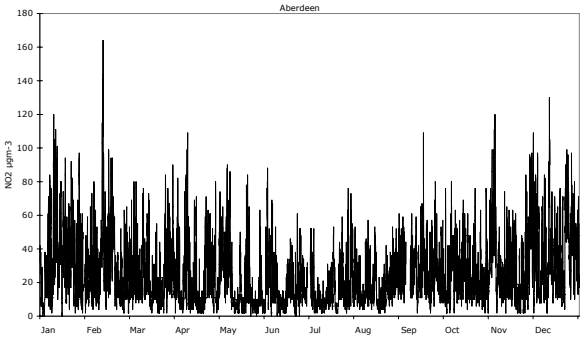
These figures show time series graphs of hourly average nitrogen dioxide concentrations at four monitoring sites of different types for 2008.



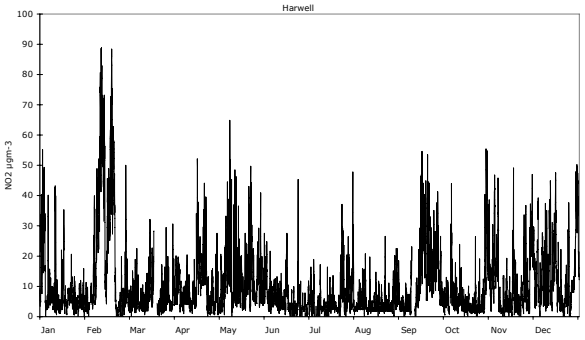
Kerbside Site
(London Marylebone Road)



Roadside Site
(*Brighton Roadside)*



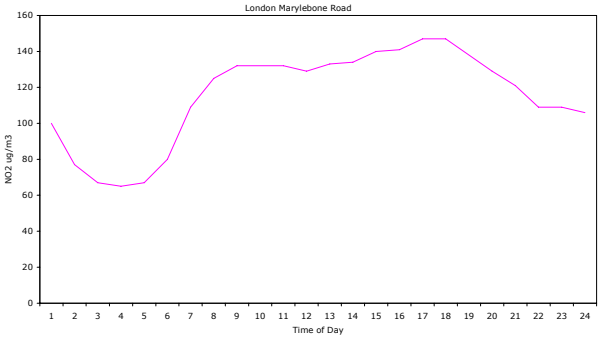
Urban Background Site
(Aberdeen)



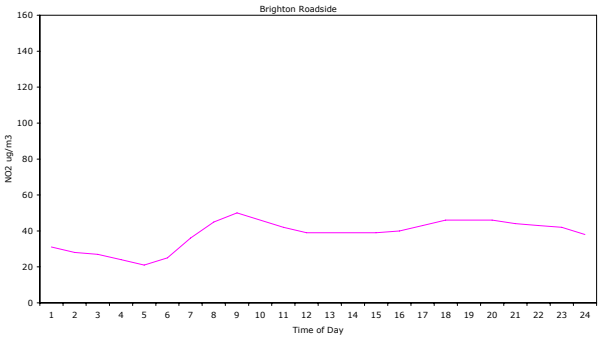
Rural Site
(Harwell)

13.6 Diurnal variations

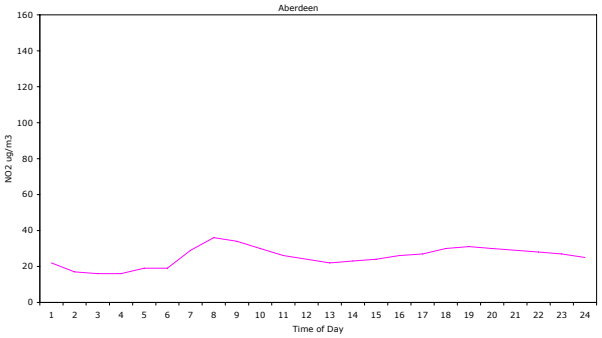
These figures show how nitrogen dioxide concentrations varied on average for each hour of day during 2008, at the same four monitoring sites. Local time is used, rather than GMT, to more closely reflect the daily cycle of man-made emissions.



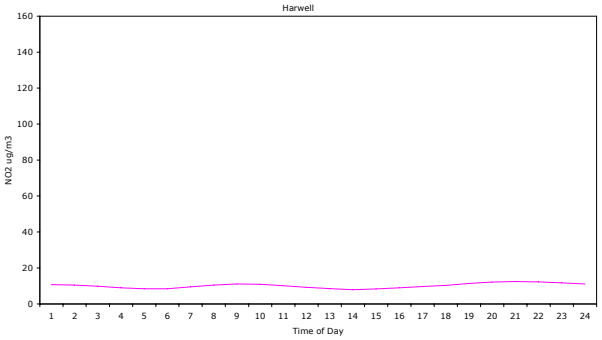
Kerbside Site
(London Marylebone Road)



Roadside Site
(*Brighton Roadside)*



Urban Background Site
(Aberdeen)

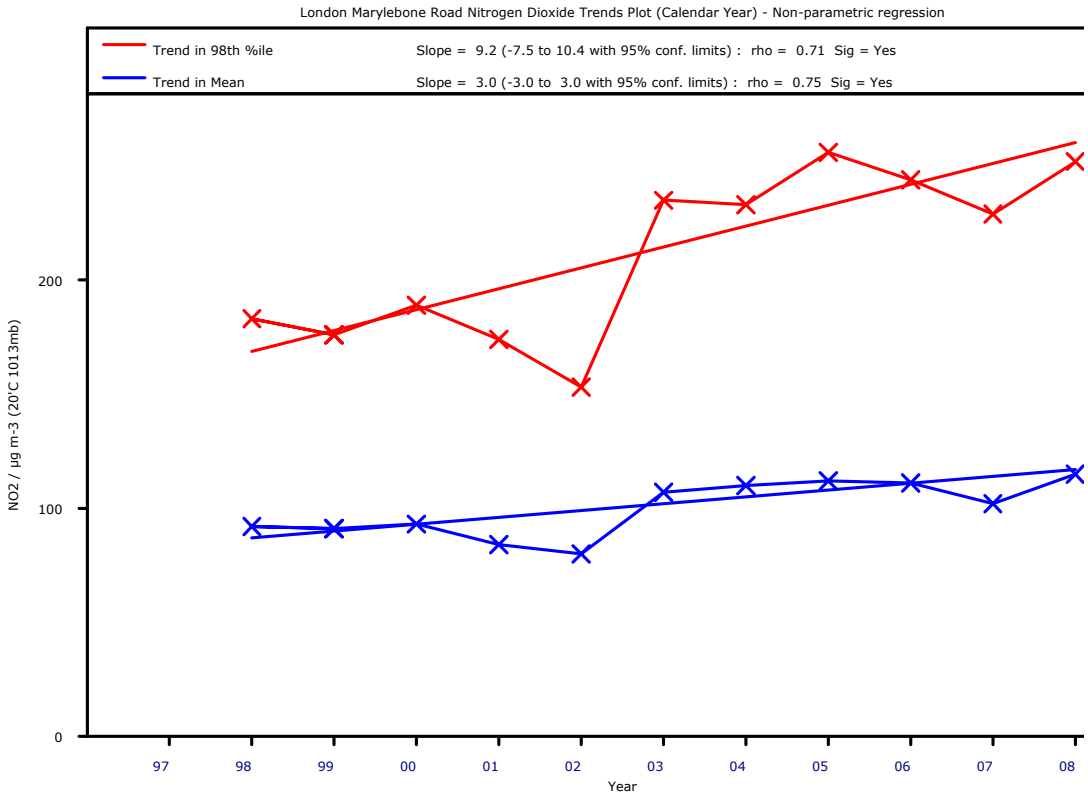


Rural Site
(Harwell)

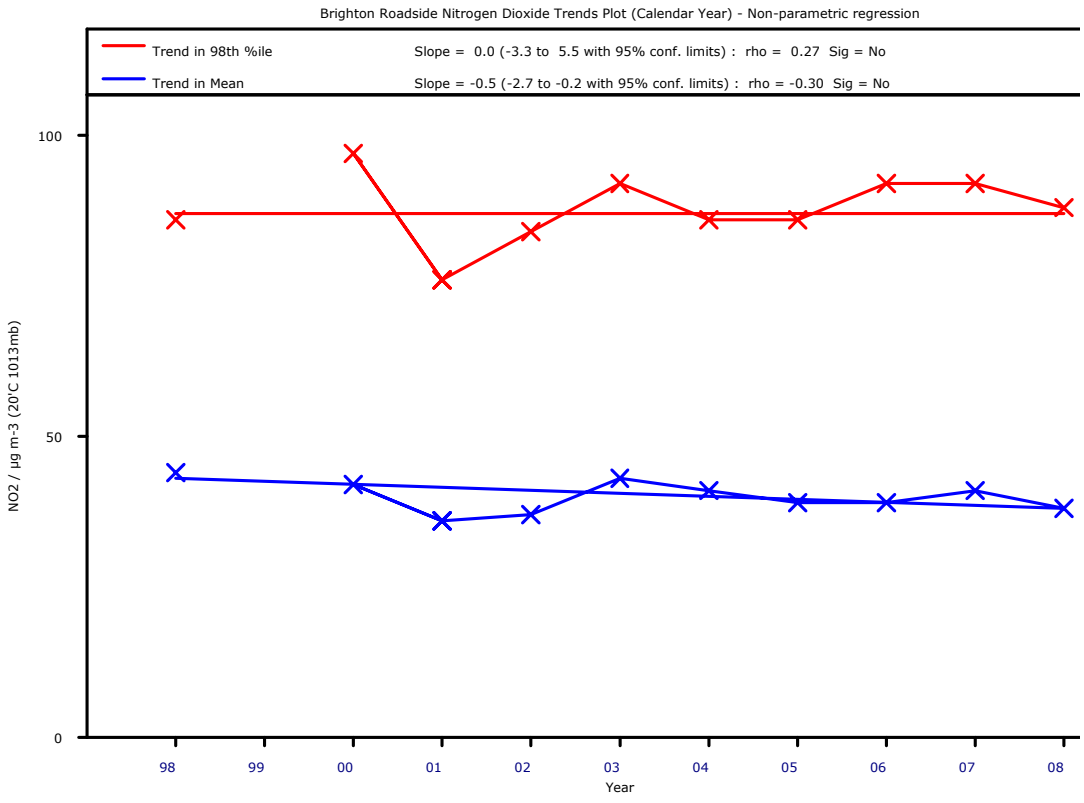
13.7 Trends in annual concentrations

Trends in concentrations are shown for sites with at least 5 years of measurement.

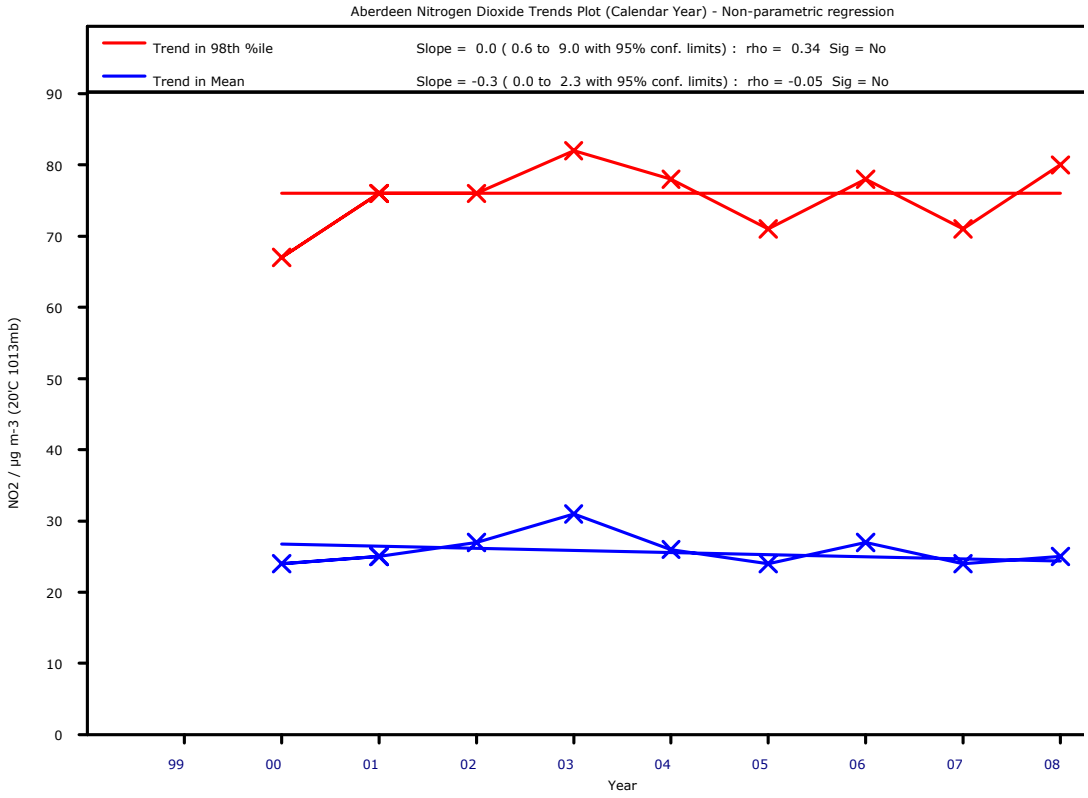
London Marylebone Road NO_2 Trends – Non-parametric regression



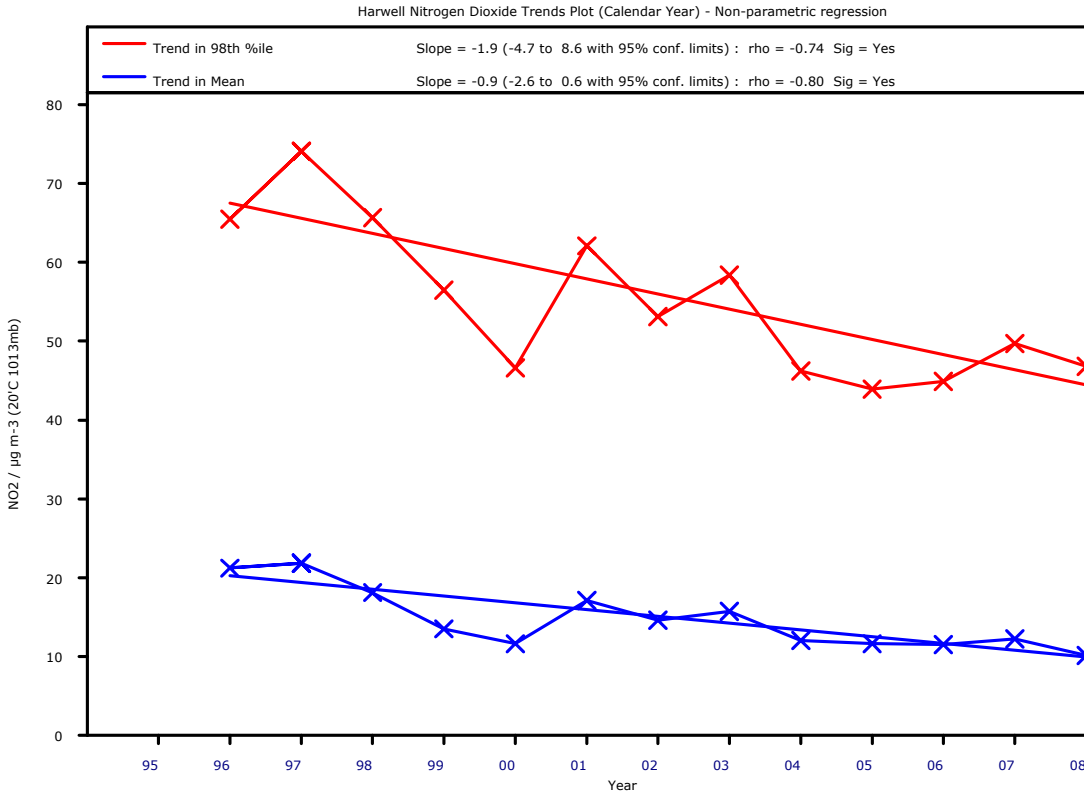
Brighton Roadside NO_2 Trends – Non-parametric regression



Aberdeen NO_2 Trends – Non-parametric regression



Harwell NO_2 Trends – Non-parametric regression



13.8 Nitrogen dioxide statistical summary 2008

i) NO_2 annual statistics I

Site	Site Type	Annual ave. of hourly means µg m^{-3}	Annual data capture of hourly means %	Max. hourly mean µg m^{-3}	99.8%ile of hourly means µg m^{-3}
England					
Barnsley Gawber	UB	19	90.9	220	132
Bath Roadside	RS	65	97.2	288	191
Billingham	UI	27	98.6	244	160
Birmingham Centre	UC	33	96.5	329	136
Birmingham Tyburn	UB	34	98.4	199	128
Blackpool Marton	UB	16	98.1	117	96
Bolton	UB	---	28.1	103	---
Bournemouth	UB	15	96.2	132	88
Brighton Preston Park	UB	20	98.6	120	92
Brighton Roadside	RS	38	97.5	160	120
Bristol Old Market	RS	62	99.4	237	181
Bristol St Paul's	UB	32	99.0	206	149
Bury Roadside	RS	69	96.1	227	178
Cambridge Roadside	RS	42	99.0	174	105
Camden Kerbside	KS	76	93.8	279	229
Canterbury	UB	17	97.3	164	109
Carlisle Roadside	RS	32	85.5	172	138
Charlton Mackrell	RU	---	28.8	56.5	---
Chesterfield	UB	18	73.5	82	69
Chesterfield Roadside	RS	22	72.4	117	86
Coventry Memorial Park	UB	19	99.2	176	111
Exeter Roadside	RS	38	87.3	162	139
Glazebury	S	---	48.7	81.4	---
Haringey Roadside	RS	37	99.2	172	126
Harwell	RU	10.1	97.9	88.8	75.6
High Muffles	RU	6.6	97.9	68.0	58.8
Horley	S	27	99.4	111	90
Hull Freetown	UC	27	92.6	149	92
Ladybower	RU	7.7	94.3	86.3	69.9
Leamington Spa	UB	27	85.7	122	101
Leeds Centre	UC	35	99.5	315	160
Leeds Headingley Kerbside	KS	49	58.6	166	141
Leicester Centre	UC	30	99.2	208	136
Leominster	S	11	94.6	122	78
Liverpool Queen's Drive Roadside	RS	40	99.7	277	166
Liverpool Speke	UB	22	94.6	96	86
London Bexley	S	34	97.5	162	111
London Bloomsbury	UC	55	99.2	176	139
London Cromwell Road 2	RS	67	83.5	210	147
London Eltham	S	26	95.7	151	103
London Haringey	UC	32	98.2	187	113
London Harlington	A	35	97.7	176	134
London Hillingdon	S	51	83.1	220	159
London Marylebone Road	KS	115	99.0	378	321
London N. Kensington	UB	33	89.8	162	122
London Teddington	UB	24.7	97.0	187.2	116.9
London Westminster	UB	40	98.1	225	111
Lullington Heath	RU	9.7	97.1	78.3	65.3
Manchester Piccadilly	UC	43	78.1	288	189
Manchester South	S	24	91.7	132	109
Market Harborough	RU	10.8	99.0	78.7	67.4
Middlesbrough	UI	21	98.6	118	90
Newcastle Centre	UC	35	92.5	126	99
Newcastle Cradlewell Roadside	RS	42	80.9	180	155
Northampton	UB	21	92.4	117	96
Norwich Centre	UC	---	36.3	139	---
Nottingham Centre	UC	33	97.8	233	138
Oxford Centre Roadside	RS	51	97.1	231	174
Oxford St Ebbes	UB	19	82.4	96	86
Plymouth Centre	UC	21	81.4	115	80
Portsmouth	UB	23	97.0	130	107
Preston	UB	21	88.2	134	92
Reading New Town	UB	22	98.2	160	126
Rochester Stoke	RU	17.8	96.8	88.1	74.1
Salford Eccles	UI	36	92.3	223	149

ii) NO_2 exceedence statistics I

Site	Mod. band	Days	High band	Days	Very High band	Days	Annual Mean > 40 µg m^{-3}	Hrs > 200 µg m^{-3}	Days
England									
Barnsley Gawber	0	0	0	0	0	0	0	**2**	**1**
Bath Roadside	1	1	0	0	0	0	**1**	**10**	**8**
Billingham	0	0	0	0	0	0	0	**5**	**5**
Birmingham Centre	1	1	0	0	0	0	0	**3**	**1**
Birmingham Tyburn	0	0	0	0	0	0	0	0	0
Blackpool Marton	0	0	0	0	0	0	0	0	0
Bolton	0	0	0	0	0	0	---	0	0
Bournemouth	0	0	0	0	0	0	0	0	0
Brighton Preston Park	0	0	0	0	0	0	0	0	0
Brighton Roadside	0	0	0	0	0	0	0	0	0
Bristol Old Market	0	0	0	0	0	0	**1**	**5**	**3**
Bristol St Paul's	0	0	0	0	0	0	0	**1**	**1**
Bury Roadside	0	0	0	0	0	0	**1**	**4**	**4**
Cambridge Roadside	0	0	0	0	0	0	**1**	0	0
Camden Kerbside	0	0	0	0	0	0	**1**	**72**	**37**
Canterbury	0	0	0	0	0	0	0	0	0
Carlisle Roadside	0	0	0	0	0	0	0	0	0
Charlton Mackrell	0	0	0	0	0	0	---	0	0
Chesterfield	0	0	0	0	0	0	0	0	0
Chesterfield Roadside	0	0	0	0	0	0	0	0	0
Coventry Memorial Park	0	0	0	0	0	0	0	0	0
Exeter Roadside	0	0	0	0	0	0	0	0	0
Glazebury	0	0	0	0	0	0	---	0	0
Haringey Roadside	0	0	0	0	0	0	0	0	0
Harwell	0	0	0	0	0	0	0	0	0
High Muffles	0	0	0	0	0	0	0	0	0
Horley	0	0	0	0	0	0	0	0	0
Hull Freetown	0	0	0	0	0	0	0	0	0
Ladybower	0	0	0	0	0	0	0	0	0
Leamington Spa	0	0	0	0	0	0	0	0	0
Leeds Centre	1	1	0	0	0	0	0	**8**	**1**
Leeds Headingley Kerbside	0	0	0	0	0	0	**1**	0	0
Leicester Centre	0	0	0	0	0	0	0	**1**	**1**
Leominster	0	0	0	0	0	0	0	0	0
Liverpool Queen's Drive Roadside	0	0	0	0	0	0	0	**6**	**3**
Liverpool Speke	0	0	0	0	0	0	0	0	0
London Bexley	0	0	0	0	0	0	0	0	0
London Bloomsbury	0	0	0	0	0	0	**1**	0	0
London Cromwell Road 2	0	0	0	0	0	0	**1**	**1**	**1**
London Eltham	0	0	0	0	0	0	0	0	0
London Haringey	0	0	0	0	0	0	0	0	0
London Harlington	0	0	0	0	0	0	0	0	0
London Hillingdon	0	0	0	0	0	0	**1**	**1**	**1**
London Marylebone Road	48	28	0	0	0	0	**1**	**822**	**178**
London N. Kensington	0	0	0	0	0	0	0	0	0
London Teddington	0	0	0	0	0	0	0	0	0
London Westminster	0	0	0	0	0	0	0	**1**	**1**
Lullington Heath	0	0	0	0	0	0	0	0	0
Manchester Piccadilly	1	1	0	0	0	0	**1**	**12**	**6**
Manchester South	0	0	0	0	0	0	0	0	0
Market Harborough	0	0	0	0	0	0	0	0	0
Middlesbrough	0	0	0	0	0	0	0	0	0
Newcastle Centre	0	0	0	0	0	0	0	0	0
Newcastle Cradlewell Roadside	0	0	0	0	0	0	**1**	0	0
Northampton	0	0	0	0	0	0	0	0	0
Norwich Centre	0	0	0	0	0	0	---	0	0
Nottingham Centre	0	0	0	0	0	0	0	**6**	**3**
Oxford Centre Roadside	0	0	0	0	0	0	**1**	**3**	**3**
Oxford St Ebbes	0	0	0	0	0	0	0	0	0
Plymouth Centre	0	0	0	0	0	0	0	0	0
Portsmouth	0	0	0	0	0	0	0	0	0
Preston	0	0	0	0	0	0	0	0	0
Reading New Town	0	0	0	0	0	0	0	0	0
Rochester Stoke	0	0	0	0	0	0	0	0	0
Salford Eccles	0	0	0	0	0	0	0	**3**	**2**

iii) NO_2 annual statistics II

Site	Site Type	Annual ave. of hourly means µg m^{-3}	Annual data capture of hourly means %	Max. hourly mean µg m^{-3}	99.8%ile of hourly means µg m^{-3}
England					
Sandwell West Bromwich	UB	27	94.3	187	128
Sandy Roadside	RS	---	38.8	141	---
Scunthorpe Town	UI	19	96.2	122	74
Sheffield Centre	UC	30	97.6	357	118
Sheffield Tinsley	UI	---	34.4	216	---
Somerton	RU	---	16.4	71.4	---
Southampton Centre	UC	36	94.3	220	155
Southend-on-Sea	UB	23	99.3	111	94
Southwark Roadside	RS	---	0.0	---	---
St Osyth	RU	12.6	87.1	111.0	71.8
Stanford-le-Hope Roadside	RS	37	91.5	168	132
Stockton-on-Tees Yarm	RS	34	65.2	273	105
Stoke-on-Trent Centre	UC	26	96.5	311	111
Sunderland Silksworth	UB	14	96.3	111	78
Thurrock	UB	32	96.8	164	111
Tower Hamlets Roadside	RS	63	97.6	195	166
Walsall Willenhall	S	24	91.6	162	107
Warrington	UB	---	16.6	113	---
Wicken Fen	RU	10.5	93.8	84.4	63.4
Wigan Centre	UB	24	98.9	118	99
Wirral Tranmere	UB	19	98.2	187	97
Yarner Wood	RU	5.3	81.7	63.4	50.2
York Fishergate	RS	33	99.6	174	115
N Ireland					
Belfast Centre	UC	32	92.2	250	122
Derry	UB	18	96.1	103	73
Scotland					
Aberdeen	UB	25	98.0	164	109
Aberdeen Union Street Roadside	RS	55	95.3	237	202
Bush Estate	RU	8.0	90.0	87.1	64.7
Dumfries	RS	37	95.4	325	155
Edinburgh St Leonards	UB	31	95.6	262	176
Eskdalemuir	RU	5.1	93.4	53.1	26.5
Fort William	S	11	88.0	84	59
Glasgow Centre	UC	35	76.9	185	149
Glasgow City Chambers	UB	48	98.1	193	151
Glasgow Kerbside	KS	82	94.9	304	233
Grangemouth	UI	17	98.7	157	111
Inverness	RS	21	98.9	160	103
Wales					
Aston Hill	RU	6.4	85.4	78.9	72.0
Cardiff Centre	UC	29	98.6	138	105
Chepstow A48	RS	41	98.4	155	126
Cwmbran	UB	14	88.2	101	74
Narberth	RE	5.8	94.1	84.8	72.8
Newport	UB	24	96.6	206	109
Port Talbot Margam	UI	18	95.2	105	84
Swansea Roadside	RS	32	98.7	174	130
Wrexham	RS	20	98.7	120	90

iv) NO_2 exceedence statistics II

Site	Mod. band	Days	High band	Days	Very High band	Days	Annual Mean > 40 µg m^{-3}	Hrs > 200 µg m^{-3}	Days
England									
Sandwell West Bromwich	0	0	0	0	0	0	0	0	0
Sandy Roadside	0	0	0	0	0	0	---	0	0
Scunthorpe Town	0	0	0	0	0	0	0	0	0
Sheffield Centre	2	1	0	0	0	0	0	**4**	**1**
Sheffield Tinsley	0	0	0	0	0	0	---	**1**	**1**
Somerton	0	0	0	0	0	0	---	0	0
Southampton Centre	0	0	0	0	0	0	0	**3**	**2**
Southend-on-Sea	0	0	0	0	0	0	0	0	0
Southwark Roadside	---	---	---	---	---	---	---	---	---
St Osyth	0	0	0	0	0	0	0	0	0
Stanford-le-Hope Roadside	0	0	0	0	0	0	0	0	0
Stockton-on-Tees Yarm	0	0	0	0	0	0	0	**1**	**1**
Stoke-on-Trent Centre	2	1	0	0	0	0	0	**3**	**1**
Sunderland Silksworth	0	0	0	0	0	0	0	0	0
Thurrock	0	0	0	0	0	0	0	0	0
Tower Hamlets Roadside	0	0	0	0	0	0	**1**	0	0
Walsall Willenhall	0	0	0	0	0	0	0	0	0
Warrington	0	0	0	0	0	0	---	0	0
Wicken Fen	0	0	0	0	0	0	0	0	0
Wigan Centre	0	0	0	0	0	0	0	0	0
Wirral Tranmere	0	0	0	0	0	0	0	0	0
Yarner Wood	0	0	0	0	0	0	0	0	0
York Fishergate	0	0	0	0	0	0	0	0	0
N Ireland									
Belfast Centre	0	0	0	0	0	0	0	**3**	**2**
Derry	0	0	0	0	0	0	0	0	0
Scotland									
Aberdeen	0	0	0	0	0	0	0	0	0
Aberdeen Union Street Roadside	0	0	0	0	0	0	**1**	**20**	**16**
Bush Estate	0	0	0	0	0	0	0	0	0
Dumfries	1	1	0	0	0	0	0	**4**	**4**
Edinburgh St Leonards	0	0	0	0	0	0	0	**6**	**3**
Eskdalemuir	0	0	0	0	0	0	0	0	0
Fort William	0	0	0	0	0	0	0	0	0
Glasgow Centre	0	0	0	0	0	0	0	0	0
Glasgow City Chambers	0	0	0	0	0	0	**1**	0	0
Glasgow Kerbside	1	1	0	0	0	0	**1**	**72**	**28**
Grangemouth	0	0	0	0	0	0	0	0	0
Inverness	0	0	0	0	0	0	0	0	0
Wales									
Aston Hill	0	0	0	0	0	0	0	0	0
Cardiff Centre	0	0	0	0	0	0	0	0	0
Chepstow A48	0	0	0	0	0	0	**1**	0	0
Cwmbran	0	0	0	0	0	0	0	0	0
Narberth	0	0	0	0	0	0	0	0	0
Newport	0	0	0	0	0	0	0	**1**	**1**
Port Talbot Margam	0	0	0	0	0	0	0	0	0
Swansea Roadside	0	0	0	0	0	0	0	0	0
Wrexham	0	0	0	0	0	0	0	0	0

14. NO_x- measurement sites, instrumentation and statistics

14.1 Measurement method

The determination of oxides of nitrogen is based on the chemiluminescent energy emitted when nitric oxide (NO) is reacted with ozone (O_3) in an evacuated chamber to form chemiluminescent nitrogen dioxide (NO_2).

14.2 Instrumentation

The following instrument types* are currently deployed in the AURN:

- Ambirak NO_2
- API M200
- Environnement AC 31M
- Horiba APNA 360
- Monitor Labs 9841
- Rotork 447
- Thermo Electron 42

** Here and elsewhere in this report, references to commercial names of equipment or products does not constitute a recommendation or endorsement by Defra, the DAs or the report authors.*

14.3 Data quality requirements of EC Directive 2008/50/EC

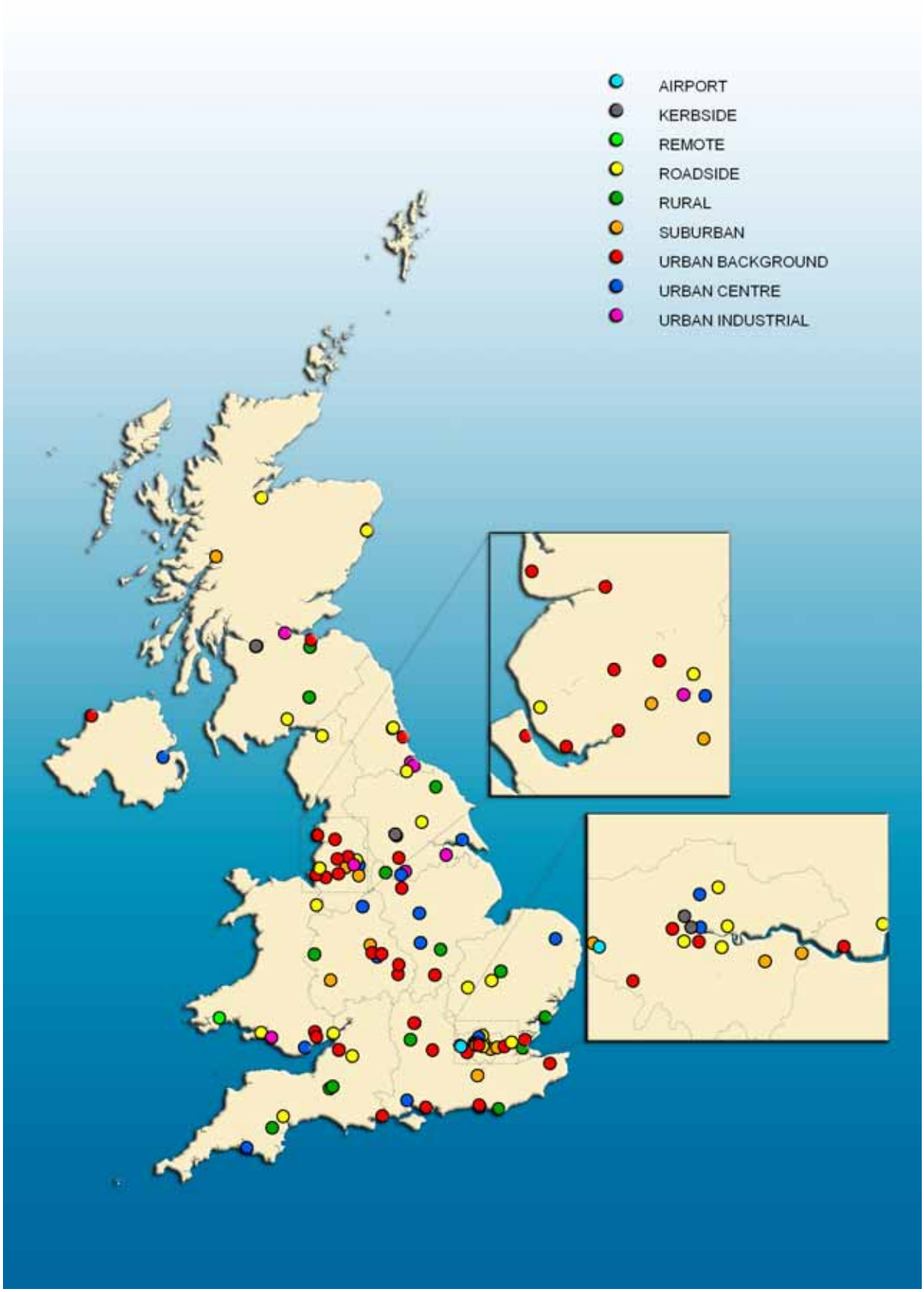
Uncertainty 15%
Minimum data capture 90%

14.4 Objectives and bandings

Summary of objectives of the National Air Quality Strategy			
	Objective*	**Measured as**	**To be achieved by**
NO_x	30 µg m^{-3}	Annual Mean	31 December 2000

Assuming NO_x is taken as NO_2. Also note this objective is for the protection of vegetation and ecosystems,* ***so it is only applicable at rural and remote sites.* *The tables show exceedence statistics for all sites, but those where this objective is applicable (i.e. rural and remote sites) are highlighted in* ***bold text****.*

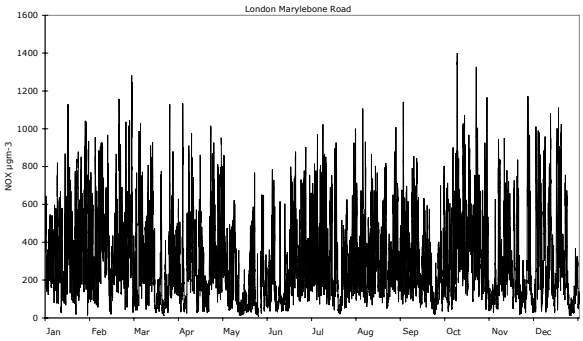
No bandings are set for total oxides of nitrogen, as the short-term effects of total NO_x will depend on the proportions of NO_2 and NO.



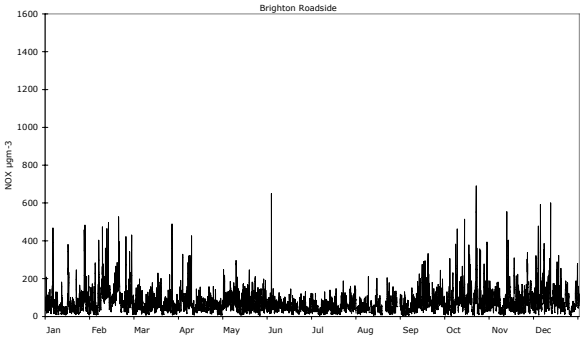
UK automatic nitrogen oxides monitoring sites 2008

14.5 Hourly average concentrations

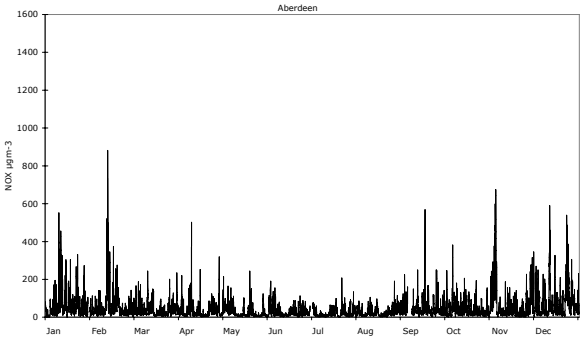
These figures show time series graphs of hourly average nitrogen oxides concentrations at four monitoring sites of different types for 2008.



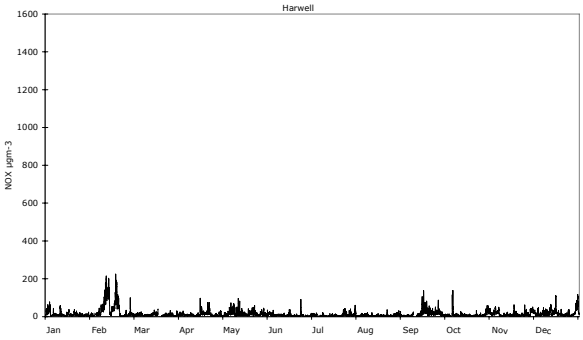
Kerbside Site
(London Marylebone Road)



Roadside Site
(*Brighton Roadside)*



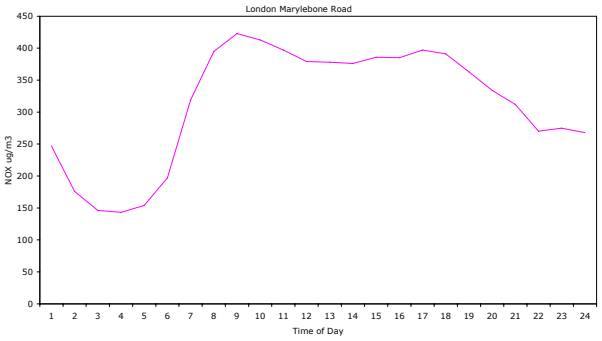
Urban Background Site
(Aberdeen)



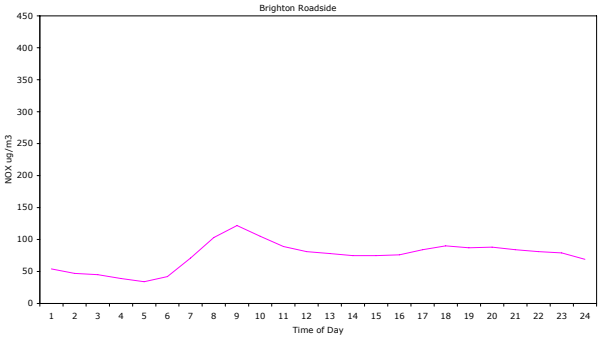
Rural Site
(Harwell)

14.6 Diurnal variations

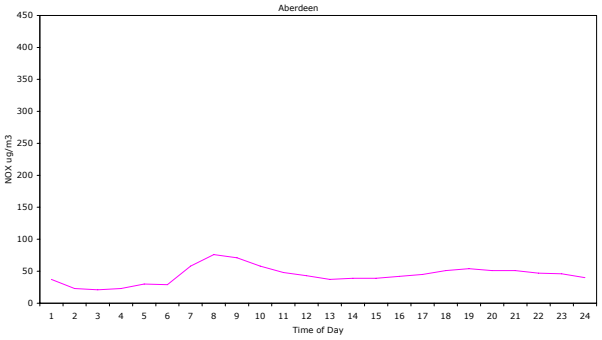
These figures show how NOx concentrations varied on average for each hour of day during the year, at the same four sites. Local time is used, rather than GMT, to more closely reflect the daily cycle of man-made emissions.



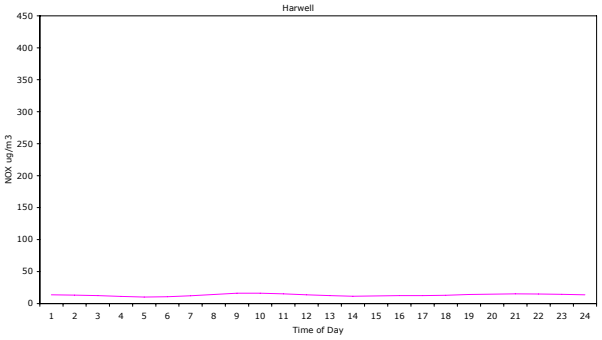
Kerbside Site
(London Marylebone Road)



Roadside Site
(*Brighton Roadside)*



Urban Background Site
(Aberdeen)

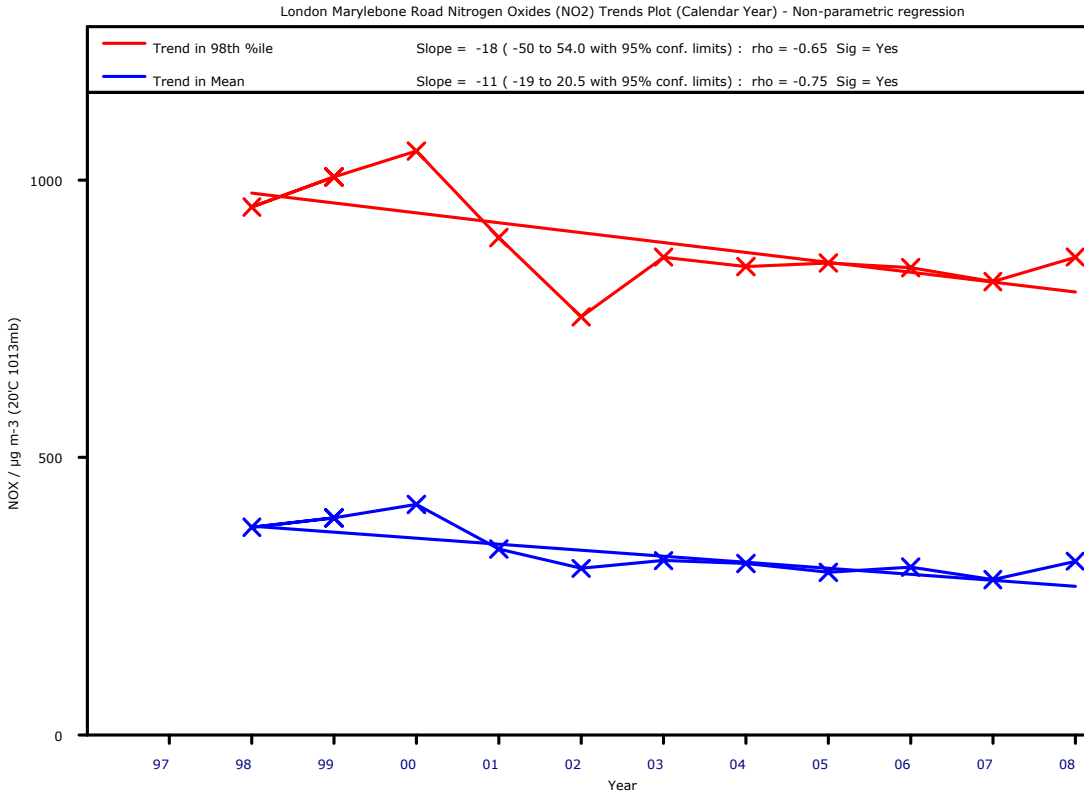


Rural Site
(Harwell)

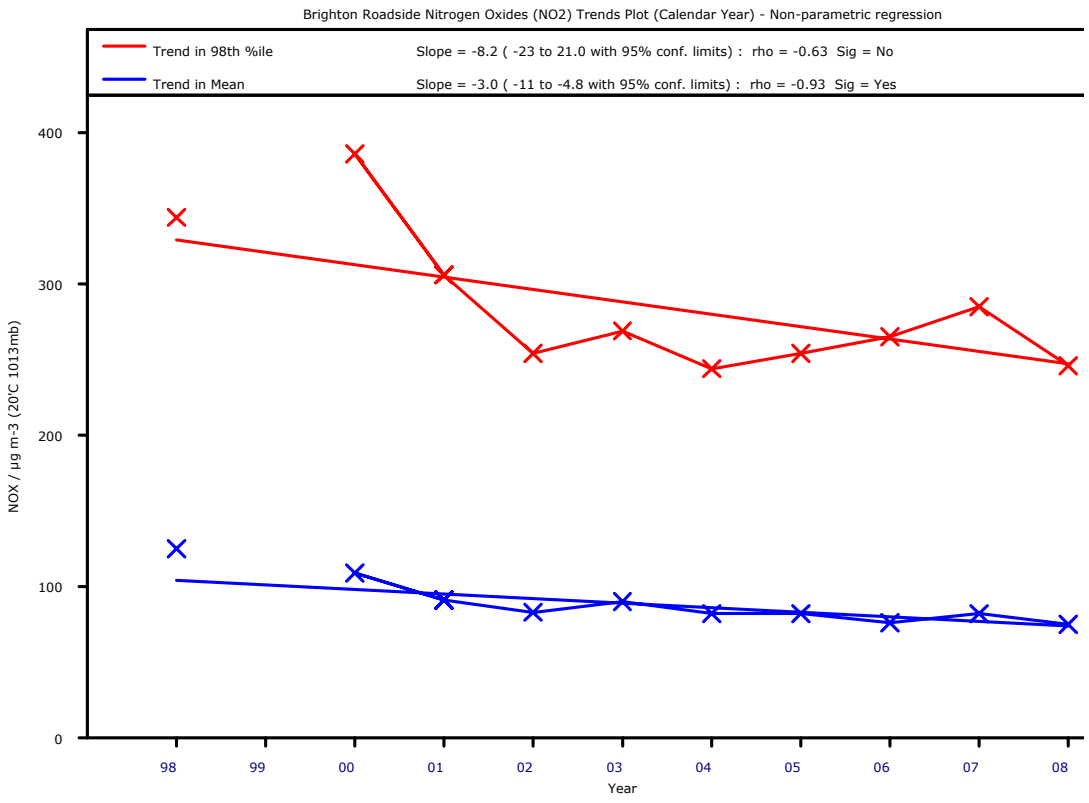
14.7 Trends in annual concentrations

Trends in concentration are shown for sites with at least 5 years of measurement.

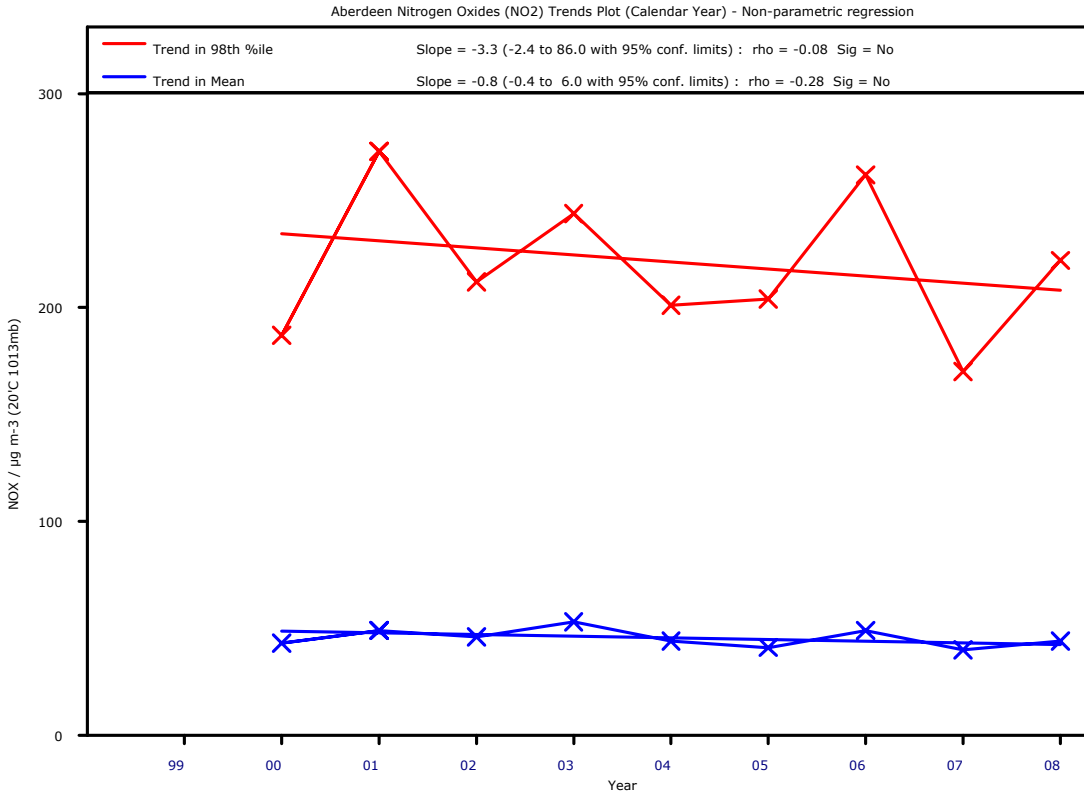
London Marylebone Road Nitrogen Oxides Trends – Non-parametric regression



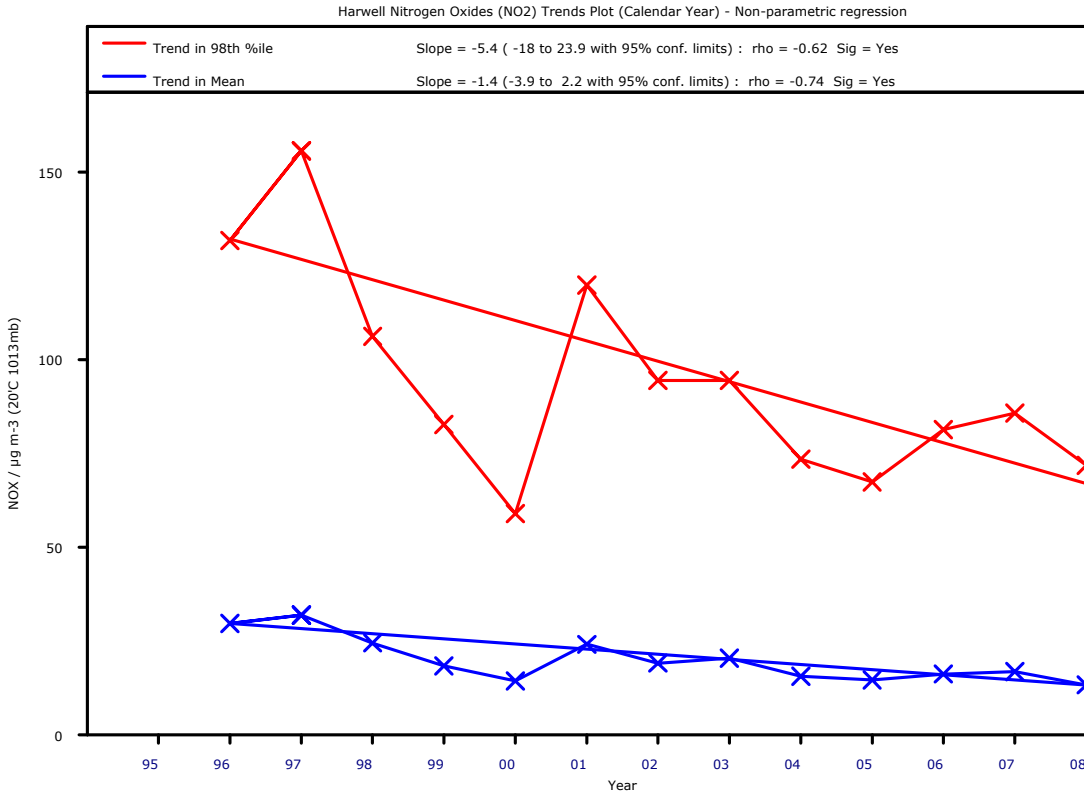
Brighton Roadside Nitrogen Oxides Trends – Non-parametric regression



Aberdeen Nitrogen Oxides Trends – Non-parametric regression



Harwell Nitrogen Oxides Trends – Non-parametric regression



14.8 Nitrogen oxides statistical summary 2008

i) NO_x annual statistics I (Rural/Remote sites in bold)

Site	Site Type	Annual average of hourly means µg m^{-3}	Annual data capture of hourly means %	Maximum hourly mean µg m^{-3}
England				
Barnsley Gawber	UB	28	90.9	823
Bath Roadside	RS	174	97.2	1159
Billingham	UI	48	98.6	934
Birmingham Centre	UC	51	96.5	1872
Birmingham Tyburn	UB	63	98.4	1576
Blackpool Marton	UB	27	98.1	462
Bolton	UB	---	28.1	476
Bournemouth	UB	22	96.2	491
Brighton Preston Park	UB	29	98.6	583
Brighton Roadside	RS	75	97.5	690
Bristol Old Market	RS	163	99.4	1389
Bristol St Paul's	UB	56	99.0	1198
Bury Roadside	RS	179	96.1	1110
Cambridge Roadside	RS	98	99.0	1024
Camden Kerbside	KS	178	93.8	1083
Canterbury	UB	31	97.3	1075
Carlisle Roadside	RS	84	85.5	802
Charlton Mackrell	**RU**	**---**	**28.8**	**101.6**
Chesterfield	UB	25	73.5	418
Chesterfield Roadside	RS	48	72.4	424
Coventry Memorial Park	UB	27	99.2	882
Exeter Roadside	RS	99	87.3	936
Glazebury	S	---	48.7	375.9
Haringey Roadside	RS	76	99.2	1161
Harwell	**RU**	**13.3**	**97.9**	**224.2**
High Muffles	**RU**	**8.3**	**97.9**	**167.7**
Horley	S	45	99.4	716
Hull Freetown	UC	44	92.6	640
Ladybower	**RU**	**9.9**	**94.3**	**158.1**
Leamington Spa	UB	43	85.7	1016
Leeds Centre	UC	64	99.5	1287
Leeds Headingley Kerbside	KS	123	58.6	850
Leicester Centre	UC	51	99.2	1211
Leominster	S	17	94.6	577
Liverpool Queen's Drive Roadside	RS	76	99.7	873
Liverpool Speke	UB	33	94.6	525
London Bexley	S	57	97.5	907
London Bloomsbury	UC	94	99.2	686
London Cromwell Road 2	RS	157	83.5	1245
London Eltham	S	40	95.7	959
London Haringey	UC	49	98.2	987
London Harlington	A	64	97.7	923
London Hillingdon	S	111	83.1	1096
London Marylebone Road	KS	313	99.0	1398
London N. Kensington	UB	49	89.8	726
London Teddington	UB	38.1	97.0	723.1
London Westminster	UB	69	98.1	1026
Lullington Heath	**RU**	**12.7**	**97.1**	**143.6**
Manchester Piccadilly	UC	86	78.1	1868
Manchester South	S	39	91.7	703
Market Harborough	**RU**	**12.3**	**99.0**	**173.6**
Middlesbrough	UI	28	98.6	481
Newcastle Centre	UC	57	92.5	726
Newcastle Cradlewell Roadside	RS	103	80.9	934
Northampton	UB	30	92.4	487
Norwich Centre	UC	---	36.3	997
Nottingham Centre	UC	59	97.8	1518
Oxford Centre Roadside	RS	152	97.1	1075
Oxford St Ebbes	UB	32	82.4	533
Plymouth Centre	UC	33	81.4	699
Portsmouth	UB	36	97.0	827
Preston	UB	34	88.2	521
Reading New Town	UB	36	98.2	798

ii) NO_x exceedence statistics I (Rural/Remote sites in bold)

Site	EC and AQS Ecosystem Air Quality Objective (Annual Mean) > 30 µg m^{-3}
England	
Barnsley Gawber	0
Bath Roadside	**1**
Billingham	**1**
Birmingham Centre	**1**
Birmingham Tyburn	**1**
Blackpool Marton	0
Bolton	---
Bournemouth	0
Brighton Preston Park	0
Brighton Roadside	**1**
Bristol Old Market	**1**
Bristol St Paul's	**1**
Bury Roadside	**1**
Cambridge Roadside	**1**
Camden Kerbside	**1**
Canterbury	**1**
Carlisle Roadside	**1**
Charlton Mackrell	**---**
Chesterfield	0
Chesterfield Roadside	**1**
Coventry Memorial Park	0
Exeter Roadside	**1**
Glazebury	---
Haringey Roadside	**1**
Harwell	**0**
High Muffles	**0**
Horley	**1**
Hull Freetown	**1**
Ladybower	**0**
Leamington Spa	**1**
Leeds Centre	**1**
Leeds Headingley Kerbside	**1**
Leicester Centre	**1**
Leominster	0
Liverpool Queen's Drive Roadside	**1**
Liverpool Speke	**1**
London Bexley	**1**
London Bloomsbury	**1**
London Cromwell Road 2	**1**
London Eltham	**1**
London Haringey	**1**
London Harlington	**1**
London Hillingdon	**1**
London Marylebone Road	**1**
London N. Kensington	**1**
London Teddington	**1**
London Westminster	**1**
Lullington Heath	**0**
Manchester Piccadilly	**1**
Manchester South	**1**
Market Harborough	**0**
Middlesbrough	0
Newcastle Centre	**1**
Newcastle Cradlewell Roadside	**1**
Northampton	0
Norwich Centre	---
Nottingham Centre	**1**
Oxford Centre Roadside	**1**
Oxford St Ebbes	**1**
Plymouth Centre	**1**
Portsmouth	**1**
Preston	**1**
Reading New Town	**1**

iii) NO_x annual statistics II (rural/remote sites in bold)

Site	Site Type	Annual average of hourly means µg m^{-3}	Annual data capture of hourly means %	Maximum hourly mean µg m^{-3}
England				
Rochester Stoke	**RU**	**25.3**	**96.8**	**355.5**
Salford Eccles	UI	62	92.3	1371
Sandwell West Bromwich	UB	41	94.3	1154
Sandy Roadside	RS	---	38.8	567
Scunthorpe Town	UI	32	96.2	663
Sheffield Centre	UC	59	97.6	1228
Sheffield Tinsley	UI	---	34.4	1157
Somerton	**RU**	**---**	**16.4**	**149.7**
Southampton Centre	UC	66	94.3	1089
Southend-on-Sea	UB	34	99.3	474
Southwark Roadside	RS	---	0.0	---
St Osyth	**RU**	**16.3**	**87.1**	**470.8**
Stanford-le-Hope Roadside	RS	81	91.5	1068
Stockton-on-Tees Yarm	RS	101	65.2	703
Stoke-on-Trent Centre	UC	46	96.5	1683
Sunderland Silksworth	UB	22	96.3	458
Thurrock	UB	55	96.8	986
Tower Hamlets Roadside	RS	141	97.6	928
Walsall Willenhall	S	39	91.6	1253
Warrington	UB	---	16.6	743
Wicken Fen	**RU**	**14.3**	**93.8**	**337.3**
Wigan Centre	UB	42	98.9	688
Wirral Tranmere	UB	27	98.2	451
Yarner Wood	**RU**	**6.7**	**81.7**	**100.1**
York Fishergate	RS	70	99.6	915
N Ireland				
Belfast Centre	UC	58	92.2	1532
Derry	UB	28	96.1	458
Scotland				
Aberdeen	UB	44	98.0	882
Aberdeen Union Street Roadside	RS	132	95.3	1251
Bush Estate	**RU**	**9.9**	**90.0**	**231.7**
Dumfries	RS	89	95.4	984
Edinburgh St Leonards	UB	53	95.6	1352
Eskdalemuir	**RU**	**6.3**	**93.4**	**78.7**
Fort William	S	17	88.0	267
Glasgow Centre	UC	70	76.9	997
Glasgow City Chambers	UB	93	98.1	1094
Glasgow Kerbside	KS	277	94.9	1753
Grangemouth	UI	31	98.7	1005
Inverness	RS	42	98.9	581
Wales				
Aston Hill	**RU**	**8.0**	**85.4**	**140.4**
Cardiff Centre	UC	47	98.6	701
Chepstow A48	RS	103	98.4	571
Cwmbran	UB	21	88.2	514
Narberth	**RE**	**8.4**	**94.1**	**127.4**
Newport	UB	45	96.6	854
Port Talbot Margam	UI	27	95.2	544
Swansea Roadside	RS	65	98.7	749
Wrexham	RS	37	98.7	512

iv) NO_x exceedence statistics II (rural/remote sites in bold)

Site	EC and AQS Ecosystem Air Quality Objective (Annual Mean) > 30 µg m^{-3}
England	
Rochester Stoke	**0**
Salford Eccles	**1**
Sandwell West Bromwich	**1**
Sandy Roadside	---
Scunthorpe Town	**1**
Sheffield Centre	**1**
Sheffield Tinsley	---
Somerton	**---**
Southampton Centre	**1**
Southend-on-Sea	**1**
Southwark Roadside	---
St Osyth	**0**
Stanford-le-Hope Roadside	**1**
Stockton-on-Tees Yarm	**1**
Stoke-on-Trent Centre	**1**
Sunderland Silksworth	0
Thurrock	**1**
Tower Hamlets Roadside	**1**
Walsall Willenhall	**1**
Warrington	---
Wicken Fen	**0**
Wigan Centre	**1**
Wirral Tranmere	0
Yarner Wood	**0**
York Fishergate	**1**
N Ireland	
Belfast Centre	**1**
Derry	0
Scotland	
Aberdeen	**1**
Aberdeen Union Street Roadside	**1**
Bush Estate	**0**
Dumfries	**1**
Edinburgh St Leonards	**1**
Eskdalemuir	**0**
Fort William	0
Glasgow Centre	**1**
Glasgow City Chambers	**1**
Glasgow Kerbside	**1**
Grangemouth	**1**
Inverness	**1**
Wales	
Aston Hill	**0**
Cardiff Centre	**1**
Chepstow A48	**1**
Cwmbran	0
Narberth	**0**
Newport	**1**
Port Talbot Margam	0
Swansea Roadside	**1**
Wrexham	**1**

15. PM_{10} - measurement sites, instrumentation and statistics

15.1 Measurement methods

The tapered element oscillating microbalance (**TEOM**) system determines particulate concentration by continuously weighing particles deposited on a filter. The **beta-attenuation monitor** (BAM) consists of a paper band filter located between a source of beta rays and a radiation detector. A pump draws ambient air through the filter and the reduction in intensity of beta-radiation measured at the detector is proportional to the mass of particulate deposited on the filter. The **Partisol** is a gravimetric sampler that collects daily samples onto a filter for subsequent weighing to determine the PM_{10} concentration.

For further information on particle measurements, please see Section 3.6 and Appendix 6.

15.2 Instrumentation

The following instrument types* are currently deployed in the AURN:

- R&P TEOM 1400
- R&P TEOM 1400 AB with 8500 FDMS
- R&P Partisol
- Met One Beta-Attenuation Monitor (BAM) 1020

Please also see detailed information on particle measurements and conversion factors used in this report (Appendix 6).

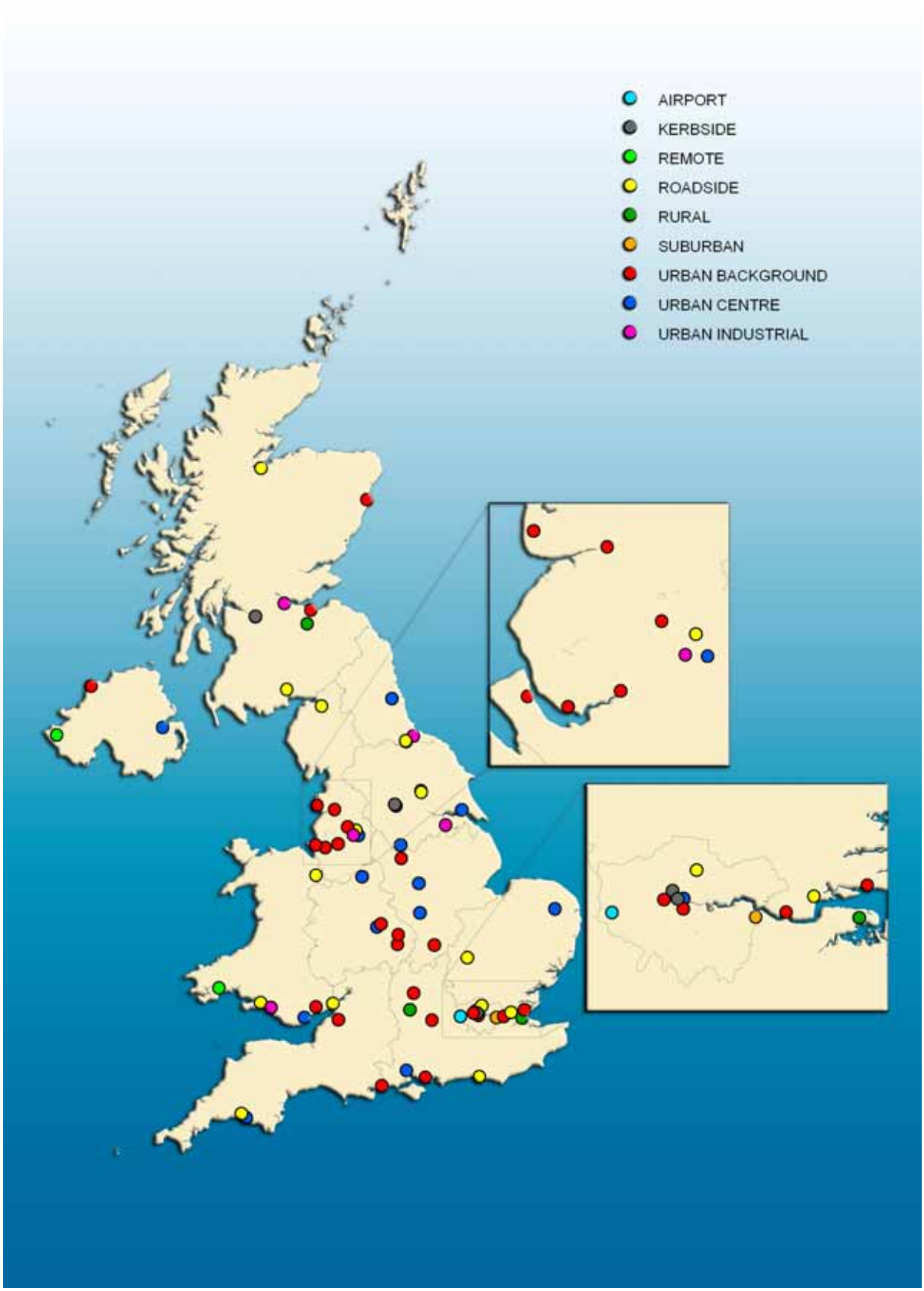
15.3 Data quality requirements of EC Directive 2008/50/EC

Uncertainty 25%, minimum data capture 90%

15.4 Objectives and bandings

Summary of objectives of the Air Quality Strategy			
	Objective	**Measured as**	**To be achieved by**
Particles (PM_{10}) (gravimetric) All authorities	50 µg m^{-3} Not to be exceeded more than 35 times per year	Daily Mean	31 December 2005
	40 µg m^{-3}	Annual Mean	31 December 2005
Particles (PM_{10}) Authorities in Scotland only	50 µg m^{-3} Not to be exceeded more than 7 times per year	Daily Mean	31 December 2010
	18 µg m^{-3}	Annual Mean	31 December 2010

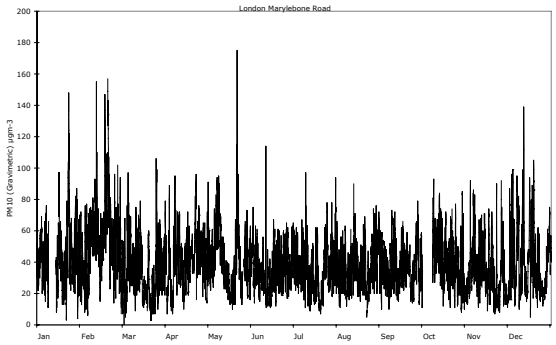
Air Quality Bands and Index Values		
Band	**Index**	**PM_{10} µg m^{-3} (Gravimetric)**
Low	1	0-16
	2	17-32
	3	33-49
Moderate	4	50-57
	5	58-66
	6	67-74
High	7	75-82
	8	83-91
	9	92-99
Very High	10	100 or more



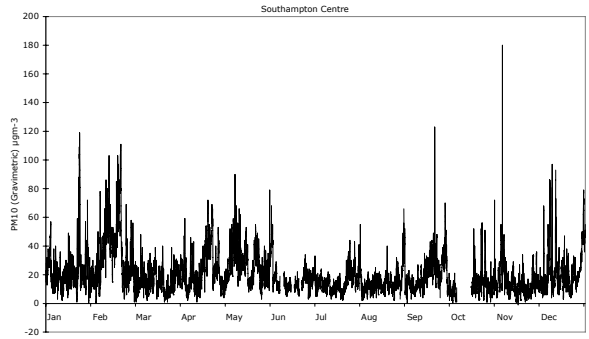
UK automatic PM_{10} particles monitoring sites 2008

15.5 Hourly average concentrations

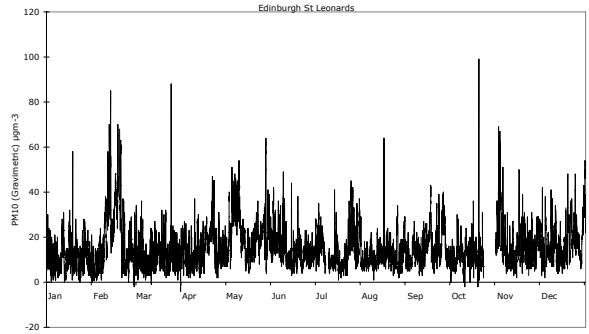
These figures show time series graphs of hourly average PM_{10} concentrations (gravimetric equivalent) at four monitoring sites of different types for 2008.



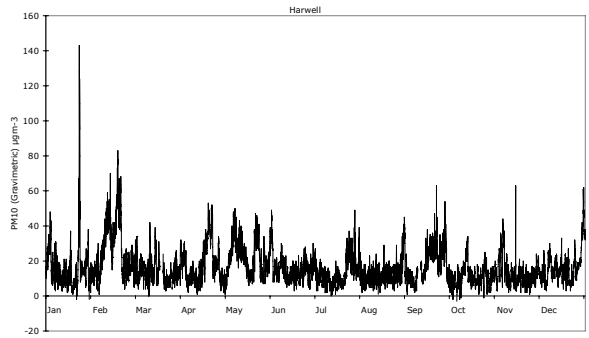
Kerbside Site
(London Marylebone Road)



Urban Centre Site
(Southampton Centre)



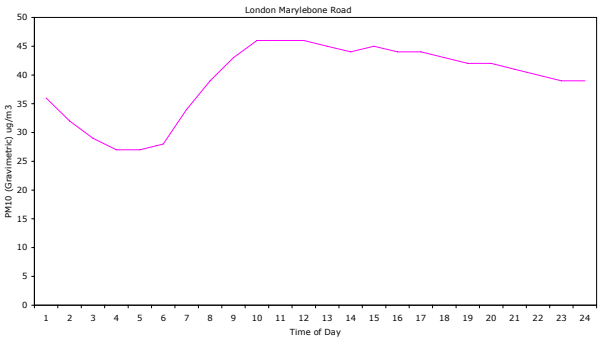
Urban Background Site
(Edinburgh St Leonards)



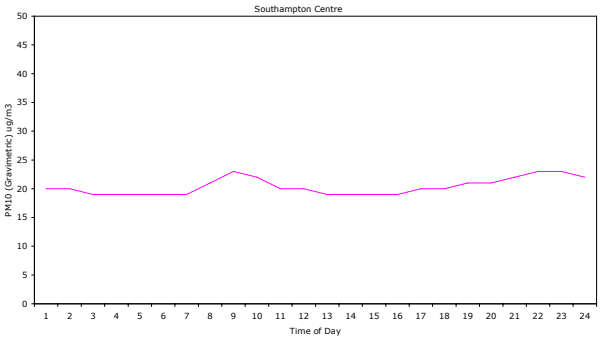
Rural Site
(Harwell)

15.6 Diurnal variations

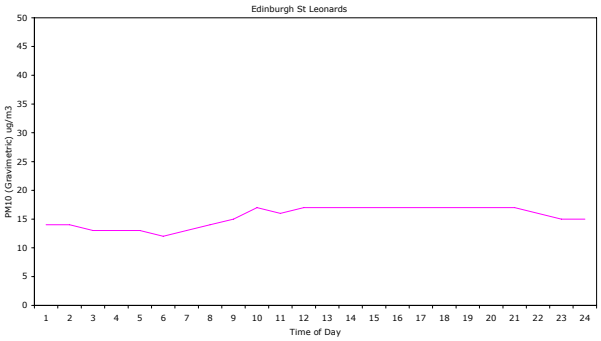
These figures show how PM_{10} concentrations varied on average for each hour of day during the year, at the same four monitoring sites. Local time is used, rather than GMT, to more closely reflect the daily cycle of man-made emissions.



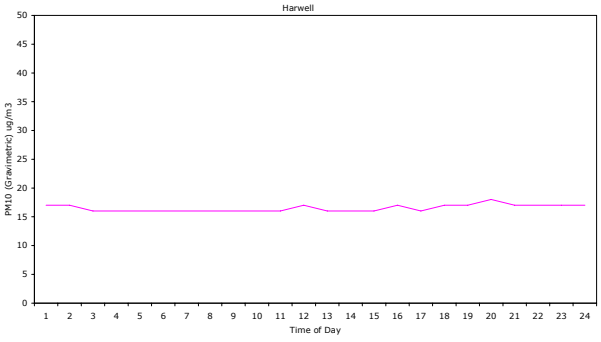
Kerbside Site
(London Marylebone Road)



Urban Centre Site
(*Southampton)*



Urban Background Site
(Edinburgh St Leonards)

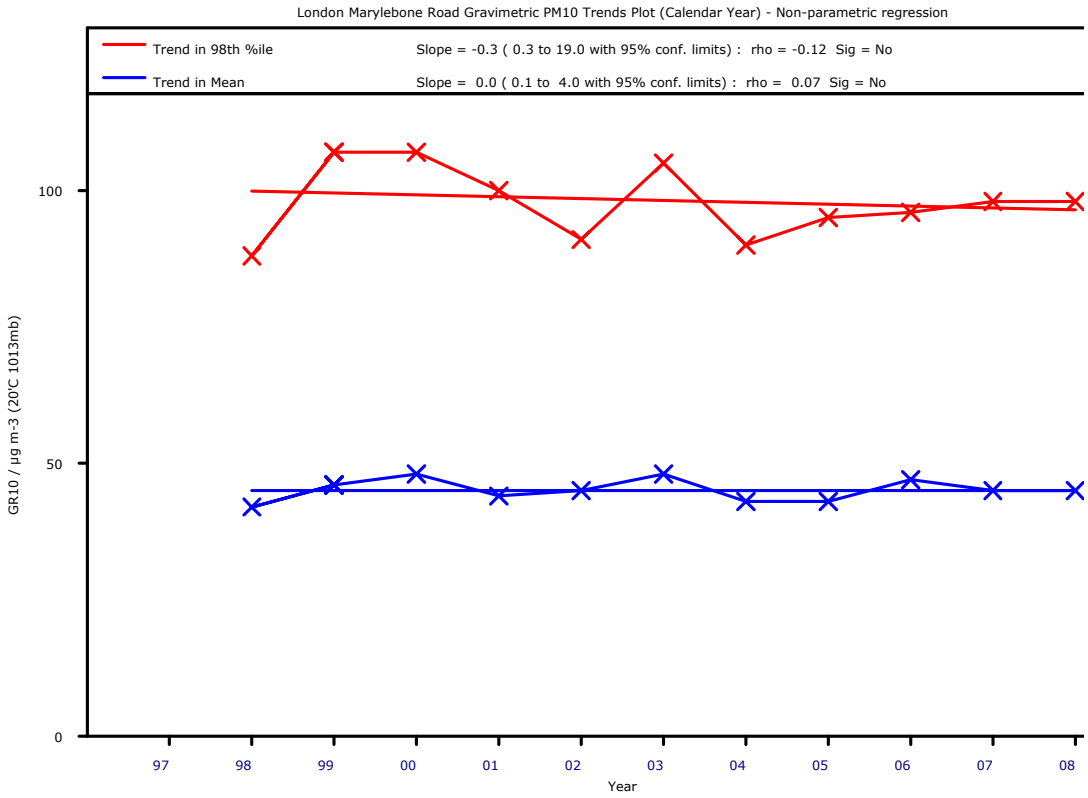


Rural Site
(Harwell)

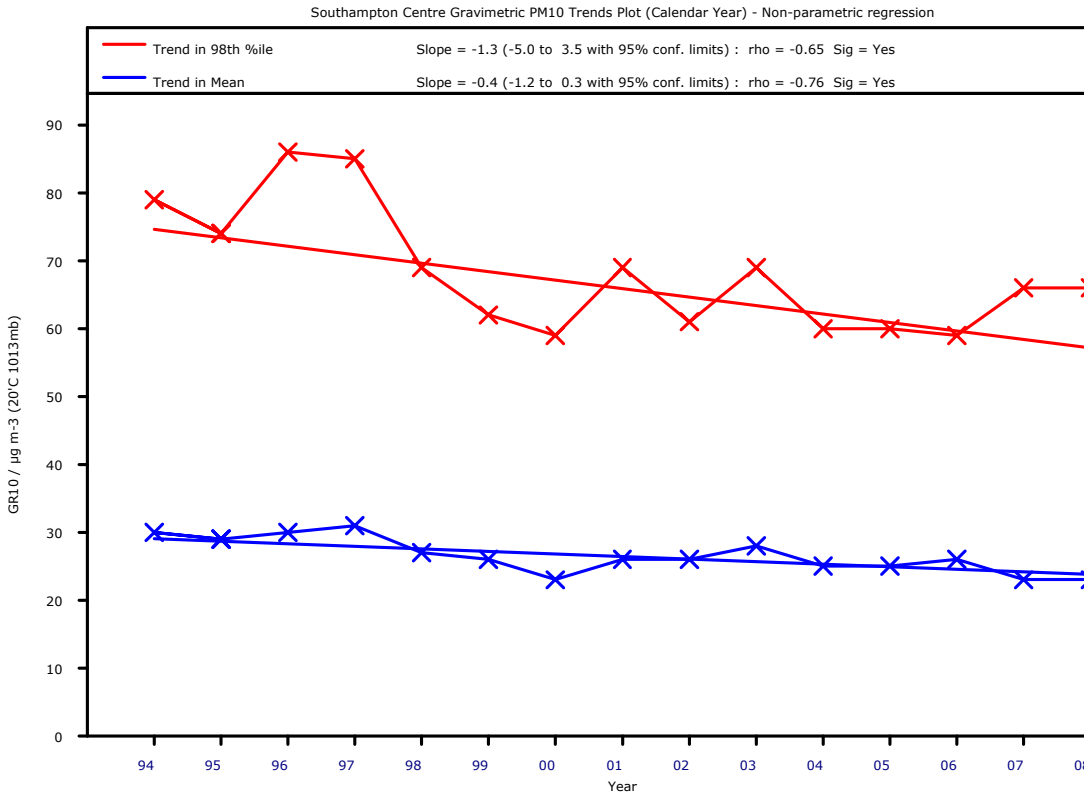
15.7 Trends in annual concentrations

Trends in concentrations are shown for sites with at least 5 years of measurement.

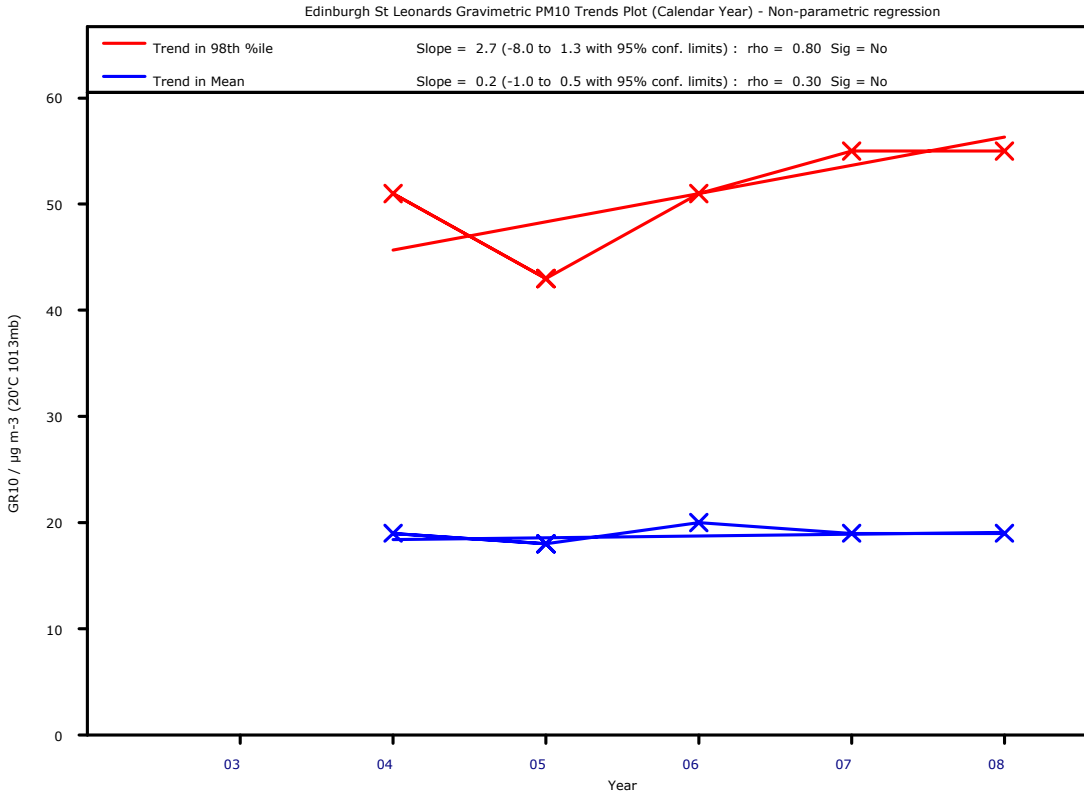
London Marylebone Road PM_{10} Trends – Non-parametric regression



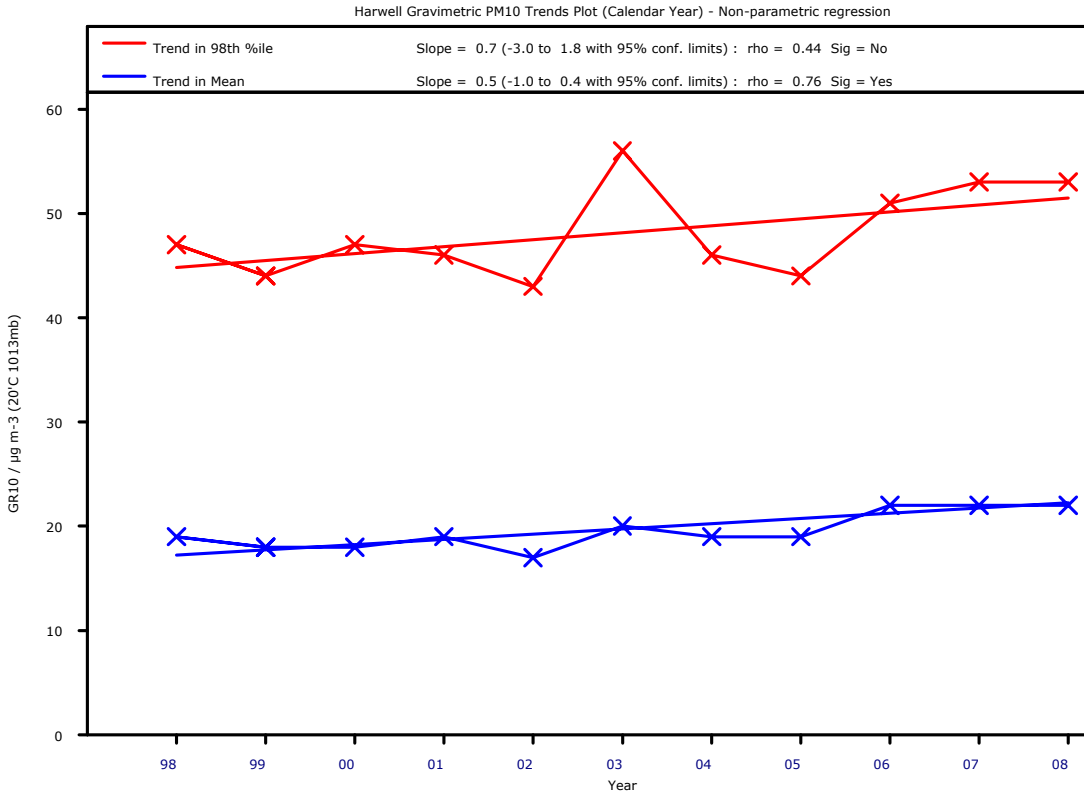
Southampton PM_{10} Trends – Non-parametric regression



Edinburgh St Leonards PM_{10} Trends – Non-parametric regression



Harwell PM_{10} Trends – Non-parametric regression



15.8 PM_{10} statistical summary 2008

i) PM_{10} annual statistics I

Site	Site Type	Ann. ave. hourly means µg m^{-3}	Ann. data capture of hourly means %	Max. hrly mean µg m^{-3}	Max. running 24-h mean µg m^{-3}	Date of max. running 24-h mean	90%ile of daily means µg m^{-3}	98%ile of daily means µg m^{-3}
England								
Birmingham Centre	UC	16	97.8	285	112	13/02/2008	30	53
Birmingham Tyburn	UB	19	76.0	126	54	06/11/2008	31	43
Blackpool Marton	UB	17	92.9	397	66	20/02/2008	30	46
Bolton	UB	---	28.8	83	59	11/05/2008	---	---
Bournemouth *	UB	21	97.5	---	---	---	33	50
Brighton Roadside *	RS	---	33.6	---	---	---	---	---
Bristol St Paul's	UB	20	97.5	465	90	24/01/2008	36	63
Bury Roadside	RS	21	96.1	144	95	19/02/2008	35	54
Camden Kerbside	KS	26	93.0	157	96	21/02/2008	43	56
Carlisle Roadside	RS	22	82.0	188	96	20/02/2008	35	52
Chesterfield	UB	18	76.5	103	62	11/05/2008	31	46
Chesterfield Roadside	RS	23	76.6	113	65	11/05/2008	36	49
Coventry Memorial Park	UB	18	91.7	144	77	19/02/2008	30	46
Haringey Roadside	RS	21	65.4	114	81	21/02/2008	36	51
Harwell	RU	17	98.1	143	82	24/01/2008	29	46
Harwell PARTISOL *	RU	---	27.6	---	---	---	---	---
Hull Freetown	UC	17	98.0	227	74	11/05/2008	30	48
Leamington Spa	UB	19	62.5	146	73	31/12/2008	32	56
Leeds Centre	UC	20	99.2	193	118	12/02/2008	34	62
Leeds Headingley Kerbside	KS	21	86.2	210	95	19/02/2008	35	49
Leicester Centre	UC	17	96.3	129	86	19/02/2008	29	50
Liverpool Speke	UB	16	98.0	299	101	06/11/2008	30	58
London Bexley	S	---	38.5	95	68	21/02/2008	---	---
London Bloomsbury	UC	23	92.4	146	84	24/01/2008	38	53
London Harlington	A	21	90.7	125	78	21/02/2008	34	55
London Marylebone Road	KS	39	95.1	255	114	21/02/2008	56	69
London Marylebone Road PARTISOL *	KS	37	57.7	---	---	---	55	67
London N. Kensington	UB	20	97.9	130	85	21/02/2008	35	51
London N. Kensington PARTISOL *	UB	---	44.5	---	---	---	---	---
London Westminster	UB	22	88.3	---	---	---	39	63
Manchester Piccadilly	UC	20	99.1	176	95	13/02/2008	34	60
Middlesbrough	UI	18	70.8	181	73	10/05/2008	34	57
Newcastle Centre	UC	17	85.3	131	84	19/02/2008	32	46
Northampton	UB	---	26.5	121	71	24/01/2008	---	---
Norwich Centre	UC	---	36.0	384	72	13/02/2008	---	---
Nottingham Centre	UC	18	90.1	174	102	13/02/2008	29	58
Oxford St Ebbes	UB	14	94.7	126	73	24/01/2008	26	39
Plymouth Centre	UC	14	70.1	95	70	19/02/2008	26	41
Portsmouth	UB	24	68.5	196	101	24/01/2008	34	57
Preston	UB	19	86.5	141	83	20/02/2008	31	50
Reading New Town	UB	---	9.6	116	67	31/12/2008	---	---
Rochester Stoke	RU	20	97.6	156	78	20/02/2008	34	45
Salford Eccles	UI	16	90.5	139	80	13/02/2008	29	42
Saltash Roadside	RS	---	36.6	98	41	31/12/2008	---	---
Sandy Roadside	RS	---	42.6	73	58	31/12/2008	---	---
Scunthorpe Town	UI	22	73.6	156	81	09/05/2008	43	66

* Measurements made using the Partisol gravimetric sampler– these provide daily averages only

ii) PM_{10} exceedence statistics I

Site	Mode-rate hrs	Days	High hours	Days	Very High hours	Days	Days > 50 µg m^{-3}	Annual Mean > 40 µg m^{-3}	Annual Mean > 18 µg m^{-3}
England									
Birmingham Centre	100	8	**29**	**4**	0	0	**11**	**11**	0
Birmingham Tyburn	0	0	0	0	0	0	**1**	**1**	0
Blackpool Marton	9	2	0	0	0	0	**5**	**5**	0
Bolton	0	0	0	0	0	0	**1**	**1**	---
Bournemouth *	50	5	0	0	0	0	**7**	**7**	0
Brighton Roadside *	125	9	**9**	**2**	0	0	**13**	**13**	---
Bristol St Paul's	183	17	0	0	0	0	**15**	**15**	0
Bury Roadside	92	6	0	0	0	0	**10**	**10**	0
Camden Kerbside	122	9	0	0	0	0	**11**	**11**	0
Carlisle Roadside	39	2	0	0	0	0	**7**	**7**	0
Chesterfield	0	0	0	0	0	0	**3**	**3**	0
Chesterfield Roadside	6	1	0	0	0	0	**4**	**4**	0
Coventry Memorial Park	70	6	0	0	0	0	**6**	**6**	0
Haringey Roadside	35	4	0	0	0	0	**6**	**6**	0
Harwell	18	2	0	0	0	0	**4**	**4**	0
Harwell PARTISOL *	0	0	0	0	0	0	**1**	**1**	---
Hull Freetown	26	2	0	0	0	0	**5**	**5**	0
Leamington Spa	19	1	0	0	0	0	**5**	**5**	0
Leeds Centre	130	9	**23**	**2**	0	0	**11**	**11**	0
Leeds Headingley Kerbside	71	4	0	0	0	0	**5**	**5**	0
Leicester Centre	106	8	0	0	0	0	**7**	**7**	0
Liverpool Speke	128	9	**7**	**1**	0	0	**9**	**9**	0
London Bexley	18	3	0	0	0	0	**3**	**3**	---
London Bloomsbury	87	9	0	0	0	0	**12**	**12**	0
London Harlington	97	7	0	0	0	0	**12**	**12**	0
London Marylebone Road	245	20	**30**	**3**	0	0	**57**	**57**	0
London Marylebone Road PARTISOL *	134	12	0	0	0	0	**29**	**29**	0
London N. Kensington	39	4	0	0	0	0	**9**	**9**	0
London N. Kensington PARTISOL *	0	0	0	0	0	0	**1**	**1**	---
London Westminster	125	8	**7**	**2**	0	0	**9**	**9**	0
Manchester Piccadilly	153	10	**4**	**1**	0	0	**9**	**9**	0
Middlesbrough	48	4	0	0	0	0	**13**	**13**	0
Newcastle Centre	37	2	0	0	0	0	**5**	**5**	0
Northampton	10	1	0	0	0	0	**3**	**3**	---
Norwich Centre	34	4	0	0	0	0	**8**	**8**	---
Nottingham Centre	109	9	**28**	**3**	0	0	**9**	**9**	0
Oxford St Ebbes	13	1	0	0	0	0	**2**	**2**	0
Plymouth Centre	51	3	0	0	0	0	**3**	**3**	0
Portsmouth	71	7	**7**	**1**	0	0	**7**	**7**	0
Preston	65	5	0	0	0	0	**6**	**6**	0
Reading New Town	12	1	0	0	0	0	**1**	**1**	---
Rochester Stoke	29	3	0	0	0	0	**2**	**2**	0
Salford Eccles	25	2	0	0	0	0	**5**	**5**	0
Saltash Roadside	0	0	0	0	0	0	0	0	---
Sandy Roadside	0	0	0	0	0	0	0	0	---
Scunthorpe Town	170	10	0	0	0	0	**18**	**18**	0

iii) PM_{10} annual statistics II

Site	Site Type	Ann. av. hourly means µg m^{-3}	Annual data capture of hourly means %	Max. hrly mean µg m^{-3}	Max. running 24-h mean µg m^{-3}	Date of max. running 24-h mean	90%ile of daily means µg m^{-3}	98%ile of daily means µg m^{-3}
England								
Sheffield Centre	UC	22	99.6	255	123	19/02/2008	41	66
Southampton Centre	UC	20	94.8	180	86	24/01/2008	36	53
Southend-on-Sea	UB	20	81.0	101	69	31/12/2008	34	50
Stanford-le-Hope Roadside	RS	21	94.0	129	85	20/02/2008	36	48
Stockton-on-Tees Eaglescliffe	RS	---	29.1	102	45	31/12/2008	---	---
Stockton-on-Tees Yarm	RS	23	65.8	222	73	10/05/2008	40	58
Stoke-on-Trent Centre	UC	19	95.4	233	82	19/02/2008	35	55
Thurrock	UB	19	97.8	115	73	21/02/2008	33	44
Warrington	UB	---	15.3	191	80	06/11/2008	---	---
Wirral Tranmere	UB	14	94.3	760	159	22/03/2008	24	37
York Bootham	UB	16	96.9	95	65	19/02/2008	26	43
York Fishergate	RS	22	95.0	419	98	18/02/2008	36	56
N Ireland								
Belfast Centre	UC	17	58.6	151	58	07/12/2008	26	44
Derry	UB	22	63.6	197	77	04/11/2008	36	55
Lough Navar	RE	12	60.4	48	39	31/12/2008	19	30
Scotland								
Aberdeen	UB	16	89.7	111	53	13/02/2008	26	35
Auchencorth Moss Partisol *	RU	8	90.7	---	---	---	17	26
Auchencorth Moss	RU	7	95.5	48	33	09/05/2008	14	23
Dumfries *	RS	---	23.0	---	---	---	---	---
Edinburgh St Leonards	UB	15	96.6	99	48	13/02/2008	24	36
Glasgow Centre	UC	19	85.5	253	68	13/02/2008	30	44
Glasgow Kerbside	KS	27	89.5	518	101	20/02/2008	44	60
Grangemouth	UI	15	89.0	99	58	19/02/2008	25	38
Inverness *	RS	12	98.9	---	---	---	21	30
Wales								
Cardiff Centre	UC	20	88.1	164	84	20/02/2008	34	52
Chepstow A48	RS	23	97.9	194	90	24/01/2008	34	47
Narberth	RE	16	95.3	172	92	24/01/2008	25	35
Newport	UB	18	66.5	191	85	24/01/2008	29	50
Port Talbot Margam	UI	29	92.5	370	158	02/08/2008	51	77
Swansea Roadside	RS	17	98.1	214	89	24/01/2008	31	47
Wrexham *	RS	17	94.0	---	---	---	34	59

* Measurements made using the Partisol gravimetric sampler– these provide daily averages only

iii) PM_{10} exceedence statistics I I

Site	Mode-rate hrs	Days	High hours	Days	Very High hours	Days	Days > 50 µg m^{-3}	Annual Mean > 40 µg m^{-3}	Annual Mean > 18 µg m^{-3}
England									
Sheffield Centre	130	12	**87**	**6**	0	0	**17**	**17**	0
Southampton Centre	101	7	0	0	0	0	**8**	**8**	0
Southend-on-Sea	41	5	0	0	0	0	**6**	**6**	0
Stanford-le-Hope Roadside	36	3	0	0	0	0	**6**	**6**	0
Stockton-on-Tees Eaglescliffe	0	0	0	0	0	0	0	0	---
Stockton-on-Tees Yarm	43	4	0	0	0	0	**14**	**14**	0
Stoke-on-Trent Centre	97	6	0	0	0	0	**10**	**10**	0
Thurrock	21	3	0	0	0	0	**3**	**3**	0
Warrington	31	2	0	0	0	0	**2**	**2**	---
Wirral Tranmere	8	2	**12**	**2**	**11**	**1**	**4**	**4**	0
York Bootham	1	1	0	0	0	0	**3**	**3**	0
York Fishergate	92	8	**5**	**2**	0	0	**12**	**12**	0
N Ireland									
Belfast Centre	0	0	0	0	0	0	**1**	**1**	0
Derry	43	6	0	0	0	0	**8**	**8**	0
Lough Navar	0	0	0	0	0	0	0	0	0
Scotland									
Aberdeen	0	0	0	0	0	0	**1**	**1**	0
Auchencorth Moss Partisol *	0	0	0	0	0	0	0	0	0
Auchencorth Moss	0	0	0	0	0	0	0	0	0
Dumfries *	0	0	0	0	0	0	**3**	**3**	---
Edinburgh St Leonards	0	0	0	0	0	0	0	0	0
Glasgow Centre	22	3	0	0	0	0	**3**	**3**	0
Glasgow Kerbside	140	11	**13**	**2**	0	0	**18**	**18**	0
Grangemouth	0	0	0	0	0	0	**2**	**2**	0
Inverness *	0	0	0	0	0	0	0	0	0
Wales									
Cardiff Centre	91	9	0	0	0	0	**9**	**9**	0
Chepstow A48	30	4	0	0	0	0	**5**	**5**	0
Narberth	18	2	0	0	0	0	**3**	**3**	0
Newport	19	3	0	0	0	0	**5**	**5**	0
Port Talbot Margam	248	31	**66**	**9**	**21**	**4**	**34**	**34**	0
Swansea Roadside	103	7	0	0	0	0	**6**	**6**	0
Wrexham *	86	8	**33**	**2**	0	0	**13**	**13**	0

* Measurements made using the Partisol gravimetric sampler– these provide daily averages only

16. $PM_{2.5}$ - measurement sites, instrumentation and statistics

16.1 Measurement method

The tapered element oscillating microbalance (TEOM) system determines particulate concentration by continuously weighing particles deposited on a filter.

16.2 Instrumentation

The following instrument types* are currently deployed in the AURN:

- R&P TEOM 1400
- R&P TEOM 1400 AB with 8500 FDMS
- R&P Partisol

** Here and elsewhere in this report, references to commercial names of equipment or products does not constitute a recommendation or endorsement by Defra, the DAs or the report authors.*

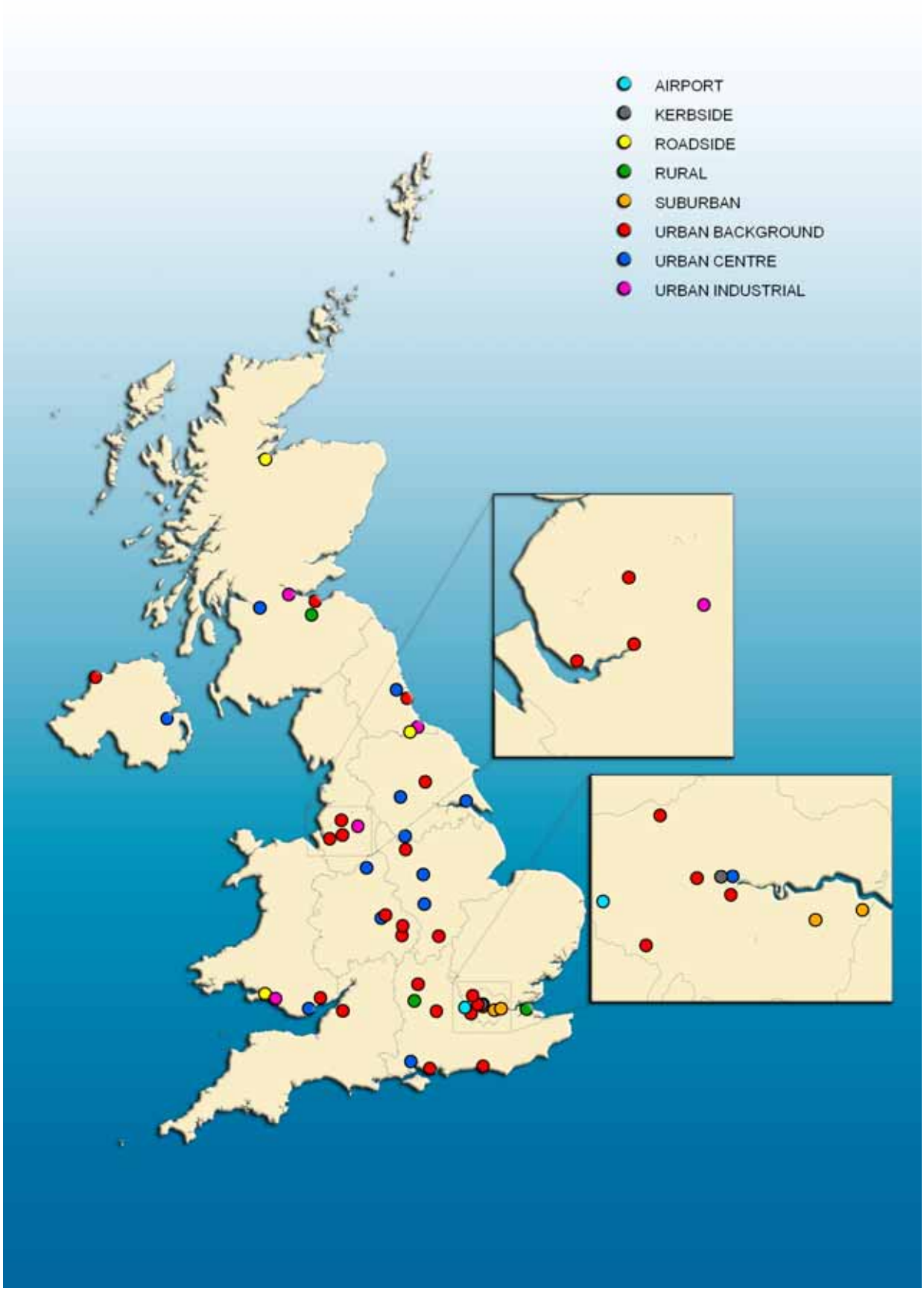
Please also see detailed information on particle measurements and conversion factors used in this report (Appendix 6).

16.3 Data quality requirements of EC Directive 2008/50/EC

Uncertainty 25%
Minimum data capture 90%

16.4 Objectives and bandings

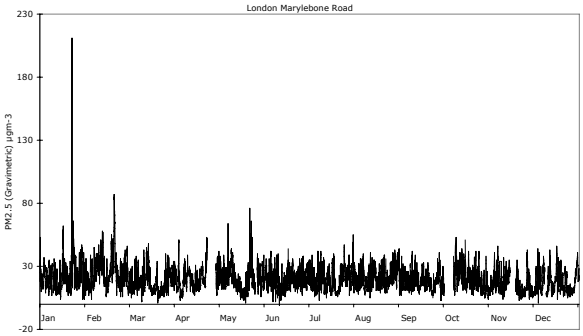
Summary of objectives of the Air Quality Strategy			
	Objective	**Measured as**	**To be achieved by**
Particles ($PM_{2.5}$) (gravimetric) All authorities	25 µg m^{-3}	Annual Mean	2020
	20% reduction in exposure reduction in urban background areas	Annual Mean	2010-2020
Particles ($PM_{2.5}$) Authorities in Scotland only	12 µg m^{-3}	Annual Mean	2020



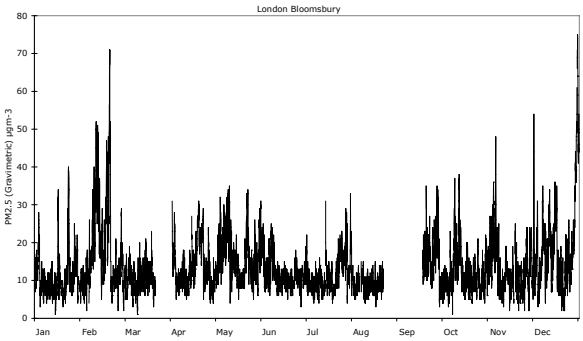
UK automatic gravimetric $PM_{2.5}$ particles monitoring sites 2008

16.5 Hourly average concentrations

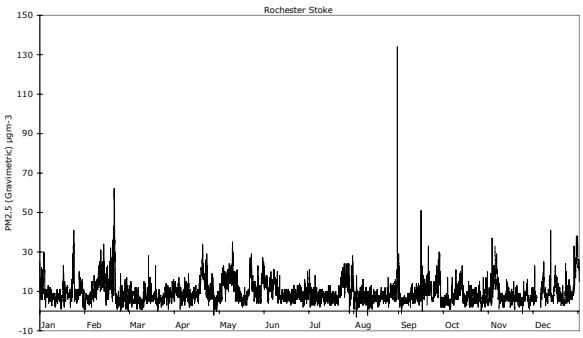
These figures show time series graphs of hourly average $PM_{2.5}$ concentrations at four monitoring sites of different types, for 2008.



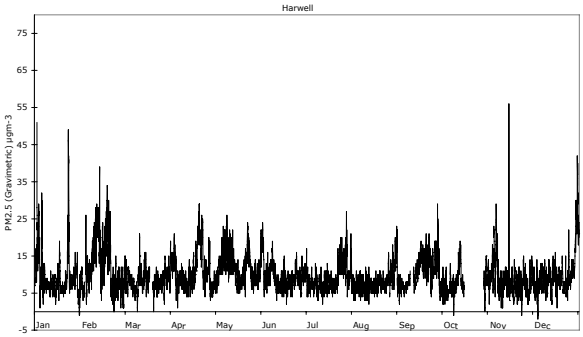
Kerbside Site
(London Marylebone Road)



Urban Centre Site
(*Bloomsbury)*



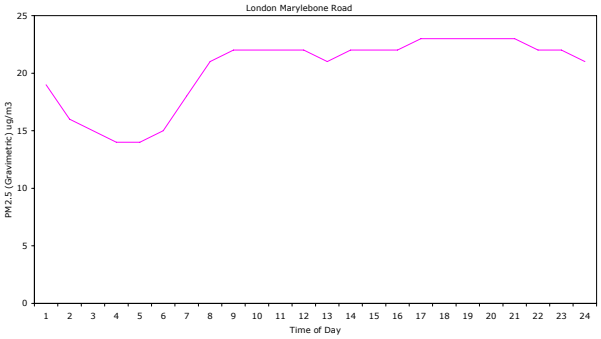
Rural Site
(*Rochester)*



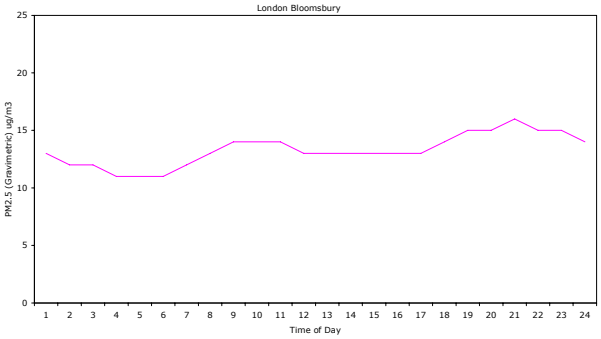
Rural Site
(Harwell)

16.6 Diurnal variations

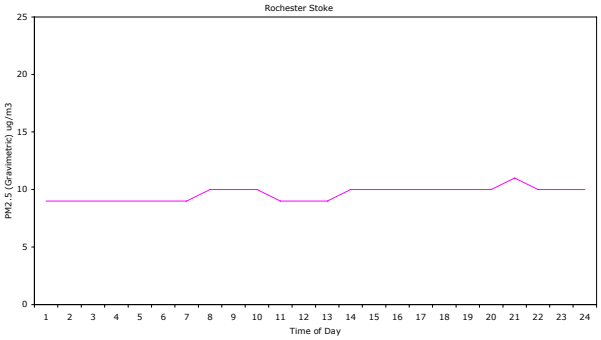
These figures show how $PM_{2.5}$ concentrations varied on average for each hour of day during 2008, at the same four monitoring sites. Local time is used, rather than GMT, to more closely reflect the daily cycle of man-made emissions.



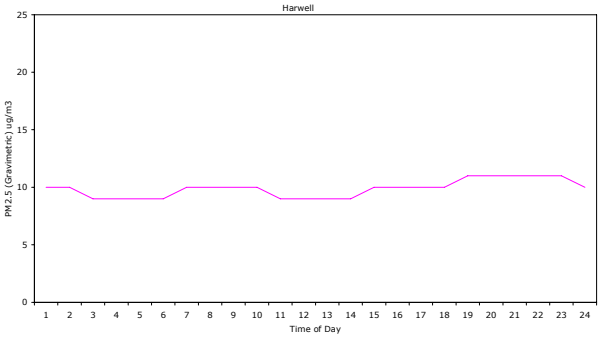
Kerbside Site
(London Marylebone Road)



Urban Centre Site
(*Bloomsbury)*



Rural Site
(*Rochester)*

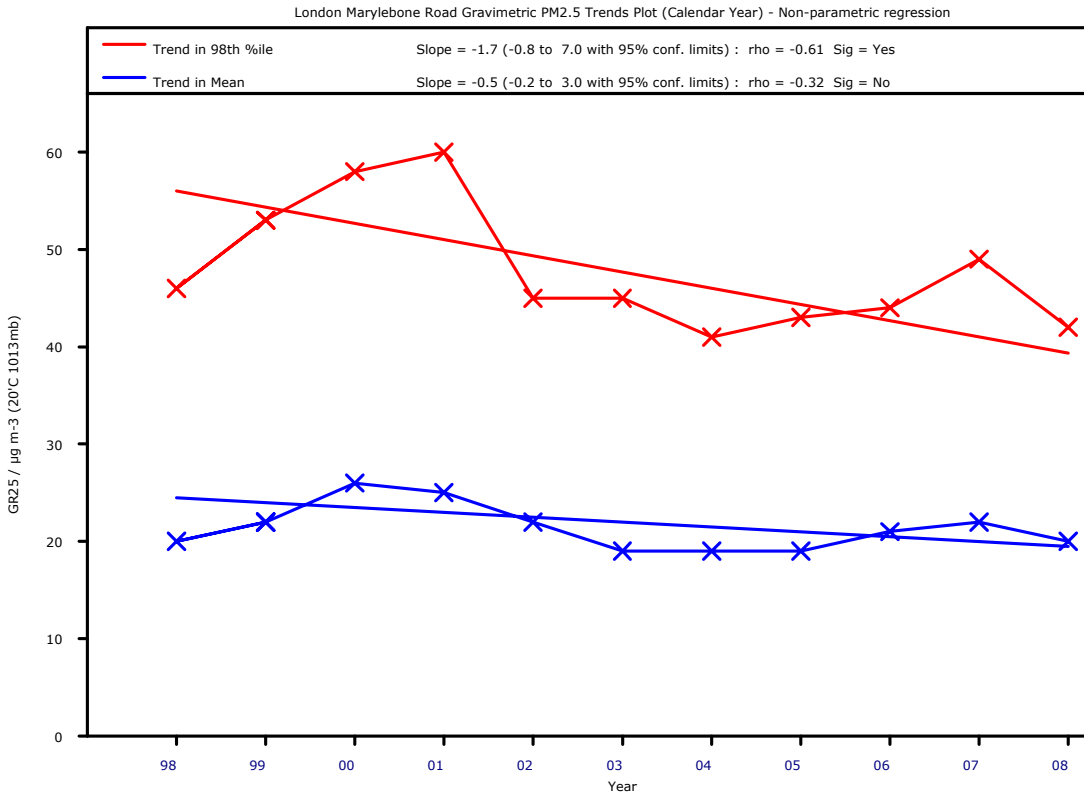


Rural Site
(Harwell)

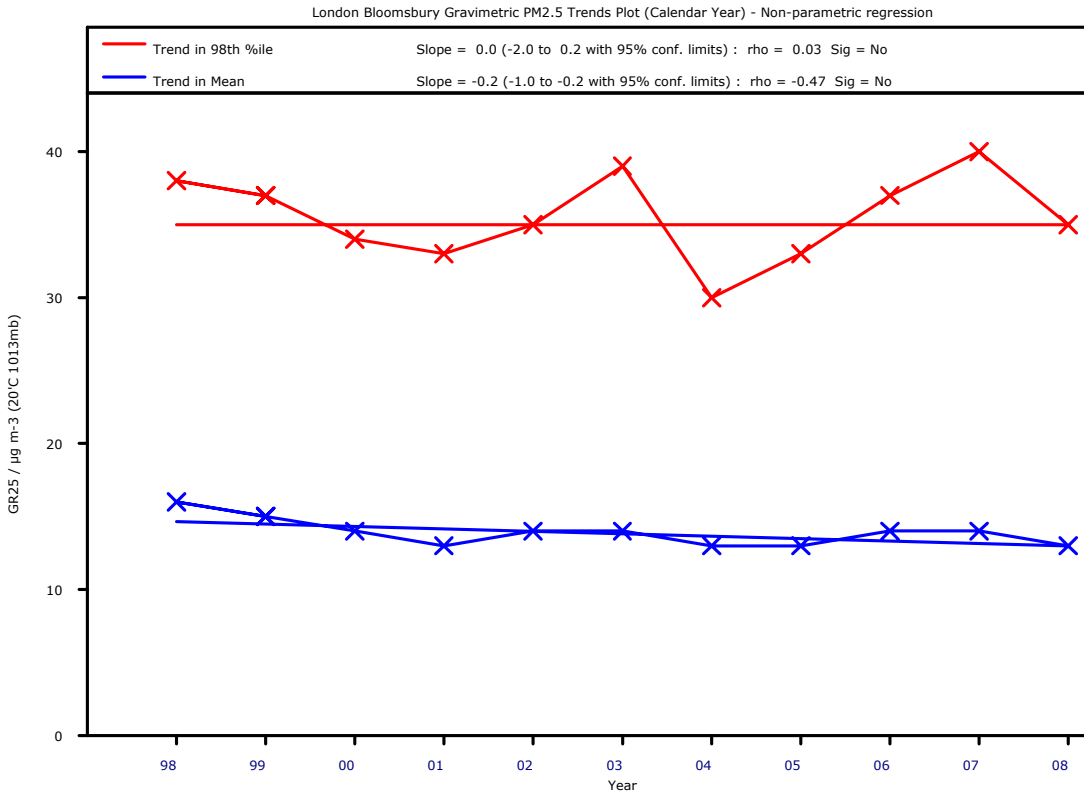
16.7 Trends in annual concentrations

Trends in concentrations are shown for sites with at least 5 years of measurement.

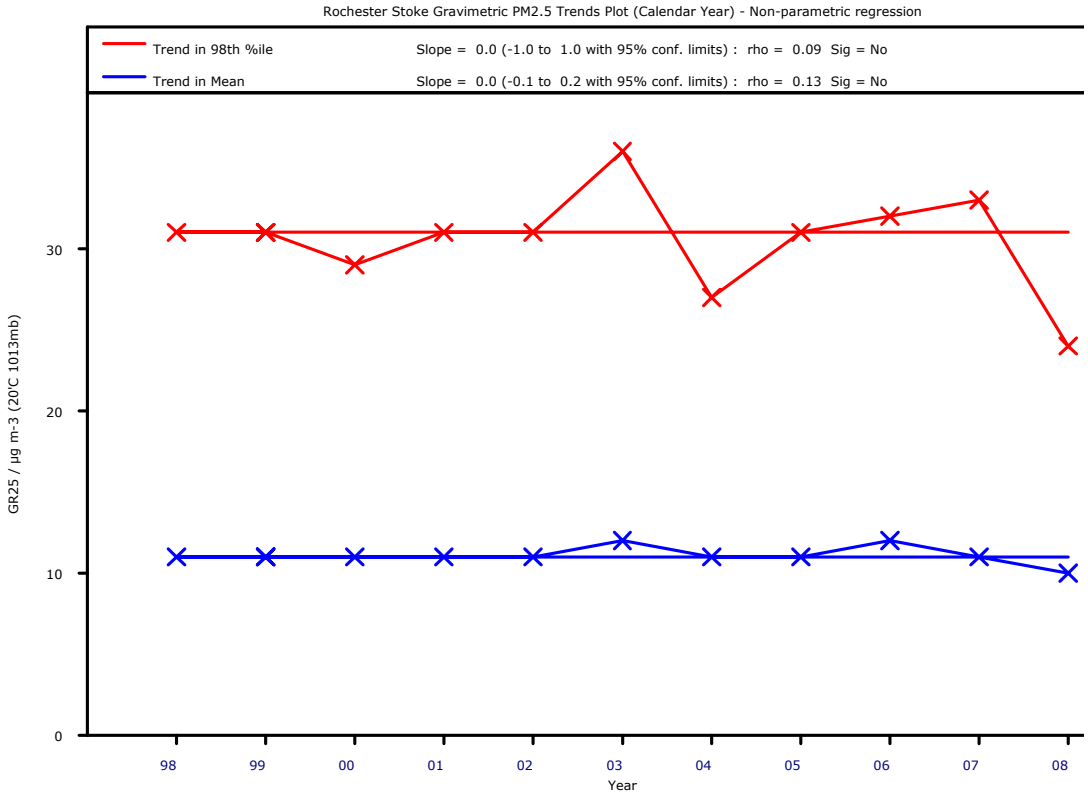
London Marylebone Road $PM_{2.5}$ Particulate Matter Trends –Non-parametric regression



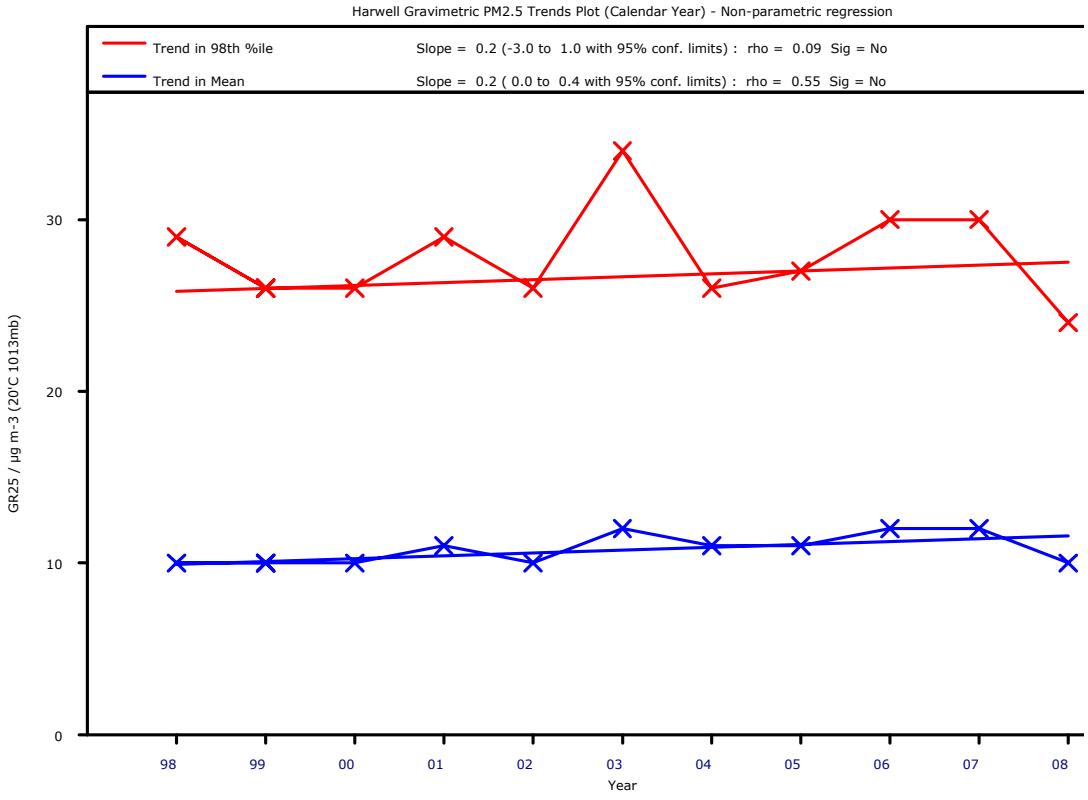
London Bloomsbury $PM_{2.5}$ Particulate Matter Trends – Non-parametric regression



Rochester $PM_{2.5}$ Particulate Matter Trends – Non-parametric regression



Harwell $PM_{2.5}$ Particulate Matter Trends – Non-parametric regression



16.8 $PM_{2.5}$ statistical summary 2008

i) $PM_{2.5}$ annual statistics

Site	Site Type	Annual average of hourly means µg m^{-3}	Annual data capture of hourly means %	Maximum hourly mean µg m^{-3}
England				
Birmingham Centre	UC	---	31.9	84
Birmingham Tyburn	UB	---	4.3	68
Brighton Preston Park	UB	---	37.2	---
Bristol St Paul's	UB	---	34.8	120
Chesterfield	UB	---	3.4	60
Coventry Memorial Park	UB	---	4.2	80
Harwell	RU	10	94.4	56
Harwell PARTISOL *	RU	---	49.5	---
Hull Freetown	UC	---	31.9	132
Leamington Spa	UB	---	2.5	74
Leeds Centre	UC	---	7.9	66
Leicester Centre	UC	---	32.8	75
Liverpool Speke	UB	---	27.9	129
London Bexley	S	11	79.1	108
London Bloomsbury	UC	13	88.7	75
London Eltham	S	14	62.4	76
London Harlington	A	---	11.5	42
London Harrow Stanmore	UB	---	3.7	63
London Marylebone Road	KS	20	93.9	211
London Marylebone Road PARTISOL *	KS	26	57.9	---
London N. Kensington	UB	---	3.9	70
London N. Kensington PARTISOL *	UB	12	60.4	---
London Teddington	UB	---	3.9	119
London Westminster	UB	---	1.9	---
Middlesbrough	UI	---	9.8	67
Newcastle Centre	UC	---	34.6	57
Northampton	UB	---	29.2	---
Nottingham Centre	UC	---	3.4	66
Oxford St Ebbes	UB	---	3.5	79
Portsmouth	UB	---	2.3	83
Reading New Town	UB	---	25.6	116
Rochester Stoke	RU	10	98.5	134
Salford Eccles	UI	---	9.6	101
Sheffield Centre	UC	---	5.7	70
Southampton Centre	UC	---	15.4	90
Stockton-on-Tees Eaglescliffe	RS	---	28.2	49
Stoke-on-Trent Centre	UC	---	14.8	70
Sunderland Silksworth	UB	---	5.8	56
Warrington	UB	---	9.3	78
Wigan Centre	UB	---	6.5	97
York Bootham	UB	---	7.5	66
N Ireland				
Belfast Centre	UC	---	24.5	113
Derry	UB	---	33.6	73
Scotland				
Auchencorth Moss	RU	5	81.7	---
Auchencorth Moss PM_{10} PM_{25}	RU	3	88.1	44
Edinburgh St Leonards	UB	---	16.7	62
Glasgow Centre	UC	---	4.2	63
Grangemouth	UI	---	6.9	62
Inverness	RS	---	44.5	---
Wales				
Cardiff Centre	UC	---	36.3	160
Newport	UB	---	5.2	61
Port Talbot Margam	UI	10	67.3	74
Port Talbot Margam $PM_{2.5}$	UI	11	89.3	---
Swansea Roadside	RS	12	95.5	202

* Measurements made using the Partisol gravimetric sampler– these provide daily averages only

ii) Exceedence statistics

Site	Site Type	Annual average of hourly means > 25 µg m^{-3}
England		
Birmingham Centre	UC	---
Birmingham Tyburn	UB	---
Brighton Preston Park	UB	---
Bristol St Paul's	UB	---
Chesterfield	UB	---
Coventry Memorial Park	UB	---
Harwell	RU	No
Harwell PARTISOL *	RU	---
Hull Freetown	UC	---
Leamington Spa	UB	---
Leeds Centre	UC	---
Leicester Centre	UC	---
Liverpool Speke	UB	---
London Bexley	S	No
London Bloomsbury	UC	No
London Eltham	S	No
London Harlington	A	---
London Harrow Stanmore	UB	---
London Marylebone Road	KS	No
London Marylebone Road PARTISOL *	KS	YES
London N. Kensington	UB	---
London N. Kensington PARTISOL *	UB	No
London Teddington	UB	---
London Westminster	UB	---
Middlesbrough	UI	---
Newcastle Centre	UC	---
Northampton	UB	---
Nottingham Centre	UC	---
Oxford St Ebbes	UB	---
Portsmouth	UB	---
Reading New Town	UB	---
Rochester Stoke	RU	No
Salford Eccles	UI	---
Sheffield Centre	UC	---
Southampton Centre	UC	---
Stockton-on-Tees Eaglescliffe	RS	---
Stoke-on-Trent Centre	UC	---
Sunderland Silksworth	UB	---
Warrington	UB	---
Wigan Centre	UB	---
York Bootham	UB	---
N Ireland		
Belfast Centre	UC	---
Derry	UB	---
Scotland		
Auchencorth Moss	RU	No
Auchencorth Moss PM_{10} PM_{25}	RU	No
Edinburgh St Leonards	UB	---
Glasgow Centre	UC	---
Grangemouth	UI	---
Inverness	RS	---
Wales		
Cardiff Centre	UC	---
Newport	UB	---
Port Talbot Margam	UI	No
Port Talbot Margam $PM_{2.5}$	UI	No
Swansea Roadside	RS	No

* Measurements made using the Partisol gravimetric sampler– these provide daily averages only

17. SO_2 - measurement sites, instrumentation and statistics

17.1 Measurement method

The sulphur dioxide analyser works on the principle of ultra violet (UV) fluorescence. SO_2 molecules are excited to higher energy states by UV radiation. These energy states decay causing an emission of secondary fluorescent radiation with intensity proportional to the concentration of SO_2 in the sample.

17.2 Instrumentation

The following instrument types* are currently deployed in the AURN:

- Ambirak SO_2
- API M100
- Environnement AF 21M
- Horiba APSA 360
- Monitor Labs 9850
- Rotork 477
- Thermo Electron 43

** Here and elsewhere in this report, references to commercial names of equipment or products does not constitute a recommendation or endorsement by Defra, the DAs or the report authors.*

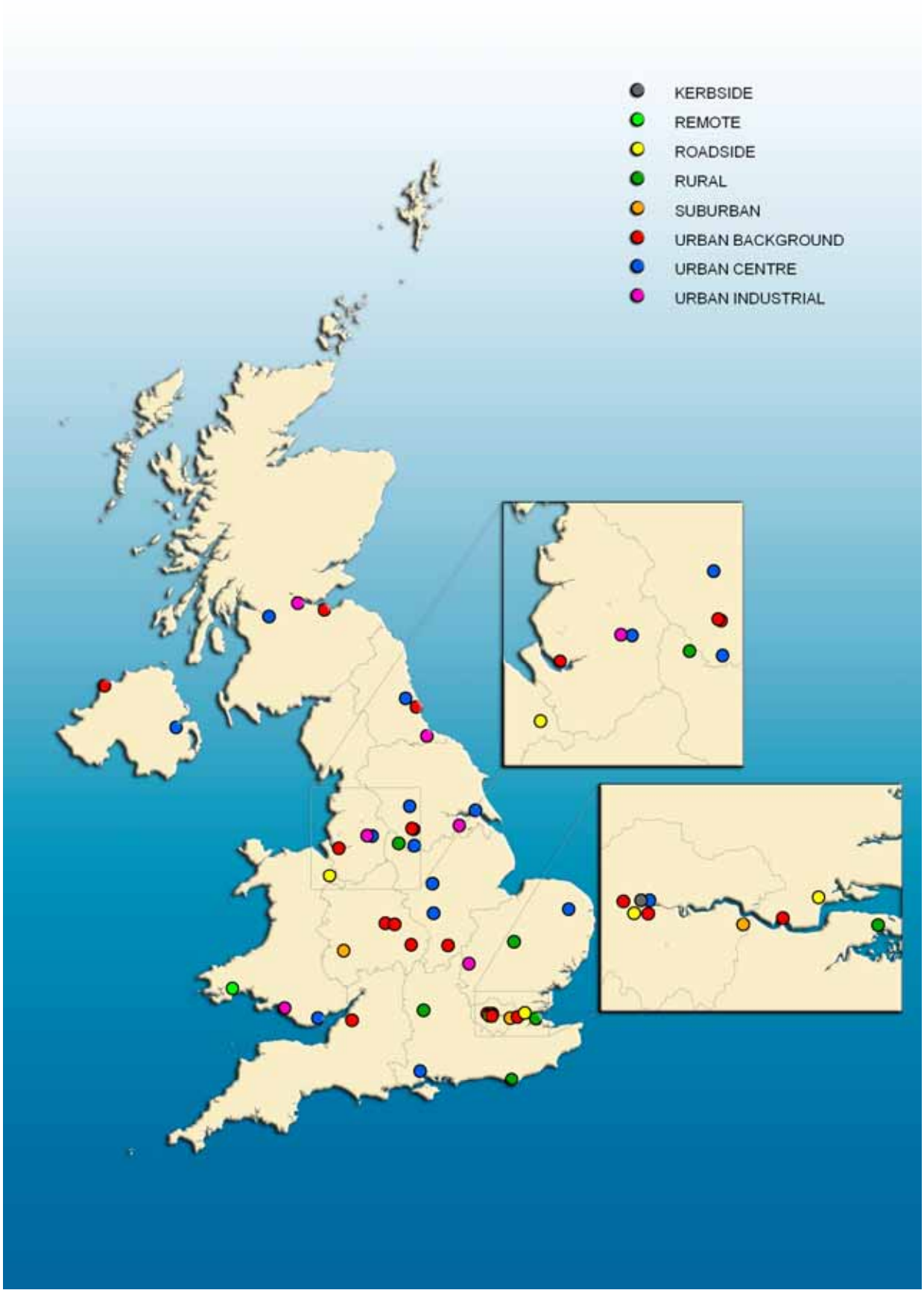
17.3 Data quality requirements of EC Directive 2008/50/EC

Uncertainty 15%, minimum data capture 90%

17.4 Objectives and bandings

Summary of objectives of the Air Quality Strategy			
	Objective	**Measured as**	**To be achieved by**
Sulphur Dioxide	266 µg m^{-3} Not to be exceeded more than 35 times per year	15 Minute Mean	31 December 2005
	350 µg m^{-3} Not to be exceeded more than 24 times per year	1 Hour Mean	31 December 2005
	125 µg m^{-3} Not to be exceeded more than 3 times per year	24 Hour Mean	31 December 2005
	(V) 20 µg m^{-3}	Annual Mean	31 December 2000
	(V) 20 µg m^{-3}	Winter Mean (01 October - 31 March)	31 December 2000

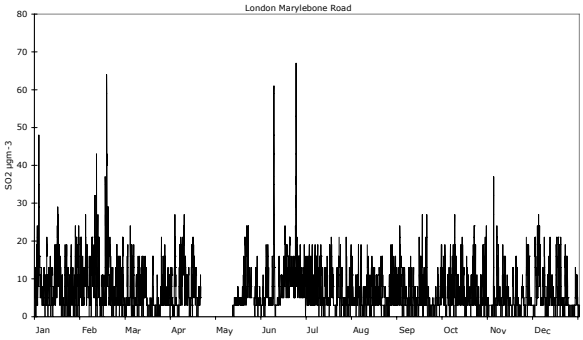
Air Quality Bands and Index Values		
Band	Index	Sulphur Dioxide µg m^{-3}
Low	1	0-88
	2	89-176
	3	177-265
Moderate	4	266-354
	5	355-442
	6	443-531
High	7	532-708
	8	709-886
	9	887-1063
Very High	10	1064 or more



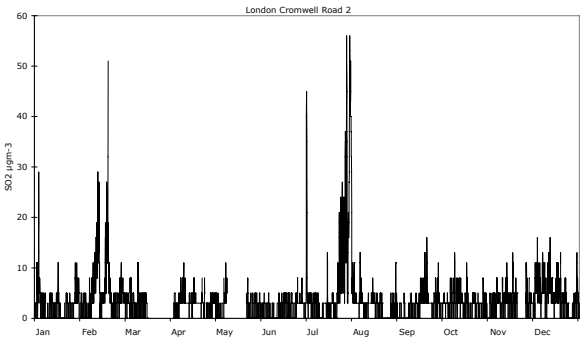
UK automatic sulphur dioxide monitoring sites 2008

17.5 Hourly average concentrations

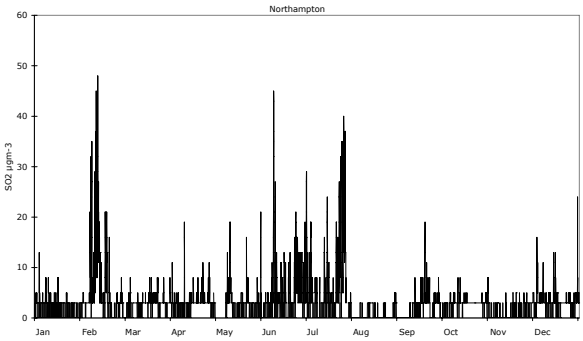
These figures show time series graphs of hourly average sulphur dioxide concentrations at four monitoring sites of different types for 2008.



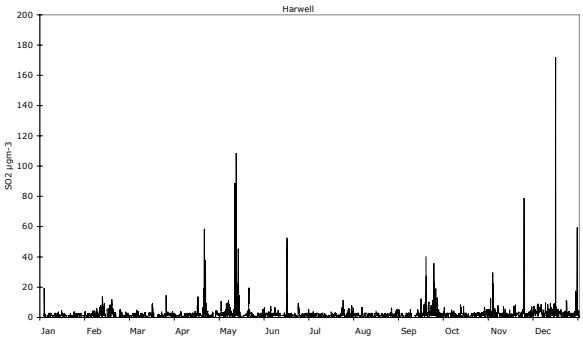
Kerbside Site
(London Marylebone Road)



Roadside Site
(*London Cromwell Road)*



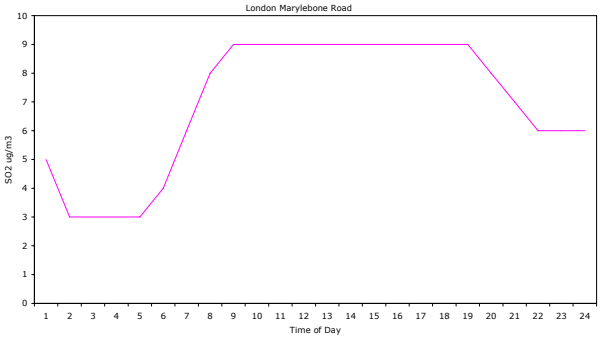
Urban Background Site
(*Northampton)*



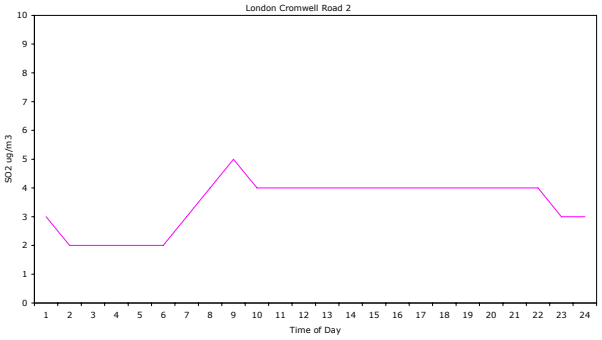
Rural Site
(Harwell)

17.6 Diurnal variations

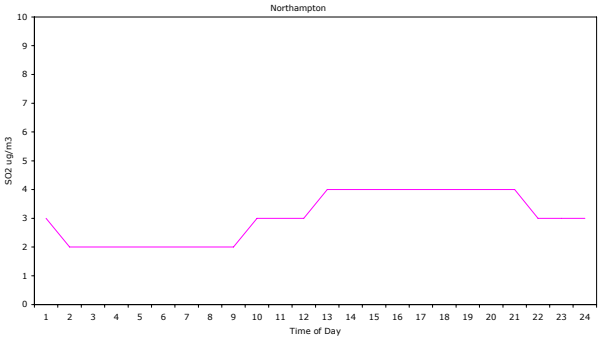
These figures show how sulphur dioxide concentrations varied on average for each hour of day during 2008, at the same four sites. Local time is used, rather than GMT, to more closely reflect the daily cycle of man-made emissions.



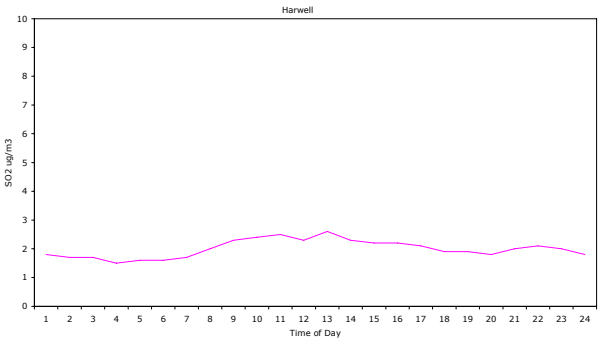
Kerbside Site
(London Marylebone Road)



Roadside Site
(*London Cromwell Road)*



Urban Background Site
(*Northampton)*

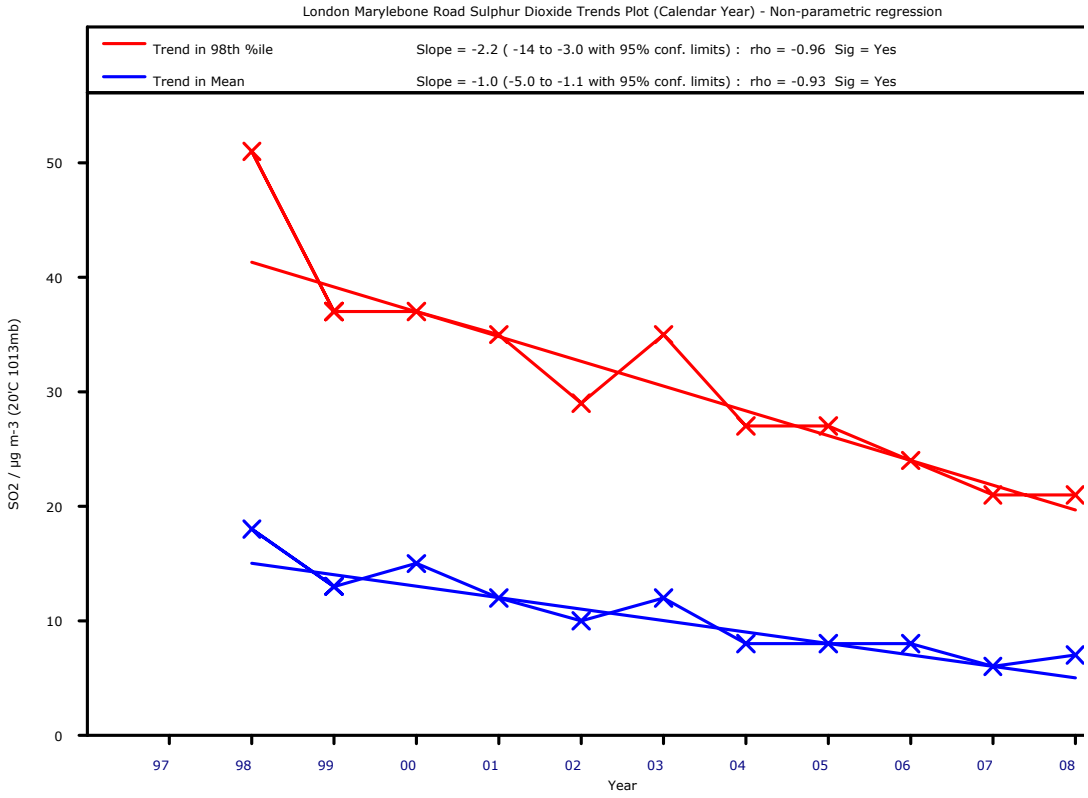


Rural Site
(Harwell)

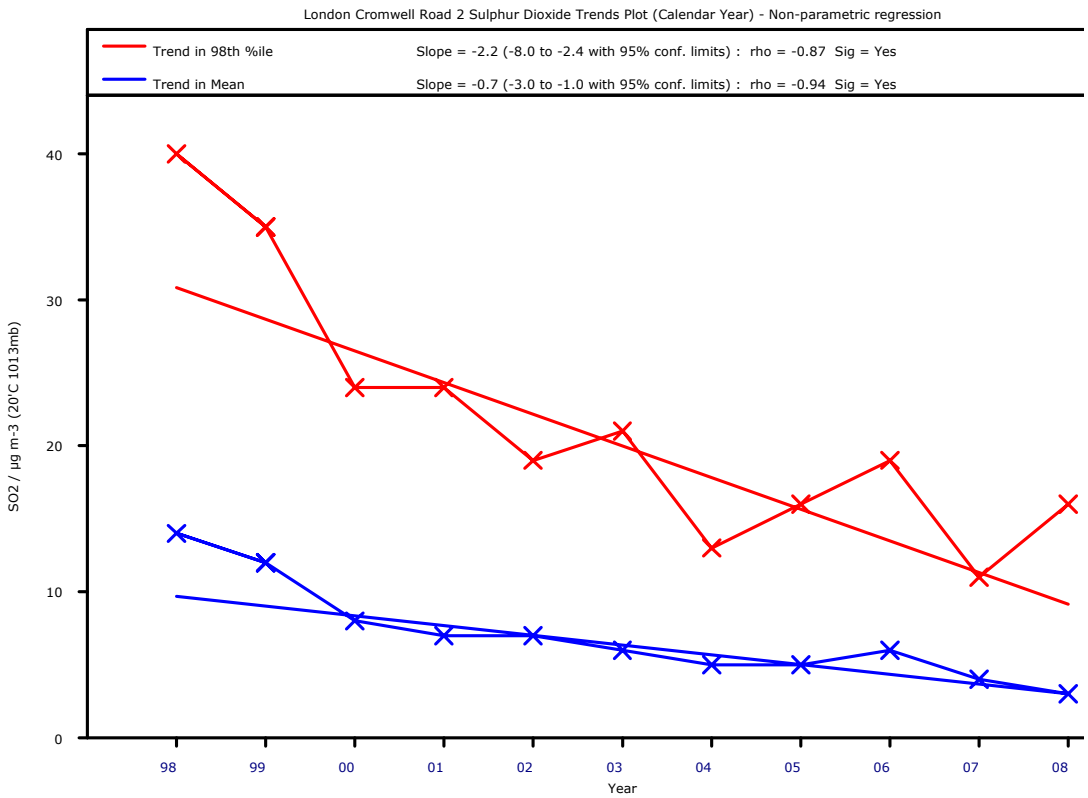
17.7 Trends in annual concentrations

Trends in concentrations are shown for sites with at least 5 years of measurement.

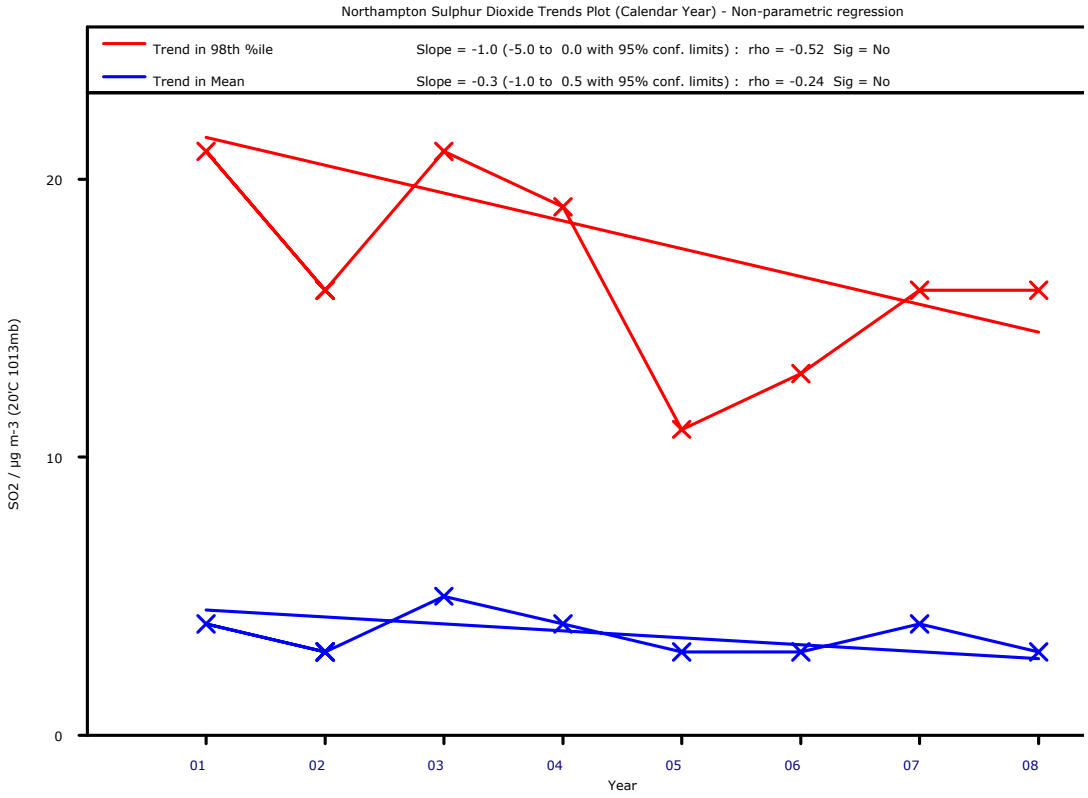
London Marylebone Road SO_2 Trends – non-parametric regression



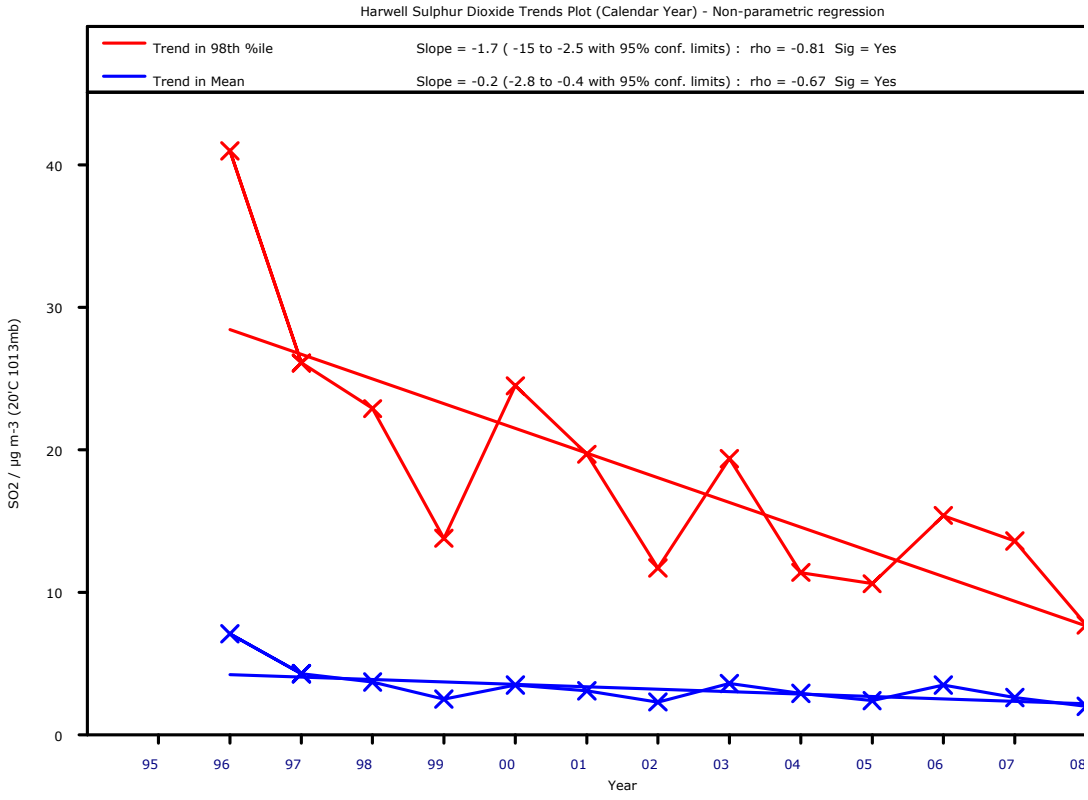
London Cromwell Road SO_2 Trends – Non-parametric regression



Northampton SO_2 Trends – Non-parametric regression



Harwell SO_2 Trends – Non-parametric regression



17.8 Sulphur dioxide statistical summary 2008

i) SO_2 annual statistics

Site	Site Type	Annual avg. of hourly means µg m^{-3}	Annual data capture of hourly means %	Max. hourly mean µg m^{-3}	Max. 15-minute mean µg m^{-3}	Date of max. 15-minute mean	99.9 %ile of 15-min means µg m^{-3}	99.7 %ile of hourly means µg m^{-3}	99 %ile of daily means µg m^{-3}
England									
Barnsley 12	UB	7	97.5	133	138	18/02/08	106	77	39
Barnsley Gawber	UB	6	95.7	88	194	11/03/08	51	40	18
Birmingham Tyburn	UB	2	98.5	40	43	31/12/08	21	19	10
Bristol St Paul's	UB	2	96.3	32	53	28/07/08	24	19	8
Harwell	RU	2.0	94.6	171.8	202.2	15/12/08	66.5	28.7	9.7
Hull Freetown	UC	4	97.4	69	80	18/02/08	51	32	11
Ladybower	RU	1.7	74.0	53.5	66.2	29/04/08	30.9	18.6	7.0
Leamington Spa	UB	3	87.4	24	37	18/02/08	19	13	7
Leeds Centre	UC	2	98.8	64	74	24/06/08	37	27	12
Leicester Centre	UC	2	98.7	24	37	11/07/08	21	16	9
Leominster	S	1	55.4	19	43	07/11/08	13	8	4
Liverpool Speke	UB	6	96.3	85	109	23/10/08	56	40	17
London Bexley	S	4	97.7	160	250	20/09/08	104	59	22
London Bloomsbury	UC	4	99.1	101	157	04/01/08	56	40	17
London Cromwell Road 2	RS	3	88.3	56	61	19/02/08	51	43	20
London Marylebone Road	KS	7	93.4	67	93	18/02/08	48	35	18
London N. Kensington	UB	3	97.6	72	98	03/01/08	43	27	12
London Westminster	UB	4	95.4	109	146	19/02/08	67	45	23
Lullington Heath	RU	---	32.3	33.8	46.6	15/12/08	---	---	---
Manchester Piccadilly	UC	4	97.1	51	85	13/02/08	27	19	10
Middlesbrough	UI	4	98.7	184	317	26/07/08	82	56	20
Newcastle Centre	UC	3	95.2	85	247	13/02/08	45	29	10
Northampton	UB	3	97.2	48	56	12/02/08	40	32	19
Norwich Centre	UC	---	36.3	19	21	08/02/08	---	---	---
Nottingham Centre	UC	2	98.6	170	396	17/08/08	29	19	10
Rochester Stoke	RU	4.3	84.8	93.6	143.6	28/01/08	81.1	47.9	15.6
Salford Eccles	UI	3	90.8	32	59	06/12/08	29	19	11
Sandwell West Bromwich	UB	3	92.8	74	154	07/10/08	56	29	14
Scunthorpe Town	UI	7	87.2	154	194	10/05/08	144	106	53
Sheffield Centre	UC	6	96.5	29	40	20/02/08	27	21	14
Southampton Centre	UC	3	95.9	72	96	16/12/08	29	19	8
Stanford-le-Hope Roadside	RS	4	93.6	141	192	16/12/08	61	37	15
Stewartby	UI	1	97.3	117	245	28/02/08	67	32	12
Sunderland Silksworth	UB	5	67.1	67	88	26/07/08	27	19	11
Thurrock	UB	3	95.4	106	144	27/05/08	51	29	13
Wicken Fen	RU	4.4	96.2	38.8	41.2	04/01/08	17.0	12.8	8.2
N Ireland									
Belfast Centre	UC	4	94.2	67	96	30/05/08	48	35	23
Derry	UB	3	87.7	45	56	01/11/08	35	21	11
Scotland									
Edinburgh St Leonards	UB	3	98.7	200	258	19/05/08	85	53	23
Glasgow Centre	UC	2	97.7	51	152	22/10/08	24	13	7
Grangemouth	UI	7	98.7	202	346	16/01/08	192	141	47
Wales									
Cardiff Centre	UC	3	96.5	27	43	15/04/08	21	16	9
Narberth	RE	3.3	94.0	166.8	263.3	29/06/08	85.1	48.7	15.9
Port Talbot Margam	UI	6	95.2	120	157	21/01/08	112	72	38
Wrexham	RS	3	97.2	29	43	03/11/08	21	16	7

ii) SO_2 exceedence statistics

Site	Moder-ate hrs	Days	High hrs	Days	Very High hrs	Days	AQS 15-min Obj.	Days	AQS & EC 1-hr mean	Days	AQS & ED Daily mean obj.
England											
Barnsley 12	0	0	0	0	0	0	0	0	0	0	0
Barnsley Gawber	0	0	0	0	0	0	0	0	0	0	0
Birmingham Tyburn	0	0	0	0	0	0	0	0	0	0	0
Bristol St Paul's	0	0	0	0	0	0	0	0	0	0	0
Harwell	0	0	0	0	0	0	0	0	0	0	0
Hull Freetown	0	0	0	0	0	0	0	0	0	0	0
Ladybower	0	0	0	0	0	0	0	0	0	0	0
Leamington Spa	0	0	0	0	0	0	0	0	0	0	0
Leeds Centre	0	0	0	0	0	0	0	0	0	0	0
Leicester Centre	0	0	0	0	0	0	0	0	0	0	0
Leominster	0	0	0	0	0	0	0	0	0	0	0
Liverpool Speke	0	0	0	0	0	0	0	0	0	0	0
London Bexley	0	0	0	0	0	0	0	0	0	0	0
London Bloomsbury	0	0	0	0	0	0	0	0	0	0	0
London Cromwell Road 2	0	0	0	0	0	0	0	0	0	0	0
London Marylebone Road	0	0	0	0	0	0	0	0	0	0	0
London N. Kensington	0	0	0	0	0	0	0	0	0	0	0
London Westminster	0	0	0	0	0	0	0	0	0	0	0
Lullington Heath	0	0	0	0	0	0	0	0	0	0	0
Manchester Piccadilly	0	0	0	0	0	0	0	0	0	0	0
Middlesbrough	1	1	0	0	0	0	**1**	**1**	0	0	0
Newcastle Centre	0	0	0	0	0	0	0	0	0	0	0
Northampton	0	0	0	0	0	0	0	0	0	0	0
Norwich Centre	0	0	0	0	0	0	0	0	0	0	0
Nottingham Centre	1	1	0	0	0	0	**1**	**1**	0	0	0
Rochester Stoke	0	0	0	0	0	0	0	0	0	0	0
Salford Eccles	0	0	0	0	0	0	0	0	0	0	0
Sandwell West Bromwich	0	0	0	0	0	0	0	0	0	0	0
Scunthorpe Town	0	0	0	0	0	0	0	0	0	0	0
Sheffield Centre	0	0	0	0	0	0	0	0	0	0	0
Southampton Centre	0	0	0	0	0	0	0	0	0	0	0
Stanford-le-Hope Roadside	0	0	0	0	0	0	0	0	0	0	0
Stewartby	0	0	0	0	0	0	0	0	0	0	0
Sunderland Silksworth	0	0	0	0	0	0	0	0	0	0	0
Thurrock	0	0	0	0	0	0	0	0	0	0	0
Wicken Fen	0	0	0	0	0	0	0	0	0	0	0
N Ireland											
Belfast Centre	0	0	0	0	0	0	0	0	0	0	0
Derry	0	0	0	0	0	0	0	0	0	0	0
Scotland											
Edinburgh St Leonards	0	0	0	0	0	0	0	0	0	0	0
Glasgow Centre	0	0	0	0	0	0	0	0	0	0	0
Grangemouth	4	4	0	0	0	0	**4**	**4**	0	0	0
Wales											
Cardiff Centre	0	0	0	0	0	0	0	0	0	0	0
Narberth	0	0	0	0	0	0	0	0	0	0	0
Port Talbot Margam	0	0	0	0	0	0	0	0	0	0	0
Wrexham	0	0	0	0	0	0	0	0	0	0	0

18. Ozone - measurement sites, instrumentation and statistics

18.1 Measurement method

The measurement of ozone is based on the absorption of ultra violet light by ozone. The absorption by an air path with no ozone present is measured to give a reference intensity. The absorption of the ozone-containing sample is then measured. The ozone concentration is calculated using the Beer-Lambert absorption equation.

18.2 Instrumentation

The following instrument types* are currently deployed in the AURN:

- Ambirak O_3
- API M400
- Environnement O341M
- Horiba APOA 360
- Monitor Labs 9850
- Rotork 427
- Thermo Electron 49

** Here and elsewhere in this report, references to commercial names of equipment or products does not constitute a recommendation or endorsement by Defra, the DAs or the report authors.*

18.3 Data quality requirements of EC Directive 2008/50/EC

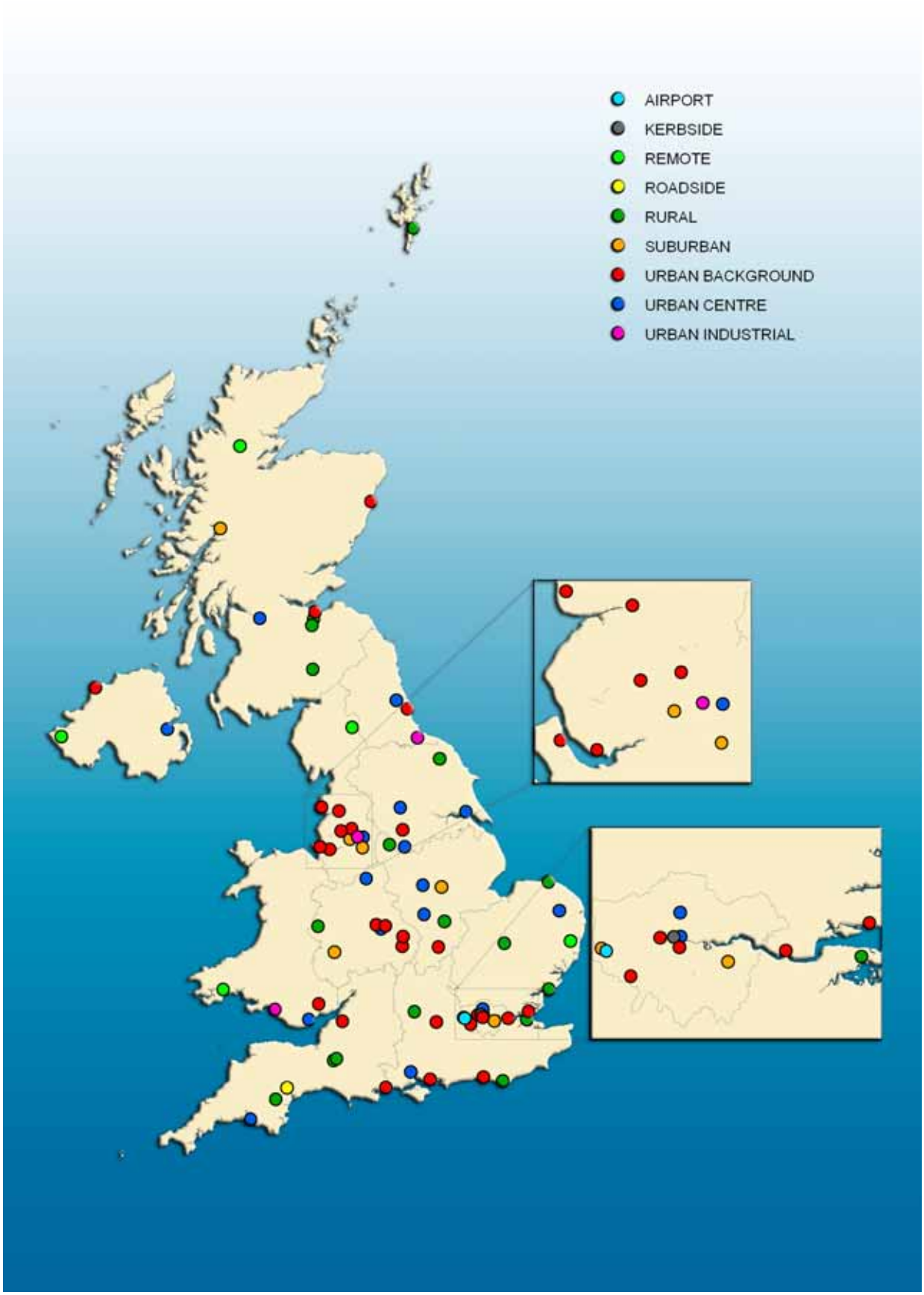
Uncertainty 15%, minimum data capture 90%

18.4 Objectives and bandings

Summary of objectives of the Air Quality Strategy			
	Objective*	**Measured as**	**To be achieved by**
Ozone	100 µg m^{-3} Not to be exceeded more than 10 times per year	Daily maximum of running 8-hour mean	31 December 2005

*Not included in the Regulations for the purpose of Air Quality Management

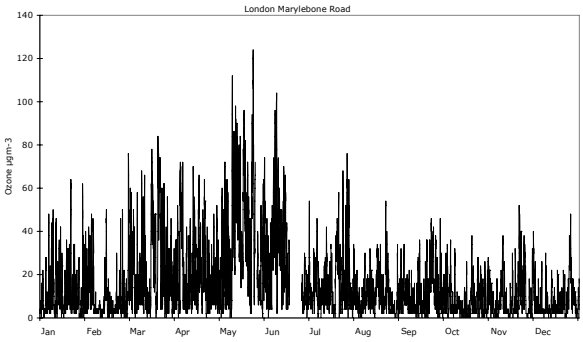
Air Quality Bands and Index Values		
Band	**Index**	**Ozone µgm^{-3}**
Low	1	0-33
	2	34-65
	3	66-99
Moderate	4	100-125
	5	126-153
	6	154-179
High	7	180-239
	8	240-299
	9	300-359
Very High	10	360 or more



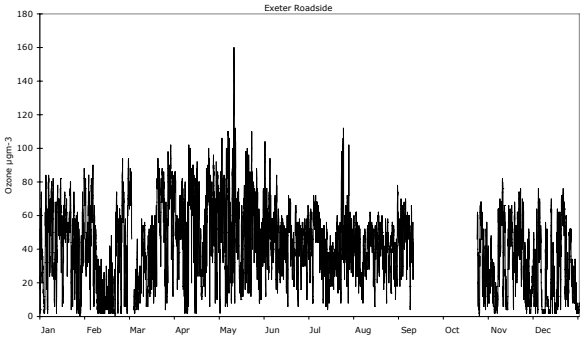
UK automatic ozone monitoring sites 2008

18.5 Hourly average concentrations

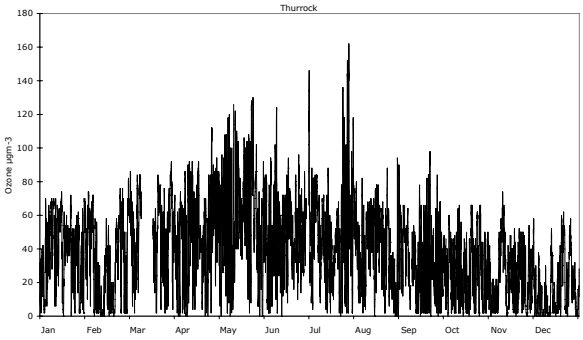
These figures show time series graphs of hourly average ozone concentrations at four monitoring sites of different types for 2008.



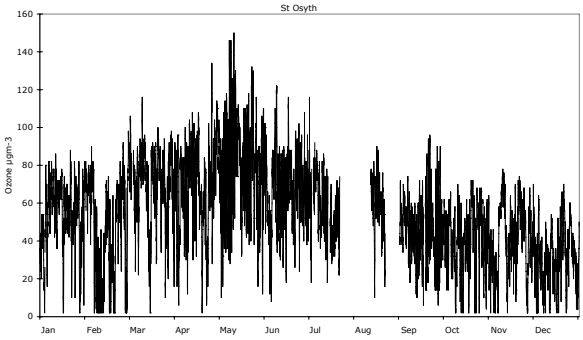
Kerbside Site
(London Marylebone Road)



Roadside Site
(*Exeter Roadside)*



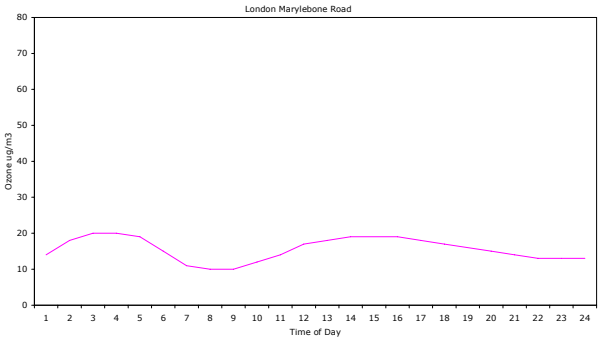
Urban Background Site
(*Thurrock)*



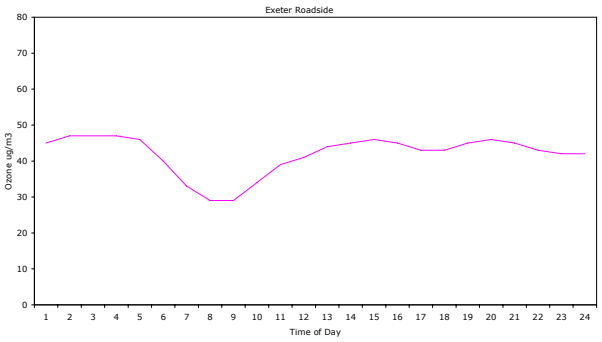
Rural Site
(St Osyth)

18.6 Diurnal variations

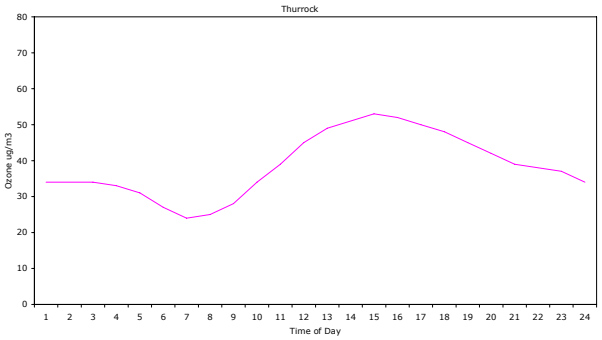
These figures show how ozone concentrations varied on average for each hour of day during the year, at the same four sites. Local time is used, rather than GMT, to more closely reflect the daily cycle of man-made emissions.



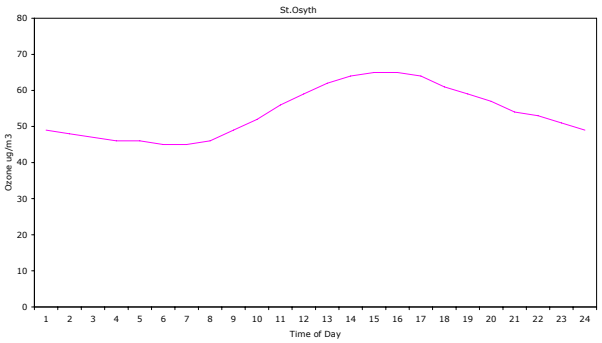
Kerbside Site
(London Marylebone Road)



Roadside Site
(*Exeter Roadside)*



Urban Background Site
(*Thurrock)*

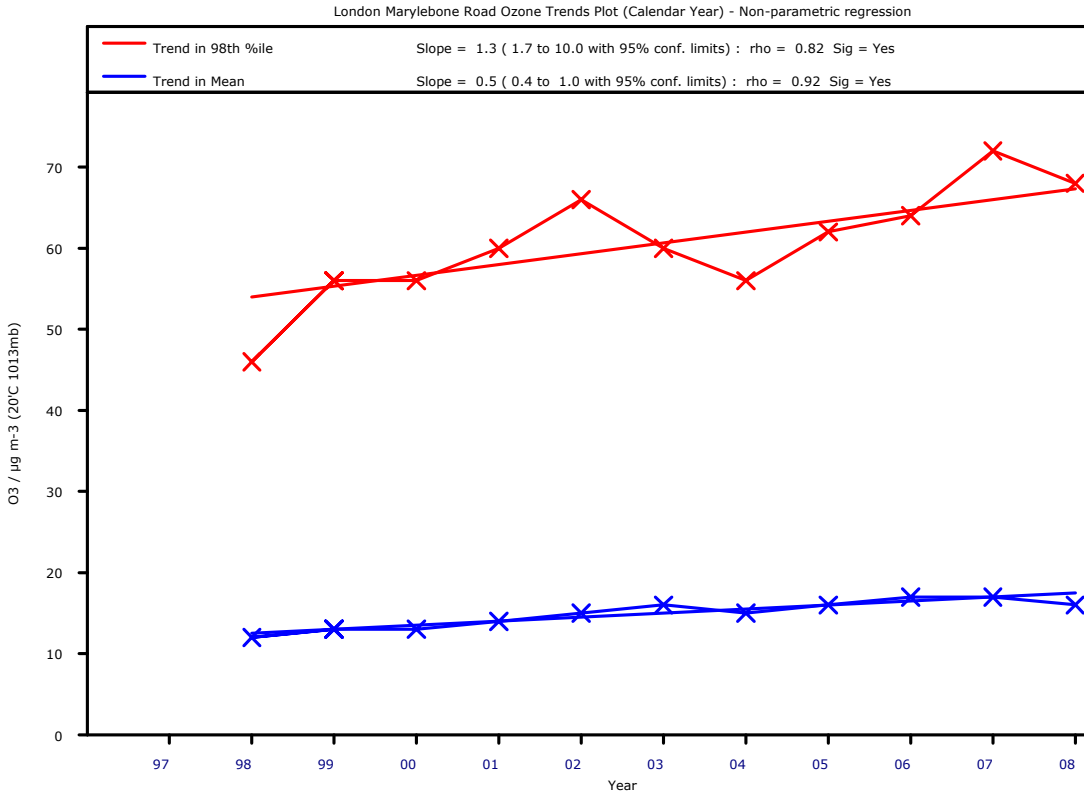


Rural Site
(St Osyth)

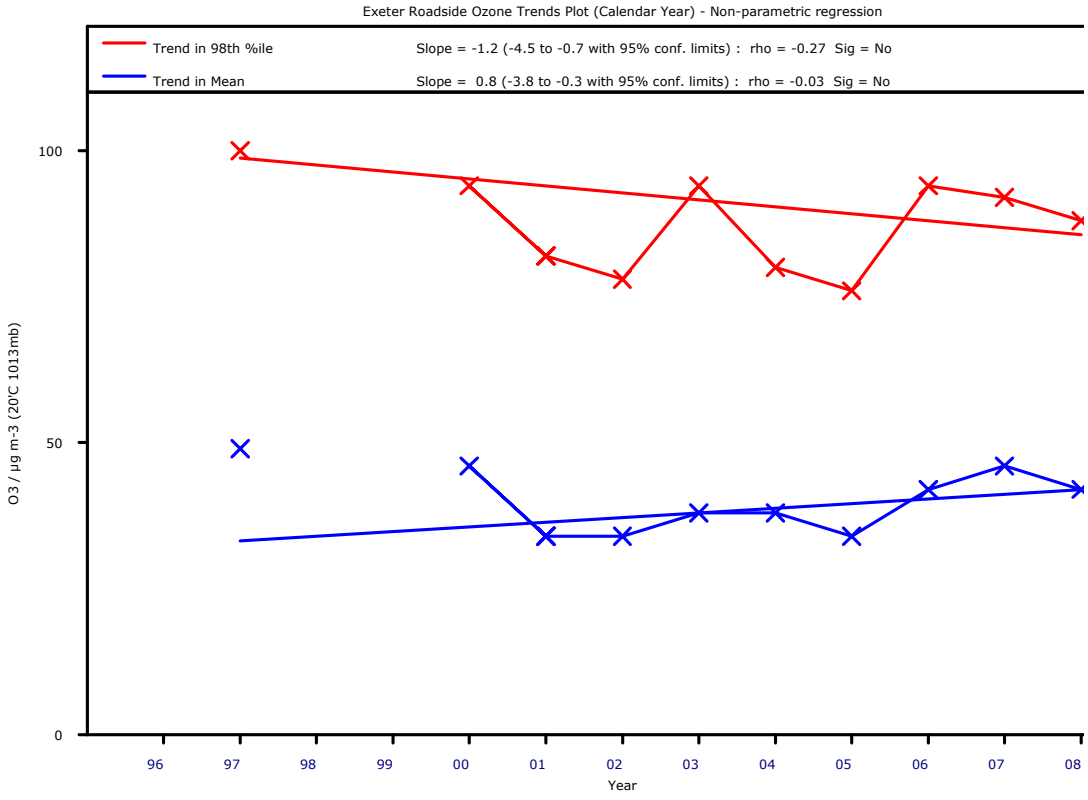
18.7 Trends in annual concentrations

Trends in concentrations are shown for sites with at least 5 years of measurement.

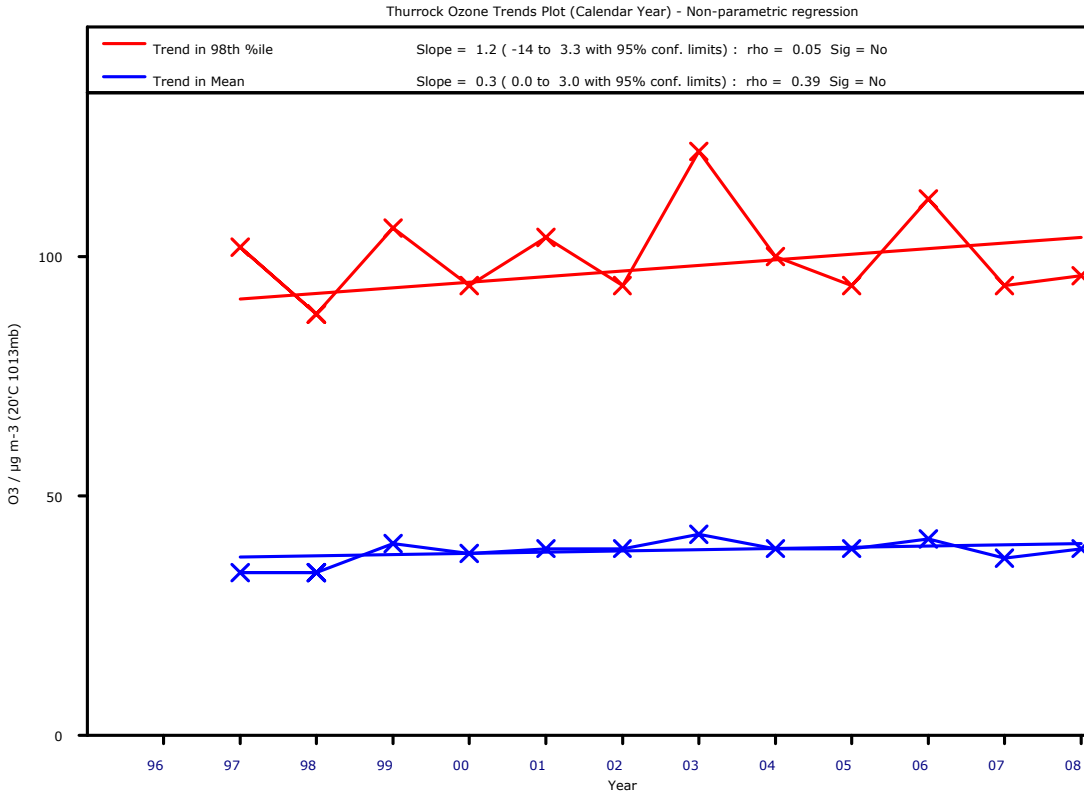
London Marylebone Road Ozone Trends – Non-parametric regression



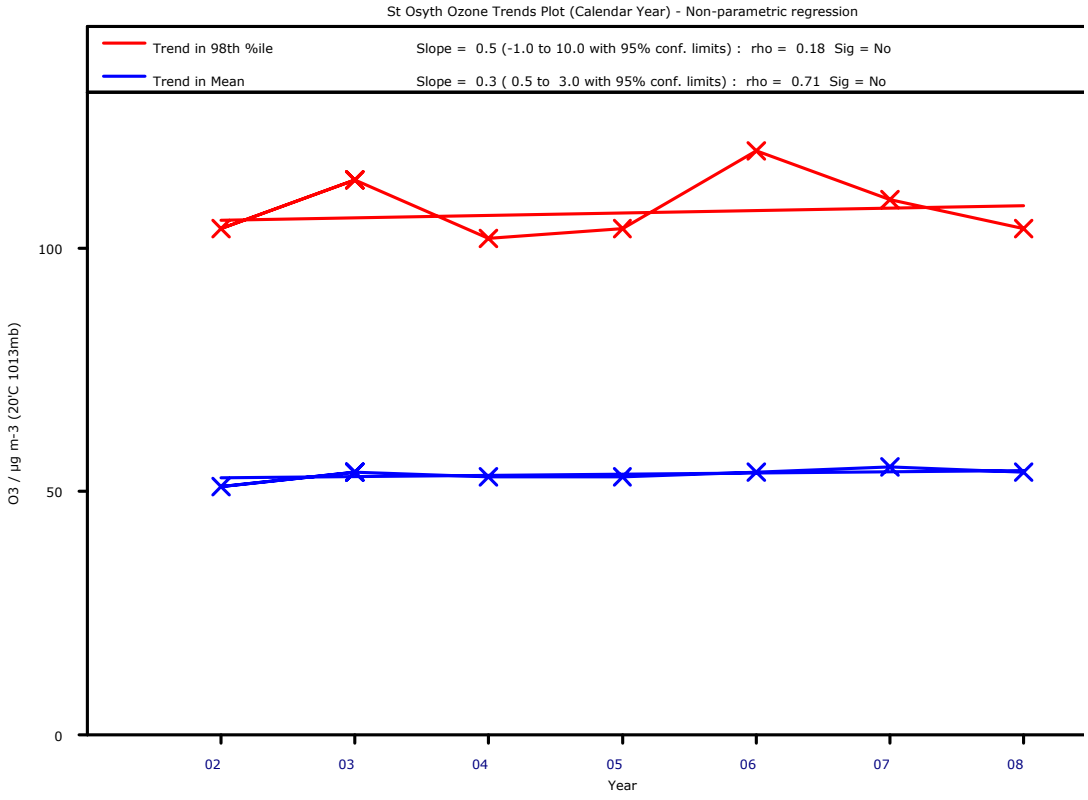
Exeter Roadside Ozone Trends – Non-parametric regression



Thurrock Ozone Trends – Non-parametric regression



St Osyth Ozone Trends – Non-parametric regression



18.8 Ozone statistical summary 2008

i) O_3 annual statistics I

Site	Site Type	Annual avg. of 1-hour means µg m^{-3}	Annual data capture of hourly means %	Max. hourly mean µg m^{-3}	Max. running 8-hour mean µg m^{-3}	Date of max. running 8-hour mean	97%ile of daily max run 8hr µg m^{-3}
England							
Barnsley Gawber	UB	46	98.7	156	134	11/05/08	99
Birmingham Centre	UC	43	97.9	160	150	11/05/08	97
Birmingham Tyburn	UB	42	98.5	174	167	11/05/08	110
Blackpool Marton	UB	57	98.5	156	129	08/05/08	105
Bolton	UB	---	35.1	166	127	11/05/08	---
Bottesford	S	49	98.8	162	152	11/05/08	113
Bournemouth	UB	55	99.1	156	143	11/05/08	126
Brighton Preston Park	UB	51	90.0	166	153	28/07/08	110
Bristol St Paul's	UB	44	95.7	158	149	11/05/08	105
Charlton Mackrell	RU	---	32.5	100	90	19/09/08	---
Coventry Memorial Park	UB	48	99.5	162	154	11/05/08	110
Exeter Roadside	RS	42	87.4	160	130	11/05/08	93
Glazebury	S	45	90.4	148	131	08/05/08	101
Great Dun Fell	RE	59	95.4	156	140	12/05/08	101
Harwell	RU	50	97.7	152	135	11/05/08	106
High Muffles	RU	57	87.9	158	148	30/04/08	123
Hull Freetown	UC	56	97.5	194	169	11/05/08	137
Ladybower	RU	58	98.2	170	161	11/05/08	111
Leamington Spa	UB	41	96.0	162	153	11/05/08	104
Leeds Centre	UC	43	99.5	170	146	11/05/08	116
Leicester Centre	UC	41	99.2	160	150	11/05/08	113
Leominster	S	51	98.0	174	163	11/05/08	107
Liverpool Speke	UB	47	98.3	150	120	08/05/08	97
London Bloomsbury	UC	28	98.4	124	112	28/07/08	84
London Eltham	S	40	96.5	160	137	10/05/08	110
London Haringey	UC	41	97.9	158	147	10/05/08	124
London Harlington	A	35	98.2	138	130	11/05/08	108
London Hillingdon	S	31	99.1	156	146	11/05/08	104
London Marylebone Road	KS	16	96.9	124	113	24/05/08	70
London N. Kensington	UB	39	98.8	152	130	09/06/08	110
London Teddington	UB	47	98.4	166	150	10/05/08	126
London Westminster	UB	35	97.8	140	120	11/05/08	100
Lullington Heath	RU	59	98.3	164	149	28/07/08	124
Manchester Piccadilly	UC	29	97.1	158	134	11/05/08	80
Manchester South	S	33	97.6	138	121	11/05/08	79
Market Harborough	RU	57	98.6	170	156	11/05/08	121
Middlesbrough	UI	48	98.5	136	121	25/07/08	99
Newcastle Centre	UC	42	96.6	134	111	10/05/08	98
Northampton	UB	48	95.8	164	158	11/05/08	113
Norwich Centre	UC	---	36.2	160	133	10/05/08	---
Nottingham Centre	UC	38	97.3	156	145	11/05/08	103
Plymouth Centre	UC	42	81.5	116	110	12/05/08	85
Portsmouth	UB	52	99.4	154	139	08/05/08	123
Preston	UB	50	98.6	170	132	11/05/08	107
Reading New Town	UB	46	97.4	156	143	08/05/08	113
Rochester Stoke	RU	45	99.0	138	125	27/07/08	101
Salford Eccles	UI	24	91.8	100	92	01/07/08	73
Sandwell West Bromwich	UB	48	95.4	168	160	11/05/08	109
Sheffield Centre	UC	44	98.5	138	118	11/05/08	93
Sibton	RE	61	68.8	166	145	31/07/08	127
Somerton	RU	---	16.4	96	92	02/03/08	---
Southampton Centre	UC	32	96.0	104	94	24/05/08	76
Southend-on-Sea	UB	52	99.3	158	148	27/07/08	119
St Osyth	RU	54	89.8	150	130	08/05/08	109
Stoke-on-Trent Centre	UC	41	93.7	156	147	11/05/08	94
Sunderland Silksworth	UB	47	98.0	120	108	31/05/08	99
Thurrock	UB	39	96.3	162	143	28/07/08	102
Weybourne	RU	63	97.3	162	158	21/04/08	127
Wicken Fen	RU	51	89.7	162	145	10/05/08	122
Wigan Centre	UB	46	97.0	176	137	11/05/08	102
Wirral Tranmere	UB	49	98.6	144	129	08/05/08	101
Yarner Wood	RU	61	88.8	174	164	11/05/08	116

ii) O_3 exceedence statistics I

Site	Moderate	Days	High	Days	Very High	Days	Air Quality Standard (Running 8-hour Mean) > 100 µg m^{-3}	Days
England								
Barnsley Gawber	128	18	0	0	0	0	**54**	**11**
Birmingham Centre	110	25	0	0	0	0	**38**	**7**
Birmingham Tyburn	295	38	0	0	0	0	**153**	**22**
Blackpool Marton	290	36	0	0	0	0	**161**	**20**
Bolton	85	14	0	0	0	0	**37**	**7**
Bottesford	322	46	0	0	0	0	**162**	**25**
Bournemouth	486	61	0	0	0	0	**265**	**38**
Brighton Preston Park	221	29	0	0	0	0	**112**	**20**
Bristol St Paul's	141	21	0	0	0	0	**68**	**13**
Charlton Mackrell	1	1	0	0	0	0	0	0
Coventry Memorial Park	235	33	0	0	0	0	**111**	**18**
Exeter Roadside	51	17	0	0	0	0	**9**	**2**
Glazebury	178	35	0	0	0	0	**71**	**11**
Great Dun Fell	244	18	0	0	0	0	**197**	**12**
Harwell	186	26	0	0	0	0	**89**	**17**
High Muffles	632	60	0	0	0	0	**445**	**44**
Hull Freetown	1104	101	**5**	**3**	0	0	**813**	**71**
Ladybower	305	33	0	0	0	0	**189**	**19**
Leamington Spa	175	22	0	0	0	0	**87**	**14**
Leeds Centre	428	49	0	0	0	0	**260**	**27**
Leicester Centre	243	27	0	0	0	0	**145**	**20**
Leominster	187	31	0	0	0	0	**91**	**15**
Liverpool Speke	111	23	0	0	0	0	**41**	**9**
London Bloomsbury	31	8	0	0	0	0	**6**	**1**
London Eltham	189	26	0	0	0	0	**95**	**16**
London Haringey	296	36	0	0	0	0	**169**	**24**
London Harlington	168	25	0	0	0	0	**79**	**15**
London Hillingdon	216	34	0	0	0	0	**96**	**15**
London Marylebone Road	17	4	0	0	0	0	**8**	**2**
London N. Kensington	193	31	0	0	0	0	**96**	**18**
London Teddington	351	48	0	0	0	0	**201**	**33**
London Westminster	111	18	0	0	0	0	**46**	**11**
Lullington Heath	450	53	0	0	0	0	**277**	**34**
Manchester Piccadilly	21	7	0	0	0	0	**9**	**1**
Manchester South	27	7	0	0	0	0	**5**	**1**
Market Harborough	446	52	0	0	0	0	**256**	**31**
Middlesbrough	112	24	0	0	0	0	**39**	**11**
Newcastle Centre	110	17	0	0	0	0	**35**	**8**
Northampton	353	36	0	0	0	0	**209**	**25**
Norwich Centre	175	22	0	0	0	0	**89**	**11**
Nottingham Centre	145	18	0	0	0	0	**78**	**13**
Plymouth Centre	42	9	0	0	0	0	**18**	**4**
Portsmouth	474	61	0	0	0	0	**267**	**35**
Preston	308	34	0	0	0	0	**190**	**21**
Reading New Town	242	35	0	0	0	0	**120**	**19**
Rochester Stoke	167	30	0	0	0	0	**72**	**13**
Salford Eccles	1	1	0	0	0	0	0	0
Sandwell West Bromwich	210	26	0	0	0	0	**113**	**15**
Sheffield Centre	63	19	0	0	0	0	**16**	**2**
Sibton	479	54	0	0	0	0	**285**	**37**
Somerton	0	0	0	0	0	0	0	0
Southampton Centre	2	2	0	0	0	0	0	0
Southend-on-Sea	535	69	0	0	0	0	**288**	**40**
St Osyth	353	46	0	0	0	0	**186**	**27**
Stoke-on-Trent Centre	86	13	0	0	0	0	**44**	**6**
Sunderland Silksworth	100	19	0	0	0	0	**25**	**7**
Thurrock	172	29	0	0	0	0	**78**	**13**
Weybourne	727	71	0	0	0	0	**487**	**51**
Wicken Fen	377	47	0	0	0	0	**215**	**30**
Wigan Centre	180	26	0	0	0	0	**81**	**12**
Wirral Tranmere	142	22	0	0	0	0	**69**	**12**
Yarner Wood	306	36	0	0	0	0	**172**	**23**

iii) O_3 annual statistics II

Site	Site Type	Annual avg. of 1-hour means µg m^{-3}	Annual data capture of hourly means %	Max. hourly mean µg m^{-3}	Max. running 8-hour mean µg m^{-3}	Date of max. running 8-hour mean	97%ile of daily max run 8hr µg m^{-3}
N Ireland							
Belfast Centre	UC	39	84.4	122	115	23/05/08	96
Derry	UB	53	97.9	172	155	08/05/08	106
Lough Navar	RE	49	96.2	138	136	08/05/08	97
Scotland							
Aberdeen	UB	50	98.9	124	119	31/05/08	108
Auchencorth Moss	RU	60	97.7	142	133	06/05/08	106
Bush Estate	RU	58	97.5	136	127	06/05/08	101
Edinburgh St Leonards	UB	49	96.0	128	121	12/05/08	104
Eskdalemuir	RU	57	90.0	156	150	08/05/08	112
Fort William	S	56	99.1	152	145	08/05/08	109
Glasgow Centre	UC	33	97.9	118	104	06/05/08	80
Lerwick	RU	70	96.1	146	140	08/05/08	112
Strath Vaich	RE	73	84.7	158	150	09/05/08	112
Wales							
Aston Hill	RU	70	84.3	174	155	11/05/08	117
Cardiff Centre	UC	43	98.8	176	154	11/05/08	101
Cwmbran	UB	55	87.1	168	162	11/05/08	110
Narberth	RE	62	72.0	148	141	07/05/08	116
Port Talbot Margam	UI	57	95.2	162	145	07/05/08	112

iv) O_3 exceedence statistics II

Site	Moderate	Days	High	Days	Very High	Days	Air Quality Standard (Running 8-hour Mean) > 100 µg m^{-3}	Days
N Ireland								
Belfast Centre	69	14	0	0	0	0	**22**	**5**
Derry	196	29	0	0	0	0	**118**	**16**
Lough Navar	100	14	0	0	0	0	**47**	**8**
Scotland								
Aberdeen	506	48	0	0	0	0	**295**	**30**
Auchencorth Moss	350	44	0	0	0	0	**180**	**25**
Bush Estate	190	31	0	0	0	0	**80**	**12**
Edinburgh St Leonards	219	29	0	0	0	0	**109**	**14**
Eskdalemuir	296	35	0	0	0	0	**191**	**18**
Fort William	411	51	0	0	0	0	**231**	**30**
Glasgow Centre	21	5	0	0	0	0	**6**	**2**
Lerwick	559	52	0	0	0	0	**405**	**34**
Strath Vaich	1171	98	0	0	0	0	**776**	**67**
Wales								
Aston Hill	431	54	0	0	0	0	**243**	**27**
Cardiff Centre	134	20	0	0	0	0	**69**	**12**
Cwmbran	256	38	0	0	0	0	**128**	**18**
Narberth	265	34	0	0	0	0	**174**	**22**
Port Talbot Margam	412	48	0	0	0	0	**257**	**26**

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Air Pollution in the UK: 2008

Part 3

In this part of the report, we provide supplementary information in a series of Appendices:

A1 - The Major Air Pollutants measured in the UK

A2 - Regional Maps of UK Automatic Air Monitoring Sites

A3 - The UK's Automatic and Sampler-based Air Monitoring Networks

A4 - Analysis of statistically significant trends in UK air pollution levels

A5 - Listing of current UK, European and WHO Air Quality Criteria

A6 - Calculation methods, statistical methods and measurement uncertainty

Appendix A1- The major air pollutants measured in the UK

We describe major sources and effects of these pollutants, together with typical UK-wide patterns of exposure.

The pollutants:

- Nitrogen oxides, and primarily nitrogen dioxide (NO_2)
- Sulphur Dioxide (SO_2)
- Carbon Monoxide (CO)
- Ozone (O_3)
- Particles- measured as PM_{10} and $PM_{2.5}$
- Benzene (C_6H_6)
- 1,3-butadiene (C_4H_6)
- Lead and heavy metals

Introduction

The principal air pollutants measured in UK National Air Monitoring networks are:

- Nitrogen oxides, and primarily nitrogen dioxide (NO_2)
- Sulphur Dioxide (SO_2)
- Carbon Monoxide (CO)
- Ozone (O_3)
- Particles- measured as PM_{10} and $PM_{2.5}$
- Benzene (C_6H_6)
- 1,3-butadiene (C_4H_6)
- Lead and heavy metals

The first five of these are measured in the AURN, whilst the two volatile organic compounds- benzene and 1,3-butadiene- are measured in the automatic hydrocarbon network. The various pollutants have different sources and behave very differently once emitted into the atmosphere. As a result, spatial and temporal patterns can differ markedly between the pollutants.

In this appendix, we briefly examine the sources, effects and distributions of these major pollutants. For more detail, please refer to the authoritative series of pollutant-specific analyses and guidelines produced by EPAQS (the UK Expert Panel on Air Quality Standards)[P1-9] and World Health Organisation[P10].

Nitrogen Oxides

Nitrogen oxides (NO_x) are formed during high temperature combustion processes from the oxidation of nitrogen in the air or fuel. The principal source of nitrogen oxides - nitric oxide (NO) and nitrogen dioxide (NO_2), collectively known as NO_x - is road traffic. For the UK as a whole, approximately 45% of all oxide of nitrogen emission originates from this source, with most of the remainder arising from power stations and other industrial sources. Since power station and industrial emissions are usually from elevated sources (i.e. high chimneys), motor vehicles represent by far the largest source of low-level NOx emission and therefore make the largest contribution (75% or greater) to long-term ground level concentrations in urban areas.

Nitric oxide is not generally considered to be harmful to health at the concentrations found in the ambient atmosphere. However, once released to the atmosphere, it rapidly oxidises to nitrogen dioxide, which has a variety of environmental and health impacts. Its direct health impact as a respiratory irritant may be significant. Nitrogen dioxide can irritate the lungs and lower resistance to respiratory infections such as influenza. Continued or frequent exposure to concentrations that are typically much higher than those normally found in the ambient air may cause increased incidence of acute respiratory illness in children.

In the presence of sunlight, nitrogen oxides can react with Volatile Organic Compounds (VOCs) to produce photochemical pollutants including ozone. Nitrogen dioxide can also be further oxidised in air to acid gases such as nitric acid, which contribute to the production of acid rain over regional scales.

The highest NOx levels in UK cities are generally observed at kerbside locations. However, since much of the NO_2 is formed from primary emissions of NO by time-dependent oxidation processes in the atmosphere, the relative decline in NO_2 concentration away from the kerbside is slower than for NO.

Modelling and monitoring studies- for example with diffusion tube samplers- have shown that NO_2 concentrations tend to be greatest in central urban areas. However, this cannot

always be assumed to be the case, especially where major road systems, industrial areas or other large sources are located away from city centre areas.

Sulphur Dioxide

Sulphur dioxide (SO_2) is an acid gas, which acts as an irritant to the respiratory system and may exacerbate or initiate symptoms in asthmatics. Even moderate concentrations of SO_2 may result in a decline in lung function in asthmatics. Tightness in the chest and coughing occur at high levels, and lung function of asthmatics may be impaired to the extent that medical help is required. Sulphur dioxide pollution is considered more harmful when particle and other pollution concentrations are high. This is a good example of combined or *synergistic* effects of air pollutants.

Primary emissions of sulphur dioxide are a major contributor to the formation of acid rain; this can be transported over long distances, with important consequences for terrestrial and aquatic ecosystems, as well as the man-made built environment.

This pollutant is formed by the oxidation of sulphur impurities in fuels during combustion processes. A very high proportion (approximately 85%) of UK SO_2 emissions originate from power stations and industrial sources. As the use of coal for domestic heating has decreased, its emissions and atmospheric concentrations in urban areas have decreased considerably over the last 20-30 years.

Geographically, SO_2 concentrations in the UK are highest in urban areas such as mining regions in the north of England and in Northern Ireland, where there is still significant use of coal for domestic heating. Modelling studies have indicated that the highest SO_2 concentrations in cities usually occur in the central areas.

Carbon Monoxide

Carbon monoxide (CO) is a colourless, odourless but toxic gas produced by incomplete combustion of fossil fuels. At worst-case ambient levels (in congested streets, car-parks or tunnels), exposure may reduce the oxygen-carrying capacity of the blood and impair oxygen delivery to the brain and other organs, particularly affecting adults with angina and diseases of the coronary arteries.

Carbon monoxide in urban areas results almost entirely from vehicle emissions. The emission rate for individual vehicles depends critically on vehicle speed, being higher at low speeds.

Since CO is a primary pollutant, its ambient concentrations closely follow emissions. In urban areas, concentrations are therefore highest at the kerbside and decrease rapidly with increasing distance from the road. Since traffic is by far the most important source of CO, its spatial distribution will follow that of traffic: this will generally result in the highest levels being observed in the city centre, where most congested areas tend to be found.

Ozone

Ozone (O_3) is a highly reactive oxidising agent, with a wide range of material, vegetation and human health impacts. Acute health effects of ozone may include eye/nose irritation, respiratory problems and airway inflammation.

In addition to its serious impacts on human health, ozone is also *phytotoxic* – damaging to many plants and commercial crops. It can also damage or age some man-made materials such as rubbers and elastomers, as well as bleaching paints and fabrics.

A natural background ozone concentration exists in the atmosphere due to mixing of ozone from the stratosphere and its generation in the troposphere. The background concentration depends on latitude and time of year: in the UK, measurements show the resulting annual average background concentration to be about 70 μg/m^3.

Ozone is not emitted directly into the atmosphere in any significant quantity and its presence in the lower atmosphere at concentrations exceeding background results primarily from a complex series of reactions in the atmosphere; these may be summarised as the sunlight-initiated oxidation of volatile organic compounds (VOCs) in the presence of nitrogen oxides (NO_x). The sources of VOCs are similar to those described for NO_x above, but also include other activities such as solvent use, petrol distribution and handling.

The reactions producing ozone occur in air containing these NO_x and VOC precursors as it moves downwind; ozone formation can occur over a timescale of a few hours to several days. As a result, ozone concentrations are decoupled temporally and spatially from precursor sources and ambient concentrations are strongly dependent on meteorological conditions, together with scavenging and deposition rates. The net result is that ozone concentrations measured at a particular location may have arisen from VOC and NOx emissions many hundreds or even thousands of miles away. Maximum concentrations, therefore, generally occur some distance downwind of the original sources of precursor emissions.

In urban areas, chemical scavenging by NO_x emissions results in ozone concentrations that are generally lower than in rural areas. Moreover, urban ozone concentrations tend to be highly variable over small spatial scales, with concentrations lowest where corresponding levels of other pollutants such as NO are highest. In cities, therefore, ozone concentrations will tend to be lower in central areas and increase in the suburbs, although the spatial variation will be complex and, in open spaces in urban areas, levels of ozone may approach those found in nearby rural areas.

Particulate Matter

Particulate Matter (PM) is a generic descriptor covering a wide range of particle size fractions, morphologies and chemical compositions. Particles are produced from a variety of natural and man-made sources. Natural sources include sea salt, soil blowoff, Saharan dust (see Section 4), forest fires and volcanic activity. Man-made sources include incomplete combustion processes (e.g. coal and diesel smoke), industry and construction activity. Industrial accidents such as the Buncefield incident (see the 2005 annual report) can also produce large quantities of particles.

Particles may be either directly emitted into the atmosphere (primary particles) or formed there by chemical reactions (secondary particles). Sulphate and nitrate aerosols are good examples of the latter; these can often transported over national or continental distances. Both particle size - usually expressed in terms of its aerodynamic diameter,- and chemical composition are greatly influenced by its origin.

Although coarse (large) particle size ranges may cause significant local nuisance or soiling impacts, the finer (small) fractions remain the focus for potential impacts on human health. This is because fine particulate matter can penetrate deep into the airways, carrying surface-absorbed harmful and carcinogenic compounds into the lungs. Particulate pollution is therefore associated with a range of health effects, including increased risk of heart and lung disease.

Two fine size fractions of particulate matter are measured in UK national monitoring networks: PM_{10} and $PM_{2.5}$. These are the mass fractions of particles collected by a sampler with a 50% inlet cut-off at aerodynamic diameter 10μm and 2.5μm respectively.

PM_{10} has been measured in the UK since the late 1980s. The principal source of PM_{10} in many cities is road traffic emissions, particularly from diesel vehicles. Existing PM_{10} measurements show that daily average concentrations are usually highest in the winter months and lowest in the summer. During winter episode periods, PM_{10} levels increase together with other traffic-related pollutants such as oxides of nitrogen. During the spring and summer, the photochemical oxidation of sulphur dioxide and oxides of nitrogen to particulate sulphate and nitrate is another important source of PM_{10}.

Concern about the potential health impacts of fine particulate matter has increased over recent years. In particular, increasing policy and measurement action – both Europe-wide and within the UK – is now focussing on even smaller particle fractions such as $PM_{2.5}$. The new Air Quality Directive 2008/50/EC- as discussed at length in Section 2.1 - introduces Limit Values for $PM_{2.5}$ particulate matter, together with an exposure-reduction target. This will require reductions in fine particle concentrations throughout each Member State and a cap on concentrations in the most polluted areas. Therefore, in recent years, the UK's national monitoring programme has incorporated a number of sites monitoring $PM_{2.5}$.

As well as health effects, particles also have a range of important non-biological impacts including:

- Soiling of man-made materials and buildings, resultant loss of amenity
- Reducing visibility (fine particles- aerosol)
- Effects on heterogeneous atmospheric chemistry

Benzene

Benzene (C_6H_6) is a fat-soluble volatile organic compound (VOC) with a range of potential health effects. Acute exposure to benzene at occupational levels can cause narcotic, anaesthetic or fatal consequences. Benzene is a proven genotoxic carcinogen, and ambient long-term exposure is implicated in the formation of a range of types of leukaemia in the general population. Potential chronic health effects of this pollutant also include central nervous system disorders, liver and kidney damage, reproductive disorders and birth defects.

Benzene has no significant natural sources, so that ambient exposure results primarily from petrol combustion in road transport emissions or evaporation of petrol (which contains benzene) from filling stations. Benzene is naturally broken down by chemical reactions in the atmosphere, although these reactions can take several days. As a result, outdoor benzene concentrations tend to closely follow road networks and traffic density patterns.

1,3-Butadiene

Evidence from occupational human exposure and laboratory studies on animals shows 1,3-butadiene (C_4H_6) to be a carcinogen, exposure to which can cause a range of cancers of the lymphoid system, blood-forming tissues, lymphomas and leukaemias. Potential chronic health effects of this pollutant also include central nervous system disorders, liver and kidney damage, reproductive disorders and birth defects.

This substance is used in some industrial sectors, primarily in the production of synthetic rubber. However, ambient exposure of the general population results primarily from fuel combustion- mainly from petrol-fuelled motor vehicles, but also from other fossil fuels, accidental fires and industrial releases.

Unlike benzene, this is not a constituent of petrol, so evaporative or fugitive emissions are not a significant source. Although 1,3-butadiene is removed by catalytic converters

and not produced from diesel engines, spatial and temporal exposure patterns in the UK are dominated by road transport.

Lead

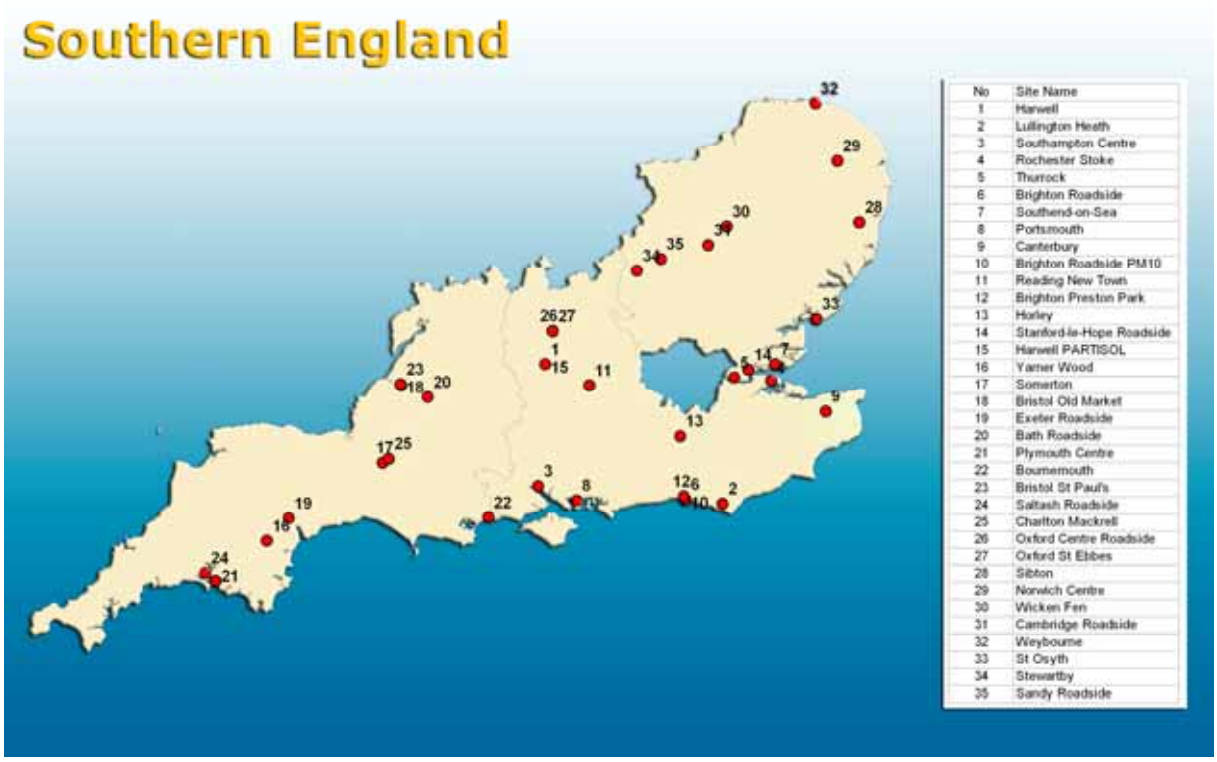
The majority of Lead (Pb) emissions arise from older vehicles fuelled with leaded petrol. Industry, in particular secondary non-ferrous metal smelters, may also contribute to emissions of lead in localised industrial areas. This source is becoming increasingly significant due to the progressive reduction in the lead content of leaded petrol and the increasing use of unleaded petrol; this has led to significant reductions in urban lead levels over recent years.

Even small amounts of lead can be harmful, especially to infants and young children. In addition, lead taken in by the mother can interfere with the health of the unborn child. Exposure has also been linked to impaired mental function, visual-motor performance and neurological damage in children, and memory and attention span.

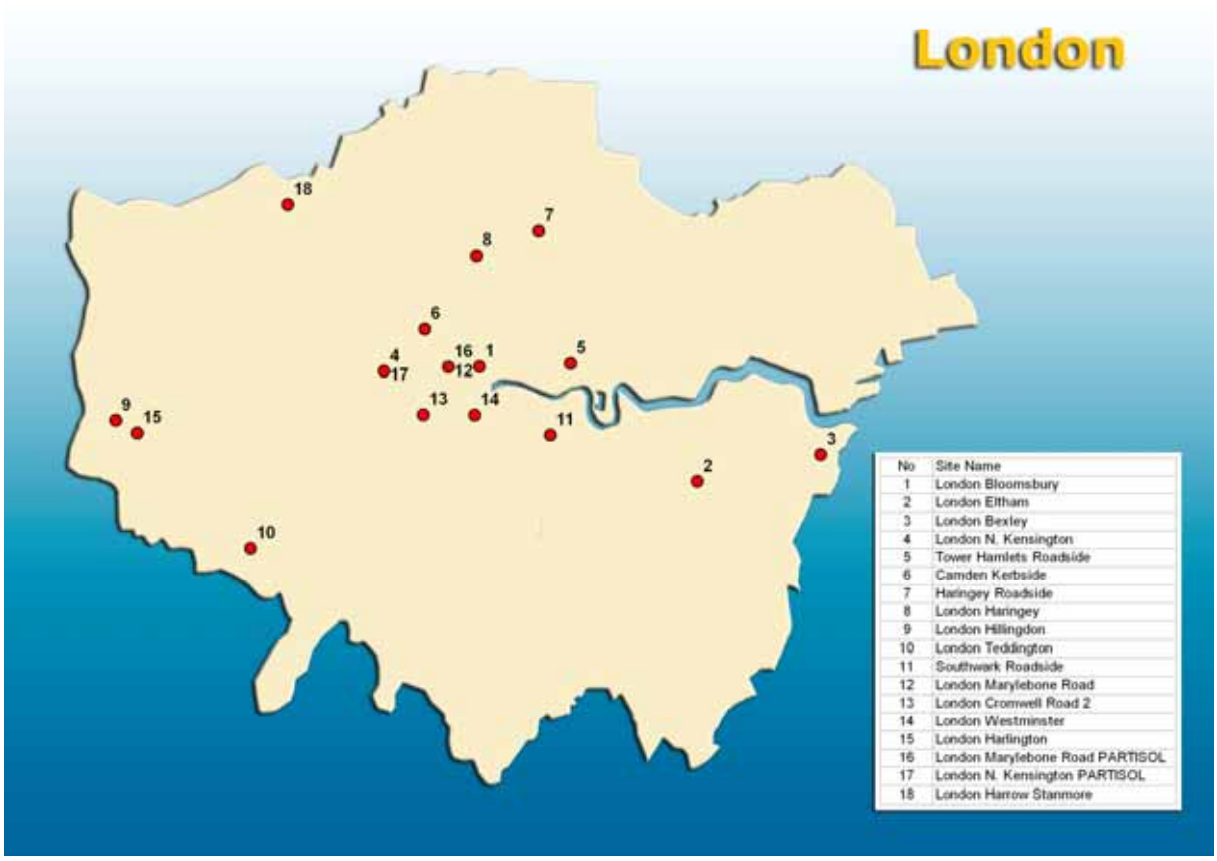
Appendix A2- regional maps of UK automatic air monitoring stations

These maps show Automatic Urban and Rural Network (AURN) and Hydrocarbon air monitoring sites in different parts of the UK.

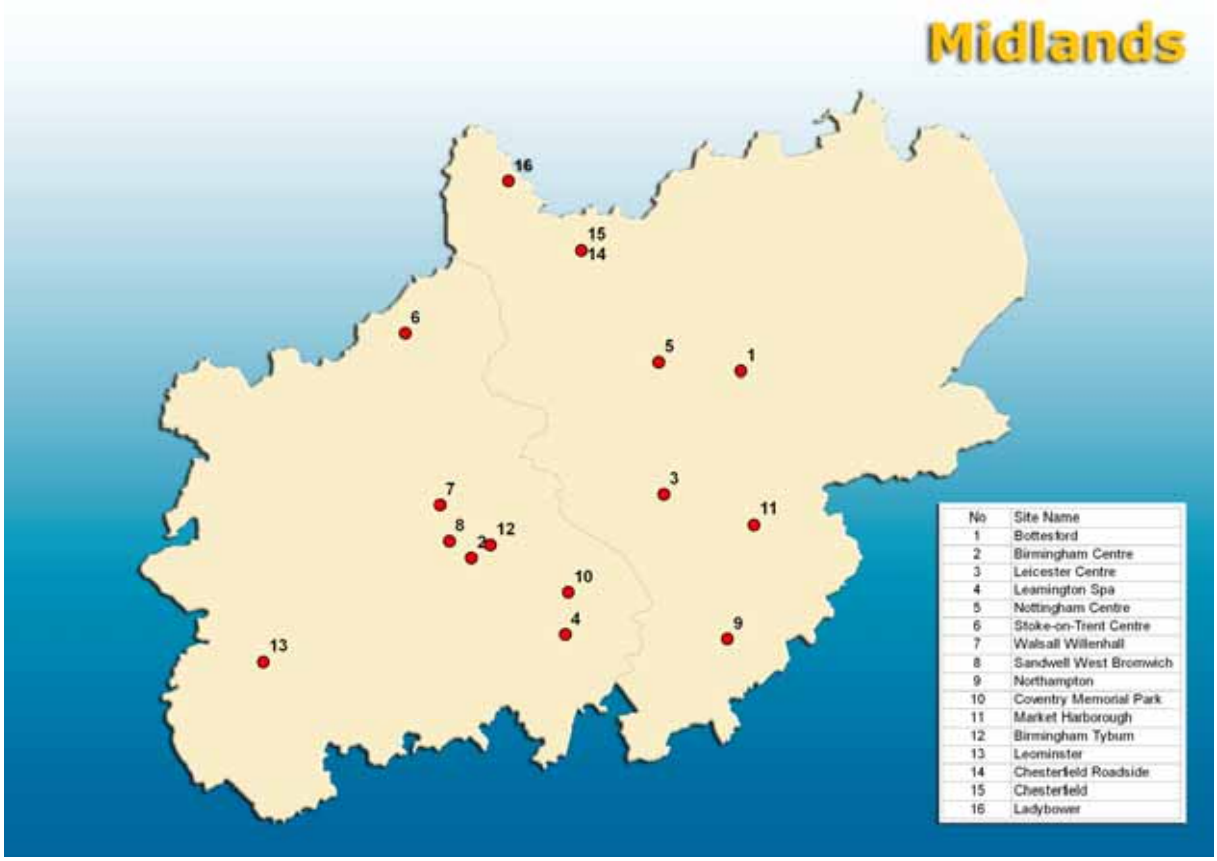
Figure A2.1	Southern England
Figure A2.2	London
Figure A2.3	Midlands
Figure A2.4	NW England
Figure A2.5	NE England
Figure A2.6	Wales
Figure A2.7	N. Ireland
Figure A2.8	Scotland



No	Site Name
1	Harwell
2	Lullington Heath
3	Southampton Centre
4	Rochester Stoke
5	Thurrock
6	Brighton Roadside
7	Southend-on-Sea
8	Portsmouth
9	Canterbury
10	Brighton Roadside PM10
11	Reading New Town
12	Brighton Preston Park
13	Horley
14	Stanford-le-Hope Roadside
15	Harwell PARTISOL
16	Yarner Wood
17	Somerton
18	Bristol Old Market
19	Exeter Roadside
20	Bath Roadside
21	Plymouth Centre
22	Bournemouth
23	Bristol St Paul's
24	Saltash Roadside
25	Charlton Mackrell
26	Oxford Centre Roadside
27	Oxford St Ebbes
28	Sibton
29	Norwich Centre
30	Wicken Fen
31	Cambridge Roadside
32	Weybourne
33	St Osyth
34	Stewartby
35	Sandy Roadside



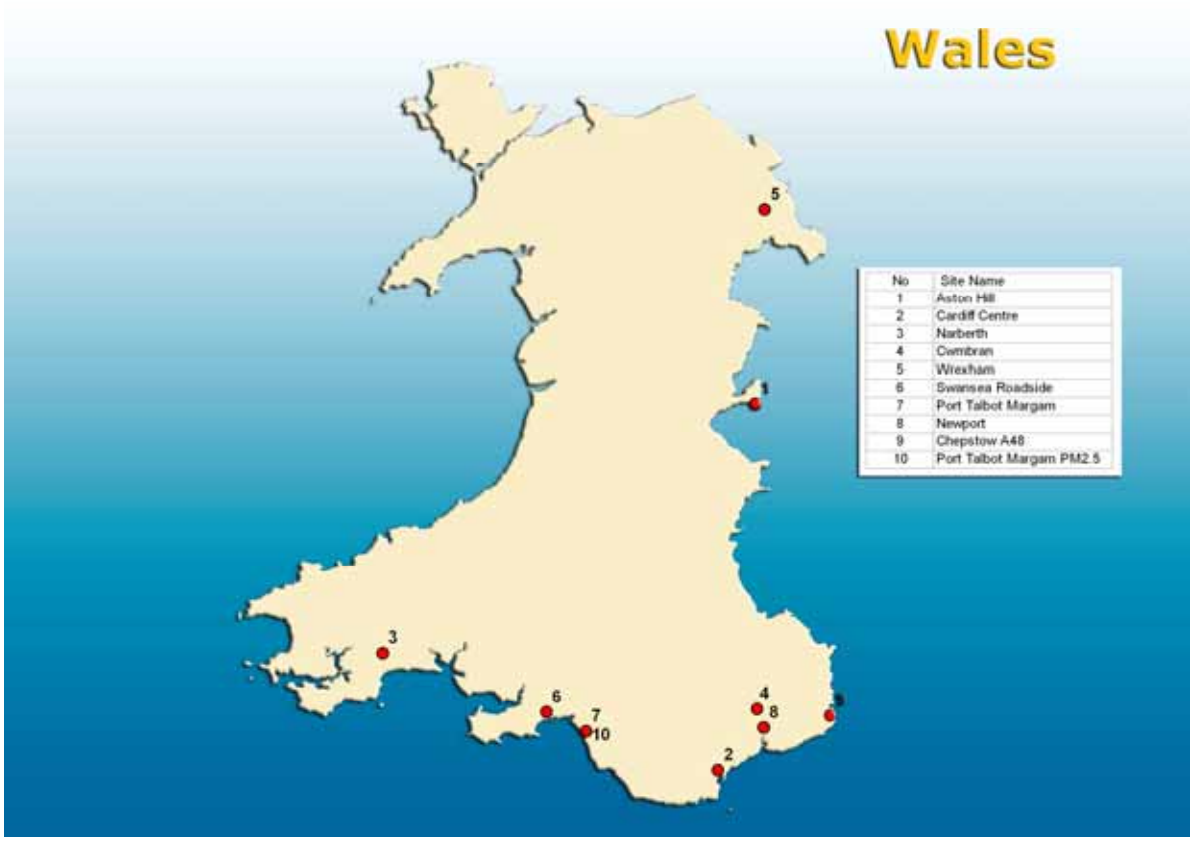
No	Site Name
1	London Bloomsbury
2	London Eltham
3	London Bexley
4	London N. Kensington
5	Tower Hamlets Roadside
6	Camden Kerbside
7	Haringey Roadside
8	London Haringey
9	London Hillingdon
10	London Teddington
11	Southwark Roadside
12	London Marylebone Road
13	London Cromwell Road 2
14	London Westminster
15	London Harlington
16	London Marylebone Road PARTISOL
17	London N. Kensington PARTISOL
18	London Harrow Stanmore

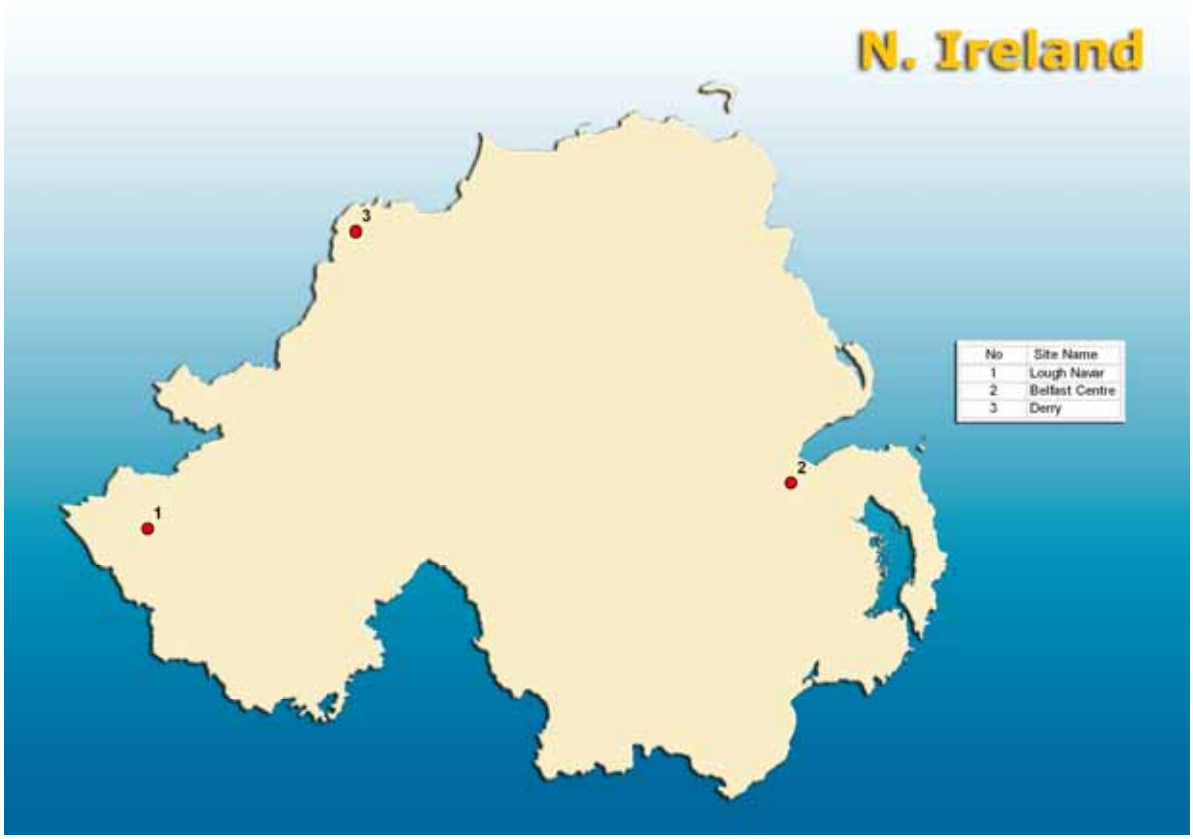


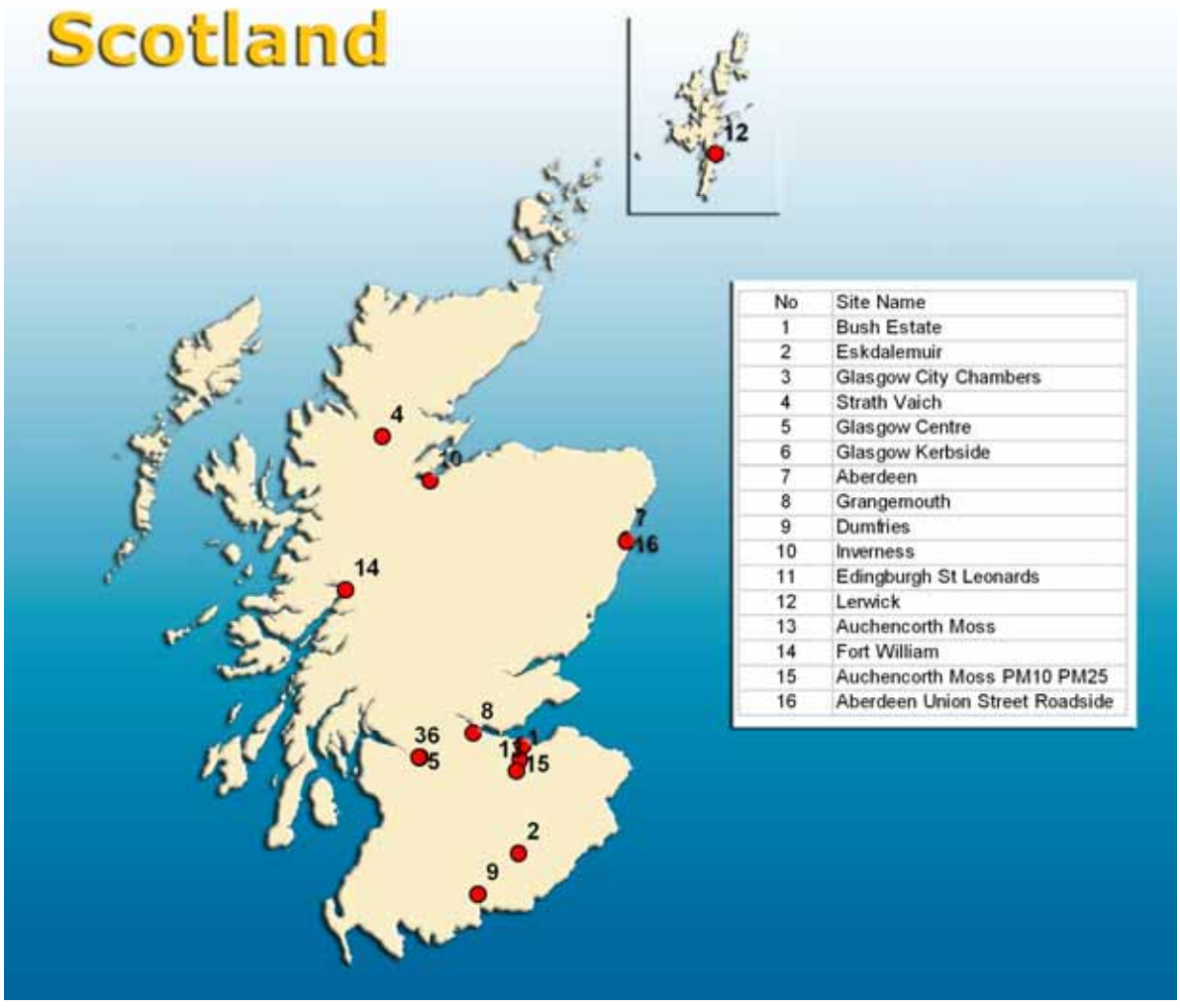
No	Site Name
1	Bottesford
2	Birmingham Centre
3	Leicester Centre
4	Leamington Spa
5	Nottingham Centre
6	Stoke-on-Trent Centre
7	Walsall Willenhall
8	Sandwell West Bromwich
9	Northampton
10	Coventry Memorial Park
11	Market Harborough
12	Birmingham Tyburn
13	Leominster
14	Chesterfield Roadside
15	Chesterfield
16	Ladybower

No	Site Name
1	Great Dun Fell
2	Glazebury
3	Liverpool Speke
4	Manchester Piccadilly
5	Manchester South
6	Bury Roadside
7	Bolton
8	Salford Eccles
9	Wirral Tranmere
10	Preston
11	Wigan Centre
12	Blackpool Marton
13	Liverpool Queen's Drive Roadside
14	Carlisle Roadside
15	Warrington


NE England
4
17
13
1
18
10
2
14
15
16
6
11
12
9
7
3
No Site Name
1 Billingham
2 High Muffles
3 Sheffield Tinsley
4 Newcastle Centre
5 Middlesbrough
6 Leeds Centre
7 Barnsley 12
8 Sheffield Centre
9 Barnsley Gawber
10 Stockton-on-Tees Yarm
11 Hull Freetown
12 Scunthorpe Town
13 Sunderland Silksworth
14 York Bootham
15 York Fishergate
16 Leeds Headingley Kerbside
17 Newcastle Cradlewell roadside
18 Stockton-on-Tees Eaglescliffe


Wales
5
1
3
6
7
10
4
8
2
No Site Name
1 Aston Hill
2 Cardiff Centre
3 Narberth
4 Cwmbran
5 Wrexham
6 Swansea Roadside
7 Port Talbot Margam
8 Newport
9 Chepstow A48
10 Port Talbot Margam PM2.5


N. Ireland
No Site Name
1 Lough Navar
2 Belfast Centre
3 Derry
1
2
3


Scotland
No Site Name
1 Bush Estate
2 Eskdalemuir
3 Glasgow City Chambers
4 Strath Vaich
5 Glasgow Centre
6 Glasgow Kerbside
7 Aberdeen
8 Grangemouth
9 Dumfries
10 Inverness
11 Edingburgh St Leonards
12 Lerwick
13 Auchencorth Moss
14 Fort William
15 Auchencorth Moss PM10 PM25
16 Aberdeen Union Street Roadside
12
4
10
7
16
14
8
36
5
15
2
9

Appendix A3- The UK's automatic and sampler-based air monitoring networks

Here we provide a concise guide to the different UK air monitoring networks, their objectives and methodologies.

A3.1 The Automatic Urban and Rural Network (AURN)

(Network managed for Defra and the DAs by Bureau Veritas & quality assured by AEA)

The AURN is the UK's largest automatic monitoring programme. It includes automatic air quality monitoring stations measuring oxides of nitrogen (NO_x), sulphur dioxide (SO_2), ozone (O_3), carbon monoxide (CO) and particles (PM_{10} and $PM_{2.5}$). These are monitored on an hourly basis at measurement sites throughout the UK.

As of September 2009, the AURN consists of 127 monitoring sites. Of these, 60 are directly funded by Defra and the devolved administrations, whilst a further 67 affiliated sites are owned and operated by local authorities; 7 of these sites are also in the London Air Quality Network (LAQN). The network has grown dramatically since it was first established in 1992 (see Figures 3.3 and 3.4 in section 3 of the main report.)

The major objectives of the network are as follows:

- Checking if statutory air quality standards and targets are met (e.g. EU Directives)
- Informing the public about air quality
- Providing information for local air quality review and assessments within the UK Air Quality Strategy
- Identifying long-term trends in air pollution concentrations
- Assessing the effectiveness of policies to control pollution

A number of organisations are involved in the day-to-day running of the network. Currently, the role of Central Management and Co-ordination Unit (CMCU) for the AURN is contracted to Bureau Veritas, whilst the Environmental Research Group (ERG) of King's College London has been appointed as Management Unit for the London Air Quality Network (LAQN). AEA undertakes the role of Quality Assurance and Control Unit (QA/QC Unit) for the entire AURN. The responsibility for operating individual monitoring sites is assigned to personnel from local organisations, such as local authority Environmental Health Officers with relevant experience in the field. Calibration gases for the network are supplied by Air Liquide Ltd and are provided with a UKAS certificate of calibration by AEA.

The techniques used for monitoring within the AURN are summarised below. These represent the current state-of-the-art for automated monitoring networks and, with the exception of the automatic PM_{10} analysers, are the reference methods of measurement defined in the relevant EU Directives. Please see Section 4 for additional information on recent evaluations of PM_{10} measurement techniques.

AURN Measurement Techniques (reviewed in greater detail in Part 2)

O_3	UV absorption
NO_2 / NO_x	Chemiluminescence
SO_2	UV fluorescence
CO	IR Absorption
PM_{10}	▸ Tapered Element Oscillating Microbalance ▸ Beta Attenuation monitor ▸ Gravimetric monitor

During 2007, Defra undertook a major review of the AURN, aimed at ensuring that it would continue to meet the UK's compliance monitoring needs in the most cost-effective way. For some pollutants, where ambient concentrations were well within EC Limit Values and AQS Objectives, monitoring was discontinued at some sites. This allowed

resources to be re-directed to locations and pollutants for which the priority was assessed to be higher. The spatial distribution of sites within the UK was also considered and, in some zones and agglomerations, (e.g. London) some sites were closed.

Carbon monoxide monitoring was significantly scaled down, being discontinued at 52 sites: this pollutant is well within EC Limit Values and AQS Objectives throughout the UK. Sulphur dioxide monitoring has also been decreased, with monitoring discontinued at 39 sites in total over 2007-08. Ozone monitoring was discontinued at 14 sites. PM_{10} particulate monitoring ceased at 25 sites in total, and NO_x and NO_2 monitoring ceased at 24 sites.

In total, 25 sites AURN sites were discontinued in 2007, with a further 5 ceasing operation in 2008. In many cases, however, they have not been shut down, but simply been de-affiliated from the AURN; these continue in operation by the relevant Local Authorities.

In order to meet the requirement for $PM_{2.5}$ analysers to be in operation by 1st January 2009, a number of PM_{10} analysers were converted to $PM_{2.5}$ - either permanently or temporarily - whilst awaiting the installation of a second analyser at the site. Forty $PM_{2.5}$ analysers were commissioned during 2008, and several more are due for installation during 2009. As part of this process, analysers that did not meet the equivalence requirements were upgraded to newer compliant types. Almost all TEOM particle analysers in the AURN have been upgraded to FDMS as part of this process.

A 3.2 The Acid Deposition Monitoring Network

(Managed and operated for Defra and the DAs by AEA and CEH)

The Acid Deposition Monitoring network (ADMN) was established in 1986 to monitor the composition of precipitation and hence to provide information on deposition of acidifying compounds in the United Kingdom. Its main emphasis has always been the assessment of potential impacts on UK ecosystems. Other measurements have also been made within the programme - sulphur dioxide, nitrogen dioxide and particulate sulphate - to provide a more complete understanding of precipitation chemistry in the United Kingdom.

This network has evolved substantially over time. It was originally based on two sub-programmes – a 'primary' network providing high quality and high frequency data, which could be used to identify trends over time, and a 'secondary' network providing information on the spatial distribution of acid deposition in the UK. Originally, there were nine primary and 59 secondary sampling sites. Subsequent changes made to the programme, including different measurement techniques, altered sampling frequencies and reductions to the number of monitoring sites, have made this distinction less clear cut.

In 1999, seven new sites were established to monitor rainwater composition in ecologically sensitive areas. Further changes in 2006 saw the exposure of triplicate nitrogen dioxide diffusion tubes at three sites and commencement of a wet-only daily precipitation collector at one site. In addition, sulphur dioxide measurements taken by the ADMN and Rural SO_2 Monitoring Network (part of the Acid Deposition Processes contract) were terminated at the end of 2005, being replaced by measurements made as part of the expanded nitric acid monitoring network (see Section A3.6). In 2007, the network covered the following measurements and sites:

The Acid Deposition Monitoring Network - site numbers & measured parameters

Precipitation Composition	– Rainwater sampling using a bulk collector on a ***fortnightly*** basis at 38 sites – Rainwater sampling using a bulk collector on a ***daily*** basis at 1 of the above sites – Additional wet-only measurements on a ***daily*** basis at 1 site
Particulate Sulphate **Nitrogen Dioxide**	– Sampled on a ***daily*** basis at 5 sites – Diffusion tube measurements on a ***monthly*** basis at 24 sites. Of these, 3 sites operate triplicate tubes.
Nitric acid, other acid gases and aerosols	– Denuder (DELTA) measurements on a ***monthly*** basis at 30 sites

A 3.3 The Hydrocarbon monitoring networks

i) The Automatic Hydrocarbon Network
(Network managed and quality assured for Defra and the DAs by AEA)

Automatic hourly measurements of speciated hydrocarbons, made using an advanced automatic gas chromatograph (VOCAIR), commenced in the UK in 1991. By 1995, monitoring had expanded considerably with the formation of a 13-site dedicated network measuring 26 species continuously at urban, industrial and rural locations.

The focus in this ground-breaking measurement programme was two-fold: firstly to assess ambient concentrations of a range of Volatile Organic Compounds (VOCs) with significant photochemical oxidant formation potential, and secondly to measure two known genotoxic carcinogens (benzene and 1,3-butadiene) for comparison against emerging UK Air Quality Objectives. Data on these 'air toxics' were also regularly reported to the public.

The automatic hydrocarbon monitoring network, as originally constituted, used state-of-the-art measurement techniques, combined with advanced software techniques for signal processing and validation. It was the first network of its kind in the world. The Automatic Hydrocarbon Network operated successfully for 10 years before the programme was re-focussed, re-designed and simplified in 2002.

By the start of 2008, the UK Automatic Hydrocarbon Network consisted of five sites, located at Glasgow, Harwell, London Eltham, London Marylebone Road and Auchencorth Moss. One these sites –Glasgow - utilises an Environnment VOC71M analyser configured to measure and report the concentrations of 1,3-butadiene, benzene, toluene, ethylbenzene, (m+p)-xylene and o-xylene.

Auchencorth Moss, Harwell and the two London sites - London Eltham and London Marylebone Road - are fitted with automatic Perkin Elmer gas chromatographs measuring a wider range of VOCs, equivalent to that studied under the original measurement programme. These instruments are capable of measuring and reporting at least 27 hydrocarbons.

Measurements from all five sites are reported to the European Commission, satisfying requirements under the Ozone Daughter Directive for monitoring photochemical ozone precursors. Corresponding benzene and the 1,3-butadiene data are used for comparison with the UK Air Quality Objectives, whilst benzene data are reported to the European

Commission to fulfil requirements of the Air Quality Directive 2008/50/EC [Q1] on ambient air quality and cleaner air for Europe.

Hourly benzene and 1,3-butadiene data from all sites continue to be reported to the public at large through a range of web, electronic, text and broadcast media.

ii) The Non-Automatic Hydrocarbon Network
(Managed and operated for Defra and the DAs by the National Physical Laboratory)

The UK Non-Automatic Hydrocarbon Network measures ambient benzene concentrations at 36 sites around the United Kingdom. Benzene is monitored to assess compliance with UK Objectives (between 3.25 μgm^{-3} and 16.25 μgm^{-3} depending on area and compliance date, expressed as a running annual mean), as well as with the corresponding EC Air Quality Directive Limit Value (5 μgm^{-3} annual average).

Until 2007, 1,3-butadiene was also monitored at nine of these locations, in order to assess compliance with the UK Air Quality Strategy Objective (2.25 $\mu g\ m^{-3}$ expressed as a running annual mean). However, the network was reviewed in 2007, and in view of the fact that:

- 1,3-butadiene levels at all the sites were well below the Objective and
- levels at half of the sites were at or below the detection limit for the method used

- Defra took the decision to discontinue monitoring 1,3-butadiene.

As the Objectives and Limit Values for benzene relate to the annual average concentration, it is not necessary to use a monitoring method with short time resolution. Sampling is therefore undertaken using pumped samplers, with sampling period of two weeks. Ambient air is pumped through sampling tubes containing a proprietary absorbent (Carbopack X), using purpose-built pump units that switch between two tubes to produce two nominally identical samples covering each fortnight. Every fortnight, the tubes are changed, and the instruments checked by Local Site Operators, who send the exposed tubes to the network management unit for analysis.

The fortnightly pumped measurement method for benzene was developed specifically for this network; this following the requirement of the 2nd Daughter Directive that, in view of their inherently lower measurement uncertainty, measurements for reporting purposes be made by pumped sampling rather than by diffusive sampling. Previously, pumped sampling for benzene had been geared to short periods of a day or less. The combination of a suitable sorbent material and sound engineering in the pump control box has led to a very successful method.

The EU instructs CEN, the European Committee for Standardisation, to set out standard methods to be used to comply with Directives. The relevant CEN benzene standards (EN 14662, five parts) include the pumped method used in this network.

In anticipation of the siting requirements in the new Air Quality Directive, some site locations in the Network were changed during a process that started in 2007 and was completed in 2008. These changes involved the closure of 10 existing sites and the opening of 11 new non-automatic benzene monitoring sites. The changes, and site locations, are shown in Table 3.7 and Figure 3.9 of the main report.

A3.4 The PAH and TOMPs Networks

(Networks managed and operated for Defra and the DAs by AEA and Lancaster University respectively since April 2004)

i) PAH

Polycyclic aromatic hydrocarbons (PAH) are a group of persistent organic compounds, some of which are toxic and/or human carcinogens; they are produced through industrial and combustion processes. There are three major policy drivers and data uses for this programme:

- The UK Air Quality Objective for PAH. This is based on the recommendations of the Expert Panel on Air Quality Standards (EPAQS), and sets an annual air quality standard of 0.25 ngm^{-3} benzo[a]pyrene to be achieved by 2010.
- The European Community's fourth Air Quality Daughter Directive (2005/107/EC), which includes a target value of 1 ngm^{-3} for the annual mean concentration of benzo[a]pyrene as a representative PAH, to be achieved by 2012.
- The UK's decision to sign, and ratify, the UNECE protocol on Persistent Organic Pollutants (POPs), which includes PAH. Under the protocol, there is a requirement for signatories to control emissions of PAH to measure and assess the long-range transport of four specified PAH.

All these policy imperatives require sound data on ambient concentrations and trends of PAH in the environment.

There were major changes to the PAH Network during 2007 and 2009, aimed at bringing the Network into compliance with the requirements of the 4th Air Quality Daughter Directive: this specifies that the particulate size fraction collected should be PM_{10}, and that each sample be taken over a maximum period of 24 hours. A number of new sites also came into operation.

The network formerly comprised 18 monitoring sites, all of which used the modified Anderson GPS-1 pesticide sampler, which captures both gas and particle-phase PAH on glass fibre and polyurethane filters over a 14 day sample period. This instrument has been deployed at the original 18 UK network locations since they commenced operation in 1991.

During 2007, the number of monitoring sites was increased to 32, in response to the monitoring requirements of 4th Air Quality Daughter Directive. Also, from the beginning of 2008, the old Andersen samplers were phased out and replaced with Digitel DAH-80 high volume aerosol samplers. These new samplers are compliant with European standard method EN 15549 in that they produce daily samples, based on collection of the PM_{10} size fraction. Thirty of the monitoring sites sample particle-phase PAH only, onto glass fibre filters, while two sites include an additional modified DAH-80 high volume sampler; this captures both gas and particle-phase PAH on glass fibre and polyurethane foam pads. These two sites have also had deposition samplers deployed at the sites during 2008.

Some samples from the TOMPS monitoring network (discussed below) were also analysed for PAH under the PAH programme. (The TOMPS network uses the sampler that the PAH network had used in previous years at most sites; the modified Andersen GPS-1 Pesticide sampler.)

Extraction of the filter and, where relevant, foam media and subsequent analysis by gas chromatography/mass spectroscopy (GC/MS) provides data on 39 PAH species. However, for the filter-only method, the results are only a representation of the PAH retained by the filter. For some of the more volatile PAH compounds, this represents only a small fraction of the total.

The deposition method measures the same suite of compounds, but is subject to a high degree of uncertainty.

ii) TOMPs

Toxic Organic Micropollutants (TOMPs) include Polychlorinated Dibenzo-p-Dioxins, Polychlorinated Dibenzofurans (PCDD/Fs), PAH as above, and Polychlorinated Biphenyls (PCBs). PCDD/Fs and PAH are formed as unwanted by-products during various industrial, chemical and combustion processes. PCBs were previously manufactured for use in a wide range of electrical and other products until 1986. These highly toxic and persistent species are ubiquitous in the environment, but are normally present at extremely low concentrations, the atmosphere being the principal route for their redistribution in the environment.

The TOMPs network provides data to inform the public of air quality, and information to support the development of policy to protect the environment. The specific aims of the TOMPs programme are:

- To identify sources of TOMPs in the UK's atmosphere.
- To quantify sources that are regarded as potentially significant.
- To measure concentrations of TOMPs in ambient air in UK cities and rural locations
- in order to assess both human exposure and the relationship between source emissions and levels in the ambient atmosphere.
- The UK's decision to ratify the UNECE protocol on Persistent Organic Pollutants (POPs), which includes PCDD/Fs, PCBs and PAH. Under the protocol, there is a requirement for signatories to control and assess the long-range transport of these compounds.
- The network is also used to investigate the behaviour of newly identified persistent organic pollutants such as brominated flame retardants and other industrial chemicals.

There were six sites in the TOMPs network during 2008: London Nobel House, Manchester and Middlesbrough (all urban sites), together with Hazelrigg, High Muffles and Stoke Ferry (all rural sites). The Stoke Ferry sampler ceased operation at the end of 2007 and was relocated at the Weybourne Observatory site (operated by the University of East Anglia) on the North Norfolk coast. The Middlesbrough sampler ceased operation in 2008 and was relocated to Auchencorth, near Edinburgh (operated by Centre for Ecology and Hydrology).

The TOMPs network samples are analysed for PCDD/Fs and PCBs. Portions from the extracts of samples are also analysed for PAH as part of the PAH network. The sampling method is based around the use of a modified Andersen GPS-1 sampler, with subsequent chemical analysis requiring the use of a range of sophisticated chemical analysis techniques. These
include:

- Gas chromatography, coupled with high-resolution mass spectrometry for the PCDD/Fs and for those PCBs with dioxin-like effects.
- Low-resolution mass spectrometry for the other PCBs.

A 3.5 UK Heavy Metals Monitoring Networks

(i) UK urban/industrial network (previously the Lead, Multi-element and Industrial Metals Networks)

(Network managed and operated for Defra and the DAs by the National Physical Laboratory)

This network monitors a range of metallic elements at urban and industrial sites. At the end of 2008, it comprised 24 sites, all of which monitored As, Cd, Cr, Cu, Fe, Hg, Mn, Ni, Pb, Pt, V and Zn. Additionally, measurements of ambient vapour phase mercury concentrations are made at 13 sites.

Historically, this network grew out of several separate long-term monitoring programmes, funded by the UK Government and latterly responding to specific needs of EC Directives in relation to toxic and industrial metals.

The network originally included:

- Five urban multi-element monitoring sites providing measurements of 9 important trace elements (Cd, Cr, Cu, Fe, Mn, Ni, Pb, Zn and V)
- Eight sites for the monitoring of ambient lead resulting from lead in petrol (2 rural, 3 urban and 3 kerbside).
- Eight sites operating in three industrial areas monitoring lead - Walsall (IMI and Brookside works) and Newcastle (Elswick works).
- A short-term survey 2000-2001 at 30 industrial site locations across the UK in order to establish the UK's position with respect to the requirements of the 4th Daughter Directive which was then being drafted. Five of these sites continued in operation.

The disparate nature of the historic monitoring networks from which this network was formed resulted in differences in methods and practices, as well as in the range of metals monitored. So, in 2003, all monitoring was rationalised into a single integrated network (with the exception of the Rural Trace Element sites), referred to as the UK Heavy Metals Monitoring Network. In September 2004, the number of elements measured at the old Industrial Metals sites was increased to ensure consistency across the Network.

Sampling is now undertaken for weekly periods at sites, in the PM_{10} fraction of particulates using R&P Partisol 2000 samplers. Analysis of samples occurs with UKAS-accredited ICP-MS analysis, with acid digest techniques, in accordance with European Standard EN 14902:2005. Consistency in approach has been achieved with historical data collection and analyses through thorough equivalence exercises.

The UK Urban Industrial Metals Network now forms the basis of the UK's compliance monitoring for:

- The First Daughter Directive (99/30/EC) which set a Limit Value for lead in air concentrations of 0.5 μgm^{-3}, expressed as an annual mean to be achieved by 1st January 2005. This limit has been incorporated into the new Directive on ambient air quality and cleaner air for Europe (Directive 2008/50/EC, 21st May 2008, Q2)
- The 4th Daughter Directive (2004/107/EC), which sets 'target values' for arsenic, cadmium, nickel (and polycyclic aromatic hydrocarbons) in the PM_{10} particulate fraction of ambient air. The 4th Daughter Directive also requires monitoring of mercury although no limit or target values are set. This Daughter Directive remains in force: it is envisaged that it will be incorporated into the new Directive 2008/50/EC at some stage in the future.

The agreement reached between the European Parliament and the Environment Council on the Directive on the Quality of Petrol and Diesel Fuels led to the ban of sales of leaded

petrol in the UK with effect from 1st January 2000. This has, in turn, led to a dramatic decline in ambient lead levels in many UK environments, which was monitored by this Network and is discussed in greater detail in Section 6 of the main report.

During 2007, as part of Defra's review of the network to ensure it continued to meet compliance monitoring requirements, four of the original "multi-element" sites were closed down (in Newcastle, London Brent, Glasgow and Leeds. Eleven new sites were subsequently established, although these did not begin operation until mid-way through 2008.

The findings of this network and its predecessors are summarized in a recently published paper [Q2]

(ii) The Rural Heavy Metals and Mercury Network

(Network managed and operated for Defra and the DAs by CEH)

In 2003-4, the Rural Trace Element Monitoring Network was established as 10 primary sites across the UK. The PM_{10} fraction of particulates is collected weekly using Partisol 2025 sequential samplers, together with weekly or 4-weekly collections of precipitation. In addition, a further three secondary sites collect precipitation samples only and two additional high elevation sites collect precipitation and cloud water samples.

Concentrations of As, Cd, Cr, Cu, Ni, Pb, Se, V, Zn, Al, Sc, Ti, Mn, Fe, Co, Rb, Sr, Mo, Sn, Sb, Ba and W in particulates, precipitation and cloud water are determined by accredited ICP-MS analysis at CEH Lancaster.

Elemental mercury (Hg_0) makes up over 97% of the total atmospheric mercury burden. The remaining amount consists of reactive gaseous mercury (RGM) and particulate mercury (Hg_P). Speciated measurements of mercury are made at the Auchencorth Site using a state-of-the-art Tekran mercury speciation system, which measures RGM, Hg_0 and Hg_P.

As concentrations of these species are so low (of the order of pgm^{-3} for RGM and Hg_0), very sensitive analytical equipment is required. The detector in the Tekran 2537A analyser employs Cold Vapour Atomic Fluorescence Spectroscopy (CVAFS). Elemental mercury is sampled and analysed for one hour, whilst RGM and Hg_P are collected on a potassium chloride (KCl) coated denuder and particulate trap, respectively. During the following hour, the collected RGM and Hg_P are desorbed and analysed. Using this method, Hg_0 is analysed with a temporal resolution of 5 minutes every other hour and hourly averages of RGM and Hg_P concentrations are obtained every other hour.

At the 10 primary sites, newly designed samplers have also been set up to collect Total Gaseous Mercury (TGM) in air (2-weekly) and mercury in precipitation (Monthly). Analysis of Total Gaseous Mercury is based on the system of Two-Stage Gold Amalgamation. Mercury is adsorbed onto gold-coated sand contained within a quartz cartridge and is desorbed by heating the cartridge to 500°C to release the trapped mercury. Desorption is carried out using a custom-built unit that interfaces with a Tekran 2537A analyser, used in off-line mode. Two sampling cartridges are used in series to detect any breakthrough of mercury from the first cartridge, which can be analysed if the capture efficiency of the first cartridge has been reduced. Mercury in precipitation is analysed using a Cold Vapour Atomic Fluorescence Spectrometer (PSA Ltd) with an analytical detection limit of 0.8ng l^{-1} (99% confidence, Controlled Reference Material NRCC-ORMS-2.)

A 3.6 The National Ammonia and Nitric Acid Monitoring Networks

(Managed and operated for Defra and the DAs by CEH - Centre for Ecology and Hydrology)

i) The NAMN

Ammonia (NH_3) emissions are estimated to have at least doubled over the last century across Europe. This rise has been primarily due to the intensification of agriculture, together with the increased use of nitrogen-based fertilizers. The main source of ammonia emissions to the atmosphere is agriculture, which accounts for more than 80% of total anthropogenic ammonia emissions to the atmosphere in the UK. Other sources include direct volatilisation from synthetic fertilizers (particularly urea), and a wide range of non-agricultural sources such as sewage, catalytic converters, wild animals and industrial processes.

Emission and deposition of NH_3 (and NH_4^+) can contribute significantly to total nitrogen deposition to the environment, contributing to eutrophication and acidification of land and freshwaters, leading to a reduction in both soil and water quality, loss of biodiversity and ecosystem change. Ammonia is also the major precursor for neutralization of atmospheric acids, affecting the long-range transport distance of both SO_2 and NO_x and leading to the formation of secondary particles (primarily ammonium sulphates and ammonium nitrate). These particles have multiple impacts including effects on atmospheric visibility, radiative scattering (and the greenhouse effect) and on human health.

Under the UNECE Gothenburg Protocol and the National Emissions Ceilings Directive of the EU, the target of both these agreements is that NH_3 emissions should not exceed 297 kt as NH_3 by 2010, with a particular focus on reducing the extent of critical loads exceedence for acidification and eutrophication effects. Abatement of NH_3 emissions is also included in EU Integrated Pollution Prevention and Control (IPPC) for the intensive pig and poultry sectors. In 2007, new "Critical Levels" (CL) of NH_3 concentrations for the protection of vegetation and ecosystem were adopted, of 1 µg NH_3 m^{-3} and 3 µg NH_3 m^{-3} annual mean for the protection of mosses and vegetation, respectively (UNECE 2007), which replaced the previous CL value of 8 µg NH_3 m^{-3} (annual mean).

In the UK, the Defra-funded National Ammonia Monitoring Network (NAMN: http://www.uk-pollutantdeposition.ceh.ac.uk/networks) was established in 1996 to quantify temporal and spatial changes in air concentrations and deposition in gaseous NH_3 and aerosol NH_4^+ (included since 1999) on a long-term basis. The monitoring provides a baseline in reduced nitrogen (NH_x) species, which is necessary for examining responses to changes in the agricultural sector and to verify compliance with targets set by international agreements. Data from the network are also used to test the performance of an atmospheric chemistry and transport model (FRAME) that was developed at the same time with a special focus on NH_x, and to contribute to national Nitrogen (N) deposition estimates.

There are currently 95 sites in the NAMN (Figure 3.8); the high spatial variability of ammonia concentrations demonstrates that this large number of sites is necessary. At 59 of these sites, where power is available, an established DEnuder for Long-Term Atmospheric (DELTA) system is used to provide the main spatial and temporal patterns of NH_3 across the UK. Aerosol NH_4^+, a secondary product is spatially more even and is monitored at a subset of DELTA sites (currently 46).

The DELTA network is complemented by the implementation of a high sensitivity passive diffusion sampler, the ALPHA (Adapted Low-cost Passive High-Absorption) sampler at a further 48 sites to assess regional and local scale variability in air NH_3 concentrations in

source regions. In the first phase of the network, the Gradko 3.5 cm membrane diffusion tube was used, but, owing to limitations in the sensitivity of the method (Limit of Detection approximately 1-2 μgm^{-3} NH_3), this was replaced by the new ALPHA sampler in the second phase of the network (since 2000). The ALPHA sampler was designed and developed specifically for monitoring ambient concentrations of NH_3, with a detection limit of around 0.02 μgm^{-3} NH_3. To provide an ongoing validation of the ALPHA sampler, its performance is continuously assessed against the DELTA system at 12 sites within the network.

The DELTA system used in the NAMN also provides a foundation for monitoring of other atmospheric components at a subset of sites, including monthly measurements of gaseous HNO_3, SO_2, HCl and aerosol NO_3^-, SO_4^{2-}, Cl^-, plus base cations Na^+, Ca^{2+} and Mg^{2+}, as part of the UK Nitric Acid Monitoring Network.

Overall, the UK NAMN structure currently consists of the following sites:

Site type	Number
DELTA sites sampling gaseous NH_3	59
DELTA sites also sampling aerosol NH_4^+	46
DELTA sites also sampling gaseous HNO_3, SO_2, HCl and aerosol NO_3^-, SO_4^{2-}, Cl^-, K^+, Ca^{2+}, Mg^{2+} as part of the Nitric Acid Monitoring Network	30
ALPHA sites	48
Intercomparison sites with both DELTA & ALPHA samplers	12
Total number of sites	95

ii) The UK Nitric Acid Monitoring Network

The UK Nitric Acid Monitoring Network has been in operation since September 1999, providing data on nitric acid, particulate nitrate and other species as part of the UK Acid Deposition Monitoring Network.

In the first phase of the network, monitoring was implemented at 12 sites using the CEH DELTA system, in an integrated fashion with the UK National Ammonia Monitoring Network (NAMN). An extension of the DELTA system at the NAMN sites was used to additionally sample gaseous HNO_3, SO_2, HCl and particulate NO_3^-, SO_4^{2-}, Cl^-, Na^+, Ca^{2+}, Mg^{2+}, in parallel with monthly sampling of NH_3 and NH_4^+ at the NAMN sites.

To improve on the national spatial coverage, the network was increased from 12 to 30 sites in the second phase of the network, starting January 2006 (Figure 3.8 in main document). The new expanded network also replaced measurements of gaseous SO_2 and particulate SO_4^{2-} previously made under the Rural Sulphur Dioxide Monitoring Programme, which terminated at the end of 2005.

Data from the network are reported on the website http://www.uk-pollutantdeposition.ceh.ac.uk/networks. The aims of the network are to provide a long-term dataset of monthly speciated measurements of acid gases and aerosols that will be used to:

- Provide temporal and spatial patterns and trends, and compare results with dispersion models
- Facilitate Pollution Climate mapping and assessment of Acid Deposition Processes
- Contribute to mass closure from the measurements of several components of particulate matter (NO_3^-, SO_4^{2-}, Cl^-, Na^+, Mg^{2+} and Ca^{2+}) together with NH_4^+ from the closely integrated NAMN), which was one of the recommendations in the Department's Air Quality Expert Group's report on Particulate matter
- Calculate national and regional deposition budgets, especially in upland areas that are sensitive to acid deposition.

A3.7 The UK Black Smoke Network

(Network managed and operated for Defra and the DAs by the National Physical Laboratory)

Black Smoke measurements were some of the earliest systematic measurements of air pollution by particulate matter in the United Kingdom, with records dating back to the 1920s. Air is sampled through a filter and the darkness of the stain, measured by optical reflectance, is converted to a Black Smoke Index, given in units of μgm^{-3}.

For many years, monitoring of Black Smoke was a regulatory requirement in the United Kingdom, and hence there was a large national monitoring network for this parameter. However, in 2005, the relevant EC Directive was repealed, and an independent review of the UK non-automatic urban networks concluded that Black Smoke monitoring should be scaled down to a network of about 20 sites, some of which should be at AURN locations.

The resulting new UK Black Smoke Network, which commenced operation on 1st September 2006, comprised 11 sites from the former Smoke and SO_2 Network sites and 10 new sites at existing AURN monitoring stations. Samplers were installed at the AURN sites between October 2006 and March 2007. The complete range of sites in the network is summarised in Table 3.6 of the main report, with site locations shown in Figure 3.10.

The new Black Smoke network initially used the same technique as its predecessor, based on the standard method BS 1747 Part 11, ISO 9835. However, between October and December 2008, the old apparatus was replaced with an automatic instrument called an aethalometer; this directly measures **black carbon** using a real-time optical transmission technique.

Black smoke measurements ceased at all sites when the aethalometer was installed - except for Edinburgh St Leonard's, Halifax, Birmingham Tyburn, North Kensington and Marylebone Road, where parallel measurements will be made for 12 months to aid the long-term intercomparison of measurements. An aethalometer was not installed into the Norwich site, as it was planned to relocate this in early 2009. Black smoke measurements continued in Norwich to the end of 2008.

The results of the second full year of the new Black Smoke Network's operation are compiled in an annual report by NPL [Q3].

Appendix A4- Analysis of statistically significant trends in UK air pollution levels

Here we summarise those measurement sites with over five years of measurements having statistically significant trends.

A4.1 Sites with significant trends for Benzene, µg m^{-3} / yr

Benzene µg m^{-3} / yr									
Site	Environment	Annual Parameter	Start Year	End Year	Slope	Low Range	High Range	Rho *	No. of years
Harwell	RU	Annual mean	1995	2008	-0.09	-0.14	0.01	-0.95	14
Harwell	RU	98 %ile	1995	2008	-0.3	-0.6	0	-0.91	14
London Eltham	S	Annual mean	1994	2008	-0.28	-0.38	-0.1	-0.92	12
London Eltham	S	98 %ile	1994	2008	-1.3	-1.57	0.23	-0.89	12
London Marylebone Road	KS	Annual mean	1998	2008	-0.73	-3.25	-1.14	-1	11
London Marylebone Road	KS	98 %ile	1998	2008	-2.17	-9.3	-3.32	-1	11

A4.2 Sites with significant trends for 1,3-Butadiene µg m^{-3} / yr

1,3-Butadiene µg m^{-3} / yr									
Site	Environment	Annual Parameter	Start Year	End Year	Slope	Low Range	High Range	Rho *	No. of years
Harwell	RU	Annual mean	1996	2008	-0.01	-0.02	0	-0.89	13
Harwell	RU	98 %ile	1996	2008	-0.05	-0.1	0.1	-0.88	13
London Eltham	S	Annual mean	1994	2008	-0.04	-0.05	-0.01	-0.99	12
London Eltham	S	98 %ile	1994	2008	-0.23	-0.23	0.03	-0.95	12
London Marylebone Road	KS	Annual mean	1998	2008	-0.21	-0.49	-0.2	-0.99	11
London Marylebone Road	KS	98 %ile	1998	2008	-0.55	-2	-0.6	-0.97	11

* *Rho is the Spearman's rank correlation coefficient, a statistical parameter that expresses the correlation between two variables. The relationship between the variables does not have to be linear, and the variables do not have to follow any particular frequency distribution (e.g. normal distribution). The magnitude of rho can be from 0 - 1, and rho can be positive or negative. The closer rho is to 1 (or -1) the more closely the two variables are correlated. If rho = 0 they are not at all correlated. For the more interested reader, further information on the Spearman's rank correlation coefficient can be found on the web-based encyclopaedia "Wikipedia" at:* *http://en.wikipedia.org/wiki/Spearman%27s_rank_correlation_coefficient*

Site Environment Types:

RU- Rural
S- Suburban
KS- Kerbside
RS- Roadside
UC- Urban Centre
UB- Urban Background
UI- Urban Industrial
RE- Remote

A4.3 Sites with significant trends for Carbon Monoxide, mgm^{-3} / yr

Carbon Monoxide mg m^{-3} / yr									
Site	Environment	Annual Parameter	Start Year	End Year	Slope	Low Range	High Range	Rho	No. of years
Bristol Old Market	RS	Annual mean	1997	2008	-0.1	-0.7	-0.2	-0.93	12
Bristol Old Market	RS	98 %ile	1997	2008	-0.4	-2.6	-0.6	-0.94	12
Bury Roadside	RS	Annual mean	1997	2008	0	-0.2	0	-0.65	11
Bury Roadside	RS	98 %ile	1997	2008	-0.2	-0.5	-0.2	-0.92	11
Cardiff Centre	UC	Annual mean	1992	2008	0	-0.1	0.1	-0.9	17
Cardiff Centre	UC	98 %ile	1992	2008	-0.1	-0.7	-0.1	-0.97	17
Glasgow Centre	UC	Annual mean	1997	2008	0	-0.1	0	-0.73	12
Glasgow Centre	UC	98 %ile	1997	2008	-0.1	-0.7	-0.1	-0.87	12
Leeds Centre	UC	Annual mean	1993	2008	0	-0.2	0	-0.85	16
Leeds Centre	UC	98 %ile	1993	2008	-0.1	-0.3	-0.1	-0.89	16
Leicester Centre	UC	Annual mean	1994	2008	-0.1	-0.1	0	-0.79	15
Leicester Centre	UC	98 %ile	1994	2008	-0.1	-0.2	0	-0.97	15
London Bexley	S	Annual mean	1994	2008	0	0	0	-0.83	15
London Bexley	S	98 %ile	1994	2008	-0.1	-0.5	0	-0.9	15
London Bloomsbury	UC	Annual mean	1992	2008	0	-0.2	0	-0.81	17
London Bloomsbury	UC	98 %ile	1992	2008	-0.1	-0.7	0.1	-0.86	17
London Cromwell Road 2	RS	Annual mean	1998	2008	-0.1	-0.1	0	-0.98	11
London Cromwell Road 2	RS	98 %ile	1998	2008	-0.3	-0.4	-0.2	-0.99	11
London Marylebone Road	KS	Annual mean	1998	2008	-0.2	-0.2	0.1	-0.95	11
London Marylebone Road	KS	98 %ile	1998	2008	-0.6	-0.7	0.1	-0.97	11
London N. Kensington	UB	Annual mean	1996	2008	0	-0.1	0.2	-0.59	13
London N. Kensington	UB	98 %ile	1996	2008	-0.1	-0.5	1	-0.94	13
Middlesbrough	UI	Annual mean	1995	2008	0	-0.1	0	-0.67	14
Middlesbrough	UI	98 %ile	1995	2008	0	-0.1	0	-0.8	14
Newcastle Centre	UC	Annual mean	1992	2008	-0.1	-0.1	0	-0.94	17
Newcastle Centre	UC	98 %ile	1992	2008	-0.2	-0.4	-0.1	-0.98	17
Salford Eccles	UI	98 %ile	1998	2008	-0.2	-0.7	0	-0.93	11
Sheffield Centre	UC	Annual mean	1996	2008	0	-0.1	0	-0.86	13
Sheffield Centre	UC	98 %ile	1996	2008	-0.1	-0.3	0.3	-0.96	13
Southampton Centre	UC	Annual mean	1994	2008	-0.1	-0.1	0	-0.92	15
Southampton Centre	UC	98 %ile	1994	2008	-0.2	-0.5	-0.1	-0.97	15
Tower Hamlets Roadside	RS	Annual mean	1996	2008	-0.1	-0.2	0.1	-0.92	13
Tower Hamlets Roadside	RS	98 %ile	1996	2008	-0.4	-0.6	0.5	-0.94	13

A4.4 (i) Sites with significant trends for Nitrogen Dioxide, µg m^{-3} / yr

Nitrogen Dioxide µg m^{-3} / yr									
Site	Environment	Annual Parameter	Start Year	End Year	Slope	Low Range	High Range	Rho	No. of years
Barnsley Gawber	UB	Annual mean	1998	2008	-1.2	-5	-0.7	-0.95	11
Belfast Centre	UC	Annual mean	1992	2008	-0.7	-2	-0.6	-0.75	17
Belfast Centre	UC	98 %ile	1992	2008	-0.6	-10.5	-1.5	-0.5	17
Billingham	UI	Annual mean	1987	2008	-0.6	-2.2	-0.5	-0.84	22
Billingham	UI	98 %ile	1987	2008	-1	-9	-0.7	-0.59	22
Birmingham Centre	UC	Annual mean	1993	2008	-1.3	-3	-0.5	-0.8	16
Birmingham Centre	UC	98 %ile	1993	2008	-2.5	-3.1	6	-0.66	16
Cardiff Centre	UC	Annual mean	1992	2008	-0.9	-4	-0.9	-0.86	17
Cardiff Centre	UC	98 %ile	1992	2008	-1.1	-8	-1	-0.68	17
Exeter Roadside	RS	98 %ile	1997	2008	2.7	-5	2.4	0.67	12
Glasgow Centre	UC	Annual mean	1997	2008	-1	-2.3	1	-0.78	11
Glasgow City Chambers	UB	Annual mean	1987	2008	-0.3	-4	-0.5	-0.66	22
Haringey Roadside	RS	Annual mean	1996	2008	-1.4	-2	2	-0.92	13
Haringey Roadside	RS	98 %ile	1996	2008	-1.6	-14.5	0	-0.67	13
Harwell	RU	Annual mean	1996	2008	-0.9	-2.6	0.6	-0.8	13
Harwell	RU	98 %ile	1996	2008	-1.9	-4.7	8.6	-0.74	13
Ladybower	RU	Annual mean	1991	2008	-0.7	-3.5	-0.7	-0.91	17
Ladybower	RU	98 %ile	1991	2008	-1.5	-3.3	0.4	-0.84	17
Leamington Spa	UB	Annual mean	1997	2008	-0.9	-1.3	1	-0.66	12
Leamington Spa	UB	98 %ile	1997	2008	-1.1	-3	1.7	-0.58	12
Leeds Centre	UC	Annual mean	1993	2008	-1.5	-1.9	4	-0.82	16
Leeds Centre	UC	98 %ile	1993	2008	-1.6	-2	11	-0.64	16
Leicester Centre	UC	Annual mean	1994	2008	-1	-1.5	2	-0.91	15
Leicester Centre	UC	98 %ile	1994	2008	-1.3	-2.3	2	-0.6	15
London Bexley	S	Annual mean	1994	2008	-0.5	-1.5	0	-0.76	15
London Bloomsbury	UC	Annual mean	1992	2008	-1.2	-1.7	0.8	-0.7	16
London Bloomsbury	UC	98 %ile	1992	2008	-3.2	-18	1	-0.68	16
London Eltham	S	Annual mean	1996	2008	-0.7	-2	2	-0.78	13
London Marylebone Road	KS	Annual mean	1998	2008	3	-3	3	0.75	11
London Marylebone Road	KS	98 %ile	1998	2008	9.2	-7.5	10.4	0.71	11
London N. Kensington	UB	Annual mean	1996	2008	-0.9	-1	6	-0.84	13
London Teddington	UB	Annual mean	1997	2008	-0.9	-3.5	-0.7	-0.73	12
Lullington Heath	RU	Annual mean	1991	2008	-0.4	-1.5	0.9	-0.89	18
Lullington Heath	RU	98 %ile	1991	2008	-1.7	-4.2	-0.4	-0.9	18
Middlesbrough	UI	Annual mean	1995	2008	-0.6	-2	-0.8	-0.86	14
Middlesbrough	UI	98 %ile	1995	2008	-0.6	-3.7	-0.5	-0.69	14
Newcastle Centre	UC	Annual mean	1992	2008	-1.3	-4	3	-0.8	17
Newcastle Centre	UC	98 %ile	1992	2008	-1.7	-10.7	10	-0.7	17
Nottingham Centre	UC	Annual mean	1997	2008	-1.4	-3.5	-1.5	-0.92	12
Oxford Centre Roadside	RS	98 %ile	1998	2008	3.8	2.1	15	0.68	11

A4.4 (ii) Sites with significant trends for Nitrogen Dioxide, µg m^{-3} / yr *(continued.)*

Nitrogen Dioxide µg m^{-3} / yr - *continued*									
Site	**Environment**	**Annual Parameter**	**Start Year**	**End Year**	**Slope**	**Low Range**	**High Range**	**Rho**	**No. of years**
Rochester Stoke	RU	Annual mean	1996	2008	-0.6	-1.5	-0.6	-0.96	13
Rochester Stoke	RU	98 %ile	1996	2008	-1	-1.1	7.7	-0.91	13
Salford Eccles	UI	Annual mean	1997	2008	-0.6	-2	0	-0.8	12
Sandwell West Bromwich	UB	Annual mean	1999	2008	-1.6	-3	1	-0.66	10
Sheffield Centre	UC	Annual mean	1996	2008	-0.7	-4	0	-0.76	13
Sheffield Centre	UC	98 %ile	1996	2008	-1.4	-5.3	8	-0.65	13
Southampton Centre	UC	Annual mean	1994	2008	-1.1	-1.8	1	-0.85	15
Southampton Centre	UC	98 %ile	1994	2008	-2.4	-3.8	2	-0.68	15
Thurrock	UB	Annual mean	1997	2008	-0.3	-1	1	-0.58	12
Wicken Fen	RU	Annual mean	1998	2008	-0.6	-0.8	0.7	-0.84	11

A4.5(i) Sites with significant trends for Oxides of Nitrogen (NO_x), µg m^{-3} / yr

Oxides of Nitrogen µg m^{-3} / yr									
Site	Environment	Annual Parameter	Start Year	End Year	Slope	Low Range	High Range	Rho	No. of years
Barnsley Gawber	UB	Annual mean	1998	2008	-2.8	-25	-4.1	-0.86	11
Bath Roadside	RS	Annual mean	1997	2008	-4.7	-22.3	-7.9	-0.64	12
Belfast Centre	UC	Annual mean	1992	2008	-1.9	-6.5	-1.9	-0.74	17
Belfast Centre	UC	98 %ile	1992	2008	-7.5	-68	-6.8	-0.51	17
Billingham	UI	Annual mean	1987	2008	-1.8	-15	-1.8	-0.92	22
Billingham	UI	98 %ile	1987	2008	-5.4	-105	-6.4	-0.84	22
Birmingham Centre	UC	Annual mean	1993	2008	-3.4	-6	-2.6	-0.91	16
Birmingham Centre	UC	98 %ile	1993	2008	-11.5	-21.3	23	-0.72	16
Brighton Roadside	RS	Annual mean	1998	2008	-3	-11.3	-4.8	-0.93	10
Bristol Old Market	RS	Annual mean	1997	2008	-7	-111	-15.9	-0.76	11
Bristol Old Market	RS	98 %ile	1997	2008	-23.1	-315	-54.9	-0.84	11
Bury Roadside	RS	Annual mean	1997	2008	-13.6	-55	-16.8	-0.96	12
Bury Roadside	RS	98 %ile	1997	2008	-34.3	-102	-25	-0.94	12
Camden Kerbside	KS	Annual mean	1996	2008	-7.8	-24.3	-4	-0.96	10
Camden Kerbside	KS	98 %ile	1996	2008	-21	-57.5	124	-0.85	10
Cardiff Centre	UC	Annual mean	1992	2008	-2.8	-19	-3.5	-0.89	17
Cardiff Centre	UC	98 %ile	1992	2008	-13.2	-80	-13.7	-0.87	17
Glasgow Centre	UC	Annual mean	1997	2008	-2.7	-15	-2.7	-0.85	11
Glasgow City Chambers	UB	Annual mean	1987	2008	-4.7	-5.4	1.8	-0.91	22
Glasgow City Chambers	UB	98 %ile	1987	2008	-21.4	-138	43	-0.89	22
Glasgow Kerbside	KS	98 %ile	1997	2008	-17.8	-70.7	-8.3	-0.66	12
Haringey Roadside	RS	Annual mean	1996	2008	-7.3	-12.5	20	-0.98	13
Haringey Roadside	RS	98 %ile	1996	2008	-23.6	-48.3	251	-0.87	13
Harwell	RU	Annual mean	1996	2008	-1.4	-3.9	2.2	-0.74	13
Harwell	RU	98 %ile	1996	2008	-5.4	-18.2	23.9	-0.62	13
Ladybower	RU	Annual mean	1991	2008	-0.8	-5.1	1	-0.9	17
Ladybower	RU	98 %ile	1991	2008	-3.2	-19.3	5.9	-0.86	17
Leamington Spa	UB	Annual mean	1997	2008	-1.2	-7	0.7	-0.63	12
Leeds Centre	UC	Annual mean	1993	2008	-5.4	-7.7	6	-0.91	16
Leeds Centre	UC	98 %ile	1993	2008	-15.5	-31.4	36	-0.79	16
Leicester Centre	UC	Annual mean	1994	2008	-2.1	-3.8	1	-0.93	15
Leicester Centre	UC	98 %ile	1994	2008	-8.9	-20.1	8.7	-0.65	15
London Bexley	S	Annual mean	1994	2008	-2.4	-9	-0.3	-0.82	15
London Bexley	S	98 %ile	1994	2008	-9.1	-82	21	-0.55	15
London Bloomsbury	UC	Annual mean	1992	2008	-4.5	-12	2.4	-0.83	17
London Bloomsbury	UC	98 %ile	1992	2008	-15.3	-88	10.2	-0.81	17
London Cromwell Road 2	RS	Annual mean	1998	2008	-8	-11	21	-0.94	11
London Cromwell Road 2	RS	98 %ile	1998	2008	-18.8	-40.8	5	-0.89	11
London Eltham	S	Annual mean	1996	2008	-2.6	-8.5	6	-0.86	13
London Eltham	S	98 %ile	1996	2008	-13.9	-46	85	-0.72	13
London Hillingdon	S	Annual mean	1997	2008	-5.7	-28	-8.9	-0.91	11
London Hillingdon	S	98 %ile	1997	2008	-24.3	-187	-38.9	-0.66	11

A4.5 (ii) Sites with significant trends for Oxides of Nitrogen (NOx), µg m^{-3} / yr (*continued*)

Oxides of Nitrogen µg m^{-3} / yr - *continued*									
Site	**Environment**	**Annual Parameter**	**Start Year**	**End Year**	**Slope**	**Low Range**	**High Range**	**Rho**	**No. of years**
London Marylebone Road	KS	Annual mean	1998	2008	-10.8	-18.5	20.5	-0.75	11
London Marylebone Road	KS	98 %ile	1998	2008	-17.8	-49.5	54	-0.65	11
London N. Kensington	UB	Annual mean	1996	2008	-2.5	-4.5	20	-0.92	13
London N. Kensington	UB	98 %ile	1996	2008	-11.6	-58	211	-0.68	13
London Teddington	UB	Annual mean	1997	2008	-1.2	-19.5	-2.2	-0.71	12
Lullington Heath	RU	Annual mean	1991	2008	-0.4	-1	0.8	-0.87	18
Lullington Heath	RU	98 %ile	1991	2008	-2.4	-4.9	1.8	-0.84	18
Manchester Piccadilly	UC	Annual mean	1996	2008	-1.8	-13	-1.2	-0.58	12
Middlesbrough	UI	Annual mean	1995	2008	-1.6	-4	0.5	-0.84	14
Middlesbrough	UI	98 %ile	1995	2008	-1.9	-19.6	10.5	-0.64	14
Newcastle Centre	UC	Annual mean	1992	2008	-4.6	-12.7	15	-0.9	17
Newcastle Centre	UC	98 %ile	1992	2008	-20.4	-59.3	76	-0.86	17
Nottingham Centre	UC	Annual mean	1997	2008	-2.7	-7.7	-2	-0.93	12
Rochester Stoke	RU	Annual mean	1996	2008	-0.7	-2.6	0.2	-0.87	13
Rochester Stoke	RU	98 %ile	1996	2008	-3.8	-10.8	24.9	-0.65	13
Salford Eccles	UI	Annual mean	1997	2008	-2.9	-8.7	-1.8	-0.89	12
Salford Eccles	UI	98 %ile	1997	2008	-9.6	-50	4.8	-0.71	12
Sandwell West Bromwich	UB	Annual mean	1999	2008	-3	-4	3	-0.69	10
Sheffield Centre	UC	Annual mean	1996	2008	-3.9	-13	7	-0.84	13
Sheffield Centre	UC	98 %ile	1996	2008	-16	-40.7	67	-0.73	13
Southampton Centre	UC	Annual mean	1994	2008	-4.4	-6.8	-1	-0.94	15
Southampton Centre	UC	98 %ile	1994	2008	-15.1	-48	3.7	-0.85	15
Stoke-on-Trent Centre	UC	Annual mean	1998	2008	-1.3	-2.8	5	-0.71	11
Thurrock	UB	Annual mean	1997	2008	-1.5	-5	1	-0.85	12
Tower Hamlets Roadside	RS	Annual mean	1996	2008	-14.1	-32.5	-12.6	-0.95	13
Tower Hamlets Roadside	RS	98 %ile	1996	2008	-36.6	-84	100	-0.88	13
Walsall Willenhall	S	Annual mean	1998	2008	-1.5	-6.5	-0.4	-0.61	11
Wicken Fen	RU	Annual mean	1998	2008	-0.7	-1.1	0.8	-0.79	11

A4.6 Sites with significant trends for PM_{10} Particulate Matter, µg m^{-3} / yr

PM_{10} Particulate Matter µg m^{-3} / yr									
Site	Environment	Annual Parameter	Start Year	End Year	Slope	Low Range	High Range	Rho	No. of years
Belfast Centre	UC	Annual mean	1992	2008	-1.2	-1.3	6	-0.97	17
Belfast Centre	UC	98 %ile	1992	2008	-4	-19.5	-6.1	-0.93	17
Birmingham Centre	UC	Annual mean	1992	2008	-0.7	-2	-0.5	-0.79	17
Birmingham Centre	UC	98 %ile	1992	2008	-2.5	-11	-2.3	-0.68	17
Bury Roadside	RS	Annual mean	1997	2008	-0.6	-5	-0.7	-0.69	12
Cardiff Centre	UC	Annual mean	1993	2008	-0.8	-4	5	-0.8	16
Cardiff Centre	UC	98 %ile	1993	2008	-2.6	-14	83	-0.7	16
Derry	UB	Annual mean	1997	2008	-0.5	-2.7	-0.6	-0.59	12
Derry	UB	98 %ile	1997	2008	-3.9	-5	17	-0.88	12
Glasgow Centre	UC	Annual mean	1997	2008	-0.8	-2	0.3	-0.75	12
Glasgow Centre	UC	98 %ile	1997	2008	-2.3	-4.5	11.7	-0.81	12
Harwell	RU	Annual mean	1998	2008	0.5	-1	0.4	0.74	11
Leeds Centre	UC	Annual mean	1993	2008	-0.9	-2	0.3	-0.66	16
Leeds Centre	UC	98 %ile	1993	2008	-3.1	-6.9	9	-0.71	16
Leicester Centre	UC	Annual mean	1994	2008	-0.1	-2	0	-0.59	15
Leicester Centre	UC	98 %ile	1994	2008	-0.9	-7	5.5	-0.56	15
London Bexley	S	Annual mean	1994	2008	-0.5	-1.8	0	-0.53	15
London Bexley	S	98 %ile	1994	2008	-1.6	-5.5	5.5	-0.75	15
London Bloomsbury	UC	Annual mean	1992	2008	-0.8	-2	0	-0.72	16
London Bloomsbury	UC	98 %ile	1992	2008	-3.3	-9.5	0.3	-0.78	16
London N. Kensington	UB	Annual mean	1996	2008	-0.1	-2	2	-0.67	13
London N. Kensington	UB	98 %ile	1996	2008	-0.9	-3	18	-0.62	13
Manchester Piccadilly	UC	Annual mean	1996	2008	-0.6	-3	1	-0.76	13
Newcastle Centre	UC	Annual mean	1992	2008	-1.4	-2.7	1	-0.89	17
Newcastle Centre	UC	98 %ile	1992	2008	-4	-8.3	1	-0.73	17
Nottingham Centre	UC	Annual mean	1997	2008	-0.5	-2.5	-0.6	-0.8	12
Salford Eccles	UI	Annual mean	1997	2008	-0.3	-3	-0.7	-0.66	12
Sheffield Centre	UC	Annual mean	1996	2008	-0.7	-3.3	-1.1	-0.78	13
Sheffield Centre	UC	98 %ile	1996	2008	-2.2	-23	-3.8	-0.57	13
Southampton Centre	UC	Annual mean	1994	2008	-0.4	-1.2	0.3	-0.76	15
Southampton Centre	UC	98 %ile	1994	2008	-1.3	-5	3.5	-0.76	15
Thurrock	UB	98 %ile	1997	2008	-1.3	-17	0	-0.73	12

A4.7 Sites with significant trends for $PM_{2.5}$ Particulate Matter, $\mu g m^{-3}$ / yr

$PM_{2.5}$ Particulate Matter µg m^{-3} / yr									
Site	Environment	Annual Parameter	Start Year	End Year	Slope	Low Range	High Range	Rho	No. of years
London Marylebone Road	KS	98 %ile	1998	2008	-1.7	-0.8	7	-0.61	11

A 4.8(i) Sites with significant trends for Sulphur Dioxide, µg m^{-3} / yr

Sulphur Dioxide µg m^{-3} / yr									
Site	Environment	Annual Parameter	Start Year	End Year	Slope	Low Range	High Range	Rho	No. of years
Barnsley 12	UB	Annual mean	1994	2008	-1.3	-1.7	5	-0.89	15
Barnsley 12	UB	98 %ile	1994	2008	-5.3	-9	8	-0.85	15
Barnsley Gawber	UB	98 %ile	1998	2008	-3.8	-17	-5.8	-0.84	10
Belfast Centre	UC	Annual mean	1992	2008	-3.3	-3.7	6	-0.97	17
Belfast Centre	UC	98 %ile	1992	2008	-15.8	-16.7	16	-0.99	17
Cardiff Centre	UC	Annual mean	1992	2008	-1.1	-3	-1	-0.96	17
Cardiff Centre	UC	98 %ile	1992	2008	-4.2	-11.5	-3.9	-0.96	17
Derry	UB	Annual mean	1998	2008	-1	-4	-0.5	-0.69	11
Derry	UB	98 %ile	1998	2008	-4.5	-34	-6.1	-0.93	11
Glasgow Centre	UC	Annual mean	1997	2008	-1.3	-1.1	0.5	-0.8	12
Glasgow Centre	UC	98 %ile	1997	2008	-2.8	-13	-2.6	-0.85	12
Harwell	RU	Annual mean	1996	2008	-0.2	-2.8	-0.4	-0.67	13
Harwell	RU	98 %ile	1996	2008	-1.7	-14.9	-2.5	-0.81	13
Ladybower	RU	Annual mean	1989	2008	-1.2	-3.8	2.3	-0.94	20
Ladybower	RU	98 %ile	1989	2008	-5.9	-26.6	14.9	-0.96	20
Leamington Spa	UB	Annual mean	1997	2008	-0.5	-0.7	0	-0.88	12
Leamington Spa	UB	98 %ile	1997	2008	-2	-4	5	-0.94	12
Leeds Centre	UC	Annual mean	1993	2008	-1.4	-3.7	-1.7	-0.98	16
Leeds Centre	UC	98 %ile	1993	2008	-6.6	-18.7	2	-0.95	16
Leicester Centre	UC	Annual mean	1994	2008	-1	-3.5	-1.2	-0.98	15
Leicester Centre	UC	98 %ile	1994	2008	-4.6	-10.5	-2	-0.96	15
London Bexley	S	Annual mean	1994	2008	-1.1	-2.8	1	-0.91	15
London Bexley	S	98 %ile	1994	2008	-7	-14.5	13	-0.89	15
London Bloomsbury	UC	Annual mean	1992	2008	-1.9	-2.3	1	-0.97	17
London Bloomsbury	UC	98 %ile	1992	2008	-9.3	-10.6	0	-0.98	17
London Cromwell Road 2	RS	Annual mean	1998	2008	-0.7	-3	-1	-0.94	11
London Cromwell Road 2	RS	98 %ile	1998	2008	-2.2	-8	-2.4	-0.87	11
London Marylebone Road	KS	Annual mean	1998	2008	-1	-5	-1.1	-0.93	11
London Marylebone Road	KS	98 %ile	1998	2008	-2.2	-14	-3	-0.96	11
London N. Kensington	UB	Annual mean	1996	2008	-0.6	-2	0	-0.92	13
London N. Kensington	UB	98 %ile	1996	2008	-2.9	-8.7	8	-0.94	13
Manchester Piccadilly	UC	Annual mean	1996	2008	-0.9	-3	-0.5	-0.79	12
Manchester Piccadilly	UC	98 %ile	1996	2008	-4.7	-19	-6.4	-0.89	12
Middlesbrough	UI	Annual mean	1995	2008	-0.9	-2	-0.9	-0.94	14
Middlesbrough	UI	98 %ile	1995	2008	-3.9	-8.7	-2	-0.94	14
Newcastle Centre	UC	Annual mean	1992	2008	-1.3	-1.3	4	-0.95	17
Newcastle Centre	UC	98 %ile	1992	2008	-7.5	-8.3	8	-0.98	17
Nottingham Centre	UC	Annual mean	1997	2008	-1.1	-2	0.5	-0.72	12
Nottingham Centre	UC	98 %ile	1997	2008	-5.8	-12	-4.3	-0.94	12
Rochester Stoke	RU	Annual mean	1996	2008	-0.4	-2.5	-0.6	-0.93	13
Rochester Stoke	RU	98 %ile	1996	2008	-3	-18.6	-4.7	-0.98	13

A4.8 (ii)Sites with significant trends for Sulphur Dioxide, µg m^{-3} / yr *(continued)*

Sulphur Dioxide µg m^{-3} / yr - *continued*									
Site	Environment	Annual Parameter	Start Year	End Year	Slope	Low Range	High Range	Rho	No. of years
Salford Eccles	UI	98 %ile	1997	2008	-1.9	-14.5	0	-0.59	12
Sandwell West Bromwich	UB	Annual mean	1999	2008	-0.6	-0.8	0.5	-0.85	10
Sandwell West Bromwich	UB	98 %ile	1999	2008	-2.6	-3	3	-0.86	10
Sheffield Centre	UC	Annual mean	1996	2008	-0.7	-5	-1.5	-0.88	13
Sheffield Centre	UC	98 %ile	1996	2008	-6.1	-24	-7.3	-0.93	13
Southampton Centre	UC	Annual mean	1994	2008	-0.5	-1.3	0	-0.93	15
Southampton Centre	UC	98 %ile	1994	2008	-1.8	-6.3	-2.4	-0.89	15
Thurrock	UB	Annual mean	1999	2008	-0.8	-1.3	0	-0.87	10
Thurrock	UB	98 %ile	1999	2008	-4.2	-7	-2	-0.94	10
Wicken Fen	RU	98 %ile	1998	2008	-0.6	-5.6	-1.2	-0.73	11

A4.9 Sites with significant trends for Ozone, µg m^{-3} / yr

Ozone µg m^{-3} / yr									
Site	Environment	Annual Parameter	Start Year	End Year	Slope	Low Range	High Range	Rho	No. of years
Aston Hill	RU	Annual mean	1987	2008	0.5	0.7	12	0.59	22
Belfast Centre	UC	Annual mean	1992	2008	0.4	-3	1.3	0.62	17
Belfast Centre	UC	98 %ile	1992	2008	0.4	-10	1.7	0.63	17
Birmingham Centre	UC	Annual mean	1992	2008	0.8	-1	1.5	0.89	17
Birmingham Centre	UC	98 %ile	1992	2008	0.7	-6	3.5	0.57	17
Bottesford	S	Annual mean	1981	2008	0.6	-0.7	7	0.63	28
Bush Estate	RU	Annual mean	1986	2008	0.3	-7	1	0.68	23
Cardiff Centre	UC	Annual mean	1992	2008	0.8	0.6	2.7	0.88	17
Glasgow Centre	UC	Annual mean	1997	2008	0.4	0.5	4	0.71	12
Glazebury	S	Annual mean	1988	2008	0.6	-5	0.4	0.64	21
Great Dun Fell	RE	98 %ile	1987	2008	-1.4	-12	1.3	-0.62	18
Ladybower	RU	98 %ile	1989	2008	-1.3	-8	2	-0.47	20
Leeds Centre	UC	Annual mean	1993	2008	1	0.3	4	0.87	16
Leeds Centre	UC	98 %ile	1993	2008	1	0.8	7	0.71	16
Leicester Centre	UC	Annual mean	1994	2008	0.6	-0.5	1.8	0.76	15
London Bloomsbury	UC	Annual mean	1992	2008	0.4	-1	1	0.86	17
London Eltham	S	Annual mean	1996	2008	0.4	-3	1	0.74	13
London Haringey	UC	Annual mean	1996	2008	1.1	-1	2	0.89	13
London Hillingdon	S	Annual mean	1997	2008	0.8	0.7	3	0.89	12
London Hillingdon	S	98 %ile	1997	2008	2	-2	5	0.65	12
London Marylebone Road	KS	Annual mean	1998	2008	0.5	0.4	1	0.92	11
London Marylebone Road	KS	98 %ile	1998	2008	1.3	1.7	10	0.82	11
London N. Kensington	UB	Annual mean	1996	2008	0.7	-4	1.7	0.87	13
London Teddington	UB	Annual mean	1997	2008	0.9	0.2	2	0.59	12
Lough Navar	RE	98 %ile	1987	2008	-0.4	-1	4	-0.56	22
Lullington Heath	RU	98 %ile	1987	2008	-1.5	-10	15	-0.46	22
Mace Head	RE	Annual mean	1987	2008	0.4	1	14	0.73	22
Middlesbrough	UI	Annual mean	1996	2008	0.4	-4	2	0.61	13
Newcastle Centre	UC	Annual mean	1992	2008	0.9	0.8	2	0.85	15
Newcastle Centre	UC	98 %ile	1992	2008	1	-4	2.3	0.8	15
Nottingham Centre	UC	Annual mean	1997	2008	1.1	0.5	3.5	0.86	12
Stoke-on-Trent Centre	UC	Annual mean	1997	2008	0.8	-3	1.2	0.6	12
Strath Vaich	RE	Annual mean	1987	2008	0.4	0.2	6	0.54	22
Wicken Fen	RU	Annual mean	1998	2008	1.7	0.5	4	0.84	11

Appendix A5- Listing of current UK, European and WHO air quality criteria

Here we summarise the UK Air Quality Strategy Standards and Objectives, together with corresponding European Community Directive Limit and Target Values and World Health Organisation advisory Guidelines for the major pollutants.

Benzene

Guideline Set By	Description	Criteria Based On	Value[1] μgm^{-3} (ppb)
The Air Quality Strategy[2] All UK England[3] & Wales[4] only: Scotland[5] & Northern Ireland [6]	Objective for Dec. 31st 2003	Running annual mean	16.25 (5)
	Objective for Dec. 31st 2010	Annual mean	5 (1.54)
	Objective for Dec. 31st 2010	Running annual mean	3.25 (1.0)
European Community 2nd Daughter Directive[7] *and* **Directive on Ambient Air Quality and CleanerAir for Europe[,8]**	Limit Value. To be achieved by Jan 1st 2010	Annual calendar year mean	5 (1.5)

(1) Conversions between μg m^{-3} and ppb are those used by the EC, i.e. 1ppb benzene = 3.25 μg m^{-3} at 20°C and 1013 mB.
(2) The Air Quality Strategy for England, Scotland, Wales and Northern Ireland. July 2007, The Stationery Office, ID 5611194 07/07.
(3) Air Quality Regulations 2007 (SI 2007/64)
(4) Air Quality Standards (Wales) Regulations 2007 (Welsh SI 2007 717 (W63))
(5) Air Quality Standards (Scotland) Regulations 2007 (SSI 2007 No. 182)
(6) Air Quality Standards (Northern Ireland) Regulations 2007 (Statutory Rule 2007 No. 265)
(7) Council Directive 2000/69/EC. Transposed into UK Air Quality Regulations by above Statutory Instruments.
(8) Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 On Ambient Air Quality And Cleaner Air For Europe, which supersedes (7).

1,3-Butadiene

Guideline Set By	Description	Criteria Based On	Value[1] / μgm^{-3} (ppb)
The Air Quality Strategy[2,3,4,5,6] All UK	Objective for Dec. 31st 2003	Running annual mean	2.25 (1)

(1) Conversion between μg m^{-3} and ppb is 1 ppb 1,3-butadiene = 2.25 μg m^{-3} at 20°C and 1013 mB.
(2) The Air Quality Strategy for England, Scotland, Wales and Northern Ireland. July 2007, The Stationery Office, ID 5611194 07/07.
(3) Air Quality Regulations 2007 (SI 2007/64)
(4) Air Quality Standards (Wales) Regulations 2007 (Welsh SI 2007 717 (W63))
(5) Air Quality Standards (Scotland) Regulations 2007 (SSI 2007 No. 182)
(6) Air Quality Standards (Northern Ireland) Regulations 2007 (Statutory Rule 2007 No. 265)

Carbon Monoxide

Guideline Set By	Description		Criteria Based On	Value[1] / mg m^{-3} (ppm)
UK Government Air Pollution Index	LOW	1	8-hour mean	0-3.8 (0-3.2)
		2		3.9-7.6 (3.3-6.6)
		3		7.7-11.5 (6.7-9.9)
	MODERATE	4	8-hour mean	11.6-13.4 (10.0-11.5)
		5		13.5-15.4 (11.6-13.2)
		6		15.5-17.3 (13.3-14.9)
	HIGH	7	8-hour mean	17.4-19.2 (15.0-16.5)
		8		19.3-21.2 (16.6-18.2)
		9		21.3-23.1 (18.3-19.9)
	VERY HIGH	10	8-hour mean	≥ 23.2 (≥ 20)
The Air Quality Strategy[2,3,4] (Except Scotland)	Objective for Dec. 31st 2003		Max. Daily Running 8-hour mean	10 (8.6)
Scotland only[5]:	Objective for Dec. 31st 2003		Running 8-hour mean	10 (8.6)
EC 2nd Daughter Directive[6] and Directive on Ambient Air Quality [7]	Limit Value. To be achieved by Jan 1st 2005		Max. daily 8-hour mean	10 (8.6)
World Health Organisation[8] *(Non-Mandatory Guidelines)*	Health Guideline		15-minute mean	100
	Health Guideline		30-minute mean	60
	Health Guideline		1-hour mean	30
	Health Guideline		8-hour mean	10

(1) Conversions between μg m^{-3} and ppb are those used by the EC, i.e. 1ppm CO = 1.16 mg m^{-3} at 20°C and 1013 mB, except where specified.
(2) The Air Quality Strategy for England, Scotland, Wales and Northern Ireland. July 2007, The Stationery Office, ID 5611194 07/07.
(3) Air Quality Regulations 2007 (SI 2007/64)
(4) Air Quality Standards (Northern Ireland) Regulations 2007 (Statutory Rule 2007 No. 265)
(5) Air Quality Standards (Wales) Regulations 2007 (Welsh SI 2007 717 (W63))
(6) Air Quality Standards (Scotland) Regulations 2007 (SSI 2007 No. 182)
(7) Council Directive 2000/69/EC. Transposed into UK Air Quality Regulations by above Statutory Instruments.
(8) Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 On Ambient Air Quality And Cleaner Air For Europe, which supersedes (7).

Nitrogen Dioxide

Guideline Set By	Description		Criteria Based On	Value[1] / μgm^{-3} (ppb)
UK Government Air Pollution Index	LOW	1	1-hour mean	0-95 (0-49)
		2		96-190 (50-99)
		3		191-286 (100-149)
	MODERATE	4	1-hour mean	287-381 (150-199)
		5		382-477 (200-249)
		6		478-572 (250-299)
	HIGH	7	1-hour mean	573-635 (300-332)
		8		636-700 (333-366)
		9		701-763 (367-399)
	VERY HIGH	10	1-hour mean	≥ 764 (≥ 400)
The Air Quality Strategy[2] *Set in regulations[3] for all UK:* *Not intended to be set in regulations:*	Objective for Dec. 31st 2005, for protection of human health		1-hour mean	200 (105) Not to be exceeded more than 18 times per calendar year.
	Objective for Dec. 31st 2005, for protection of human health		Annual mean	40 (21)
	Objective for Dec. 31st 2000, for protection of vegetation.		Annual mean NO_x (NO_x as NO_2)	30 (16)
EC 1985 NO_2 Directive [4] *Limit remains in force until fully repealed 01/01/2010.*	Limit Value		Calendar year of data: 98%ile of hourly means.	200 (105)
1st Daughter Directive[5] and Directive on Ambient Air Quality [6]	Limit Value for protection of human health. To be achieved by Jan. 1st 2010		1-hour mean	200 (105) not to be exceeded more than 18 times per calendar year
	Limit Value for protection of human health. To be achieved by Jan. 1st 2010		Calendar year mean	40 (21)
	Limit Value (total NO_x) for protection of vegetation. To be achieved by Jul. 19th 2001		Calendar year mean	30 (16)
World Health Organisation[7] *(Non-Mandatory)*	Health Guideline		1-hour mean	200
	Health Guideline		Annual mean	40

(1) Conversions between μg m^{-3} and ppb are as used by the EC, i.e. 1ppb NO_2 = 1.91 μg m^{-3} at 20°C and 1013 mB.
(2) The Air Quality Strategy for England, Scotland, Wales and Northern Ireland. July 2007, The Stationery Office, ID 5611194 07/07.
(3) Air Quality Regulations 2007 (SI 2007/64), Air Quality Standards (Wales) Regulations 2007 (Welsh SI 2007 717 (W63)), Air Quality Standards (Scotland) Regulations 2007 (SSI 2007 No. 182), Air Quality Standards (Northern Ireland) Regulations 2007 (Statutory Rule 2007 No. 265)
(4) Council Directive 85/203/EEC.
(5) Council Directive 1999/30/EC. Transposed into UK Air Quality Regulations in England by SI 2001/2315, in Scotland by SSI 2001/224, in Wales by SI 2001/2683 (W224), and by Statutory Rule 2002 (94) in Northern Ireland.
(6) Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 On Ambient Air Quality And Cleaner Air For Europe, which supersedes (5).
(7) WHO Guidelines for Air Quality WHO/SDE/OEH/00.02 (2000).

Particulate Matter as PM_{10}

Guideline Set By	Description		Criteria Based On	Value / μgm^{-3}
UK Government Air Pollution Index (measured by TEOM)	LOW	1	24-hour mean	0-16
		2		17-32
		3		33-49
	MODERATE	4	24-hour mean	50-57
		5		58-66
		6		67-74
	HIGH	7	24-hour mean	75-82
		8		83-91
		9		92-99
	V. HIGH	10	24-hour mean	≥ 100
UK Government Air Pollution Index (measured by reference-equivalent methods)	LOW	1	24-hour mean	0-19
		2		20-40
		3		41-62
	MODERATE	4	24-hour mean	63-72
		5		73-84
		6		85-94
	HIGH	7	24-hour mean	95-105
		8		106-116
		9		117-127
	V. HIGH	10	24-hour mean	≥ 128
The Air Quality Strategy(1) **Set in regulations for all UK(2).**	Objective for Dec. 31st 2004		24-hour mean	50 Not to be exceeded more than 35 times per calendar year.
	Objective for Dec. 31st 2004		Annual mean	40
Set in regulations Scotland only(3)	Objective for Dec. 31st 2010		24-hour mean	50 Not to be exceeded more than 7 times per calendar year.
	Objective for Dec. 31st 2010		Annual mean	18
The Air Quality Strategy(1) *Not set in regulations: London only*	Objective for Dec. 31st 2010		24-hour mean	50 Not to be exceeded more than 10 times per calendar year.
	Objective for Dec. 31st 2010		Annual mean	23
1ST Daughter Directive (3) **Directive on Ambient Air Quality and Cleaner Air for Europe (5)**	Limit Value to be achieved by Jan 1st 2005		24-hour mean	50 Not to be exceeded more than 35 times per calendar year.
	Limit Value to be achieved by Jan 1st 2005		Annual mean	40

(1) The Air Quality Strategy for England, Scotland, Wales and Northern Ireland. July 2007, The Stationery Office, ID 5611194 07/07.
(2) Air Quality Regulations 2007 (SI 2007/64), Air Quality Standards (Wales) Regulations 2007 (Welsh SI 2007 717 (W63)), Air Quality Standards (Scotland) Regulations 2007 (SSI 2007 No. 182), Air Quality Standards (Northern Ireland) Regulations 2007 (Statutory Rule 2007 No. 265)
(3) Air Quality Standards (Scotland) Regulations 2007 (SSI 2007 No. 182)
(4) Council Directive 1999/30/EC. Transposed into UK Air Quality Regulations by above Statutory Instruments.
(5) Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 On Ambient Air Quality And Cleaner Air For Europe, which supersedes (4).

Particulate Matter as $PM_{2.5}$

Guideline Set By	Description	Criteria Based On	Value / μgm^{-3}
The Air Quality Strategy(1) **Set in regulations for all UK.**	Objective for 2020, all UK except Scotland	Annual mean	25
	Objective for 2020, Scotland only	Annual mean	12
	Exposure reduction target, urban background areas	Annual mean	20% reduction in annual mean concentration between 2010 and 2020.
Directive on Ambient Air Quality and Cleaner Air for Europe (2)	Exposure reduction target (3), urban background areas Initial baseline (2008-2010) concentration μgm^{-3} *0-8.5* *>8.5- <13* *= 13 - <18* *= 18 - < 22* *> 22*	Average Exposure Indicator (AEI): 3-year running Annual mean.	% reduction between 2010 and 2020 *0%* *10%* *15%* *20%* *-all appropriate measures to achieve 18 μgm^{-3}.*
	Exposure concentration obligation, to be met by 2015	Annual mean	20
	Target Value (to be achieved by 1 Jan 2010)	Annual mean	25
	Limit Values Stage 1 (by 1 Jan 2015) Stage 2 (by 1 Jan 2020 – to be reviewed in 2013)	Annual mean	 25 20

(1) The Air Quality Strategy for England, Scotland, Wales and Northern Ireland. July 2007, The Stationery Office, ID 5611194 07/07.$PM_{2.5}$ not under regulation at this time.
(2) Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 On Ambient Air Quality And Cleaner Air For Europe.
(3) The exposure reduction target is based on reduction of an Average Exposure Indicator (AEI) between 2010 and 2020. The AEI for the baseline year 2010 is the 3-year running annual mean concentration for years 2008, 2009 and 2010. The AEI for 2020 is the 3-year running annual mean based on 2018, 2019 and 2020. If the AEI reaches 8.5 μgm^{-3} before 2020, and is maintained at or below this level, no further reduction is required.

Polycyclic Aromatic Hydrocarbons (PAH)

Guideline Set By	Description	Criteria Based On	Value / ngm^{-3}
The Air Quality Strategy(1) England, Wales, Scotland and Northern Ireland. *Not set in regulations.*	Objective for Dec. 31st 2010	Annual mean *(using B(a)P as an indicator)*	0.25
European Community 4th Daughter Directive	Target value	Total content in the PM_{10} fraction averaged over a calendar year.	1.0
World Health Organisation(3) *(Non-Mandatory Guidelines)*	- (No guideline, as there is no "safe" threshold for this pollutant)	Concentration of BaP producing excess lifetime cancer risk of 1/10,000	1.2

(1) The Air Quality Strategy for England, Scotland, Wales and Northern Ireland. July 2007, The Stationery Office, ID 5611194 07/07.
(2) 4th Daughter Directive (Directive 2004/107/EC Of The European Parliament And Of The Council, of 15 December 2004)
(3) WHO Guidelines for Air Quality WHO/SDE/OEH/00.02 (2000).

Sulphur Dioxide

Guideline Set By	Description		Criteria Based On	Value(1) / μgm^{-3} (ppb)
UK Government Air Pollution Index	LOW	1	15-minute mean	0-88 (0-32)
		2		89-176 (33-66)
		3		177-265 (67-99)
	MODERATE	4	15-minute mean	266-354 (100-132)
		5		355-442 (133-166)
		6		443-531 (167-199)
	HIGH	7	15-minute mean	532-708 (200-266)
		8		709-886 (267-332)
		9		887-1063 (333-399)
	VERY HIGH	10	15-minute mean	≥ 1064 (≥ 400)
The Air Quality Strategy(2) *Set in regulations(3) for all UK.*	Objective for Dec. 31st 2005, for protection of human health.		15-minute mean	266 (100) Not to be exceeded > 35 times per calendar year.
	Objective for Dec. 31st 2004, for protection of human health		1-hour mean	350 (132) Not to be exceeded > 24 times per calendar year.
	Objective for Dec. 31st 2004, for protection of human health		24-hour mean	125 (47) Not to be exceeded > 3 times per calendar year.
Not intended to be set in regulations.	Objective for Dec. 31st 2000, for protection of vegetation.		Annual mean & winter (1st October – 31st March) mean	20 (8)
1st Daughter Directive(4) and Directive on Ambient Air Quality (5)	Objective for Jan 1st 2005, for protection of human health		1-hour mean	350 (132) Not to be exceeded more than 24 times per calendar year.
	Objective for Jan 1st 2005, for protection of human health		Daily 24-hour mean	125 (47) Not to be exceeded more than 3 times per calendar year.
	Objective for Jul 19th 2001, for protection of vegetation.		Annual mean & winter (1st October – 31st March) mean	20 (8)
World Health Organisation(6) *(Non-Mandatory Guidelines)*	Health Guideline		10-minute mean	500
	Health Guideline		24-hour mean	125
	Health Guideline		Annual mean	50

(1) Conversions between μg m^{-3} and ppb are as used by the EC, i.e. 1ppb SO_2 = 2.66 μg m^{-3} at 20°C and 1013 mB.
(2) The Air Quality Strategy for England, Scotland, Wales and Northern Ireland. July 2007, The Stationery Office, ID 5611194 07/07.
(3) Air Quality Regulations 2007 (SI 2007/64), Air Quality Standards (Wales) Regulations 2007 (Welsh SI 2007 717 (W63)), Air Quality Standards (Scotland) Regulations 2007 (SSI 2007 No. 182), Air Quality Standards (Northern Ireland) Regulations 2007 (Statutory Rule 2007 No. 265)
(4) Council Directive 1999/30/EC. Transposed into UK Air Quality Regulations by above Statutory Instruments.
(5) Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 On Ambient Air Quality And Cleaner Air For Europe, which supersedes (4).
(6) WHO Guidelines for Air Quality WHO/SDE/OEH/00.02 (2000).

Ozone

Guideline Set By	Description		Criteria Based On	Value[1] / μgm^{-3} (ppb)
UK Government Air Pollution Index	LOW	1	Max 1-hour and 8-hour mean	0-32 (0-16)
		2		33-66 (17-32)
		3		67-99 (33-49)
	MODERATE	4	Max 1-hour and 8-hour mean	100-126 (50-62)
		5		127-152 (63-76)
		6		153-179 (77-89)
	HIGH	7	Max 1-hour and 8-hour mean	180-239 (90-119)
		8		240-299 (120-149)
		9		300-359 (150-179)
	VERY HIGH	10	Max 1-hour and 8-hour mean	≥ 360 (≥ 180)
The Air Quality Strategy[2] All UK.	Objective for Dec. 31st 2005 [2]		Daily max. running 8-hour mean	100 (50) Not to be exceeded more than 10 times per calendar year.
	Target Value for protection of vegetation. To be achieved by 5 years, beginning 2010[2]		AOT40[2] calculated from 1h values May- July.	18,000 μg m^{-3} h averaged over 5 years.
European Community 3rd Daughter Directive[3] and Directive on Ambient Air Quality [4]	Target Value To be achieved by 3-year period beginning 2010.		Max. daily 8-hour mean.	120 μg m^{-3} Not to be exceeded on more than 25 days per year, averaged over 3 years.
	Target Value for protection of vegetation. To be achieved by 5 years, beginning 2010		AOT40[5] calculated from 1h values May- July.	18,000 μg m^{-3} h averaged over 5 years.
	Information threshold		1-hour mean	180
	Alert threshold		1-hour mean	240
World Health Organisation[6] *(Non-Mandatory Guidelines)*	Health Guideline		8-hour mean	120

(1) Conversions between μg m^{-3} and ppb are as used by the EC, i.e. 1ppb O_3 = 2.00 μg m^{-3} at 20°C and 1013 mB.
(2) The Air Quality Strategy for England, Scotland, Wales and Northern Ireland. July 2007, The Stationery Office, ID 5611194 07/07.
(3) Directive (2002/3/EC)
(4) Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 On Ambient Air Quality And Cleaner Air For Europe, which supersedes (4).
(5) AOT40 statistic is the sum of the differences between hourly concentrations greater than 80 μg m^{-3} (=40ppb) and 80 μg m^{-3}, over a given period using only the 1-hour averages measured between 0800 and 2000.
(6) WHO Guidelines for Air Quality WHO/SDE/OEH/00.02 (2000).

Lead (Pb)

Guideline Set By	Description	Criteria Based On	Value / $\mu g m^{-3}$
The Air Quality Strategy(1) **Set in regulations for all UK.**	Objective for Dec. 31st 2004	Annual mean	0.5 (= 500 ng m^{-3})
	Objective for Dec. 31st 2008	Annual mean	0.25 (= 250 ng m^{-3})
1st Daughter Directive (1999/30/EEC)(2) and Directive on Ambient Air Quality (3)	Limit Value to be achieved by Jan 1st 2005	Annual mean	0.5 (= 500 ng m^{-3})
	Limit Value to be achieved by Jan 1st 2010 in the immediate vicinity of industrial sources	Annual mean	0.5 (= 500 ng m^{-3})
World Health Organisation(4) *(Non-Mandatory Guidelines)*	Health-Based Guideline	Annual Mean	0.5 (= 500 ng m^{-3})

(1) The Air Quality Strategy for England, Scotland, Wales and Northern Ireland. July 2007, The Stationery Office, ID 5611194 07/07.
(2) Council Directive 1999/30/EC
(3) Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 On Ambient Air Quality And Cleaner Air For Europe, which supersedes (2).
(4) WHO Guidelines for Air Quality WHO/SDE/OEH/00.02 (2000).

Metallic Elements Arsenic (As), Cadmium (Cd), Mercury (Hg) and Nickel (Ni), and hydrocarbon Benzo (a) Pyrene

Guideline Set By	Description	Criteria Based On	Value / ng m^{-3}
4th Daughter Directive (205/107/EC)	Target Value for As	Calendar year mean	6
	Target Value for Cd	Calendar year mean	5
	Target Value for Hg	Calendar year mean	Not set
	Target Value for Ni	Calendar year mean	20
	Target Value for B(a)P	Calendar year mean	1

Target values to be non-mandatory.

Description of UK Government Pollution Indices

Old "Band"	New Index	Health Descriptor
LOW	1	Effects are unlikely to be noticed even by individuals who know they are sensitive to air pollutants.
	2	
	3	
MODERATE	4	Mild effects unlikely to require action may be noticed amongst sensitive individuals.
	5	
	6	
HIGH	7	Significant effects may be noticed by sensitive individuals and action to avoid or reduce these effects may be needed (e.g. reducing exposure by spending less time in polluted areas outdoors). Asthmatics will find that their "reliever" inhaler is likely to reverse the effects on the lung.
	8	
	9	
VERY HIGH	10	The effects on sensitive individuals described for "High" levels of pollution may worsen.

Air Quality Regulations: Statutory Instruments

Date	Country	S.I. No.	Purpose
30/03/2000	England	SI 2000 No. 928	Inclusion of original Air Quality Strategy Objectives into regulations in England
19/07/2000	Wales	SI 2000 No. 1940 (W138)	Inclusion of original Air Quality Strategy Objectives into regulations in Wales
31/03/2000	Scotland	SSI 2000 No. 97	Inclusion of original Air Quality Strategy Objectives into regulations in Scotland
09/06/2001	Scotland	SSI 2001 No. 224	Transposition of 1st Daughter Directive into Air Quality Limit Values Regulations for Scotland.
25/06/2001	UK	SI 2001 No. 2315	Transposition of 1st Daughter Directive into Air Quality Limit Values Regulations for England.
17/07/2001	Wales	SI 2001 No. 2683 (W224)	Transposition of 1st Daughter Directive into Air Quality Limit Values Regulations for Wales.
08/03/2002	Northern Ireland	Statutory Rule 2002 (94)	Implementation of 1st Daughter Directive in NI.
11/06/2002	Scotland	SSI 2002 297	Amendment of Air Quality Regulations to include more stringent objectives for PM_{10}, CO and benzene, specifically for Scotland.
21/11/2002	Northern Ireland	Statutory Rule 2002 (357)	Transposition of 2nd Daughter Directive into Air Quality Limit Values Regulations for Northern Ireland
11/12/2002	England	SI 2002 No 3043	Amendment of Air Quality Regulations to include more stringent objectives for CO and benzene, in England.
16/12/2002	England	SI 2002 No 3117	Transposition of 2nd Daughter Directive into Air Quality Limit Values Regulations for England
17/12/2002	Scotland	SSI 2002 556	Transposition of 2nd Daughter Directive into Air Quality Limit Values Regulations for Scotland
17/12/2002	Wales	Welsh SI 2002 3182 (W298)	Amendment of Air Quality Regulations to include more stringent objectives for CO and benzene, in Wales
17/12/2002	Wales	Welsh SI 2002 3183 (W299)	Transposition of 1st and 2nd Daughter Directives into Air Quality Limit Values Regulations for Wales.
01/09/2003	Northern Ireland	Statutory Rule 2003 No. 342	Air Quality Regulations (Northern Ireland) 2003. Set out LA obligations w.r.t. local air quality management.
09/09/2003	UK	SI 2003 No. 2121	The Air Quality Limit Values Regulations 2003. Transpose 1st, 2nd and 3rd Daughter Directives into Air Quality Limit Values Regulations for England: repeal regulations relating to previous directives on sulphur dioxide and suspended particulates, and NO_2.
09/09/2003	Northern Ireland	Statutory Rule 2003 No. 240	The Air Quality (Ozone) Regulations (Northern Ireland) 2003. Transpose 3rd Daughter Directive.
01/01/2004	Northern Ireland	Statutory Rule 2003 No. 543	Air Quality (Amendment) Regulations (Northern Ireland) 2003. Correct a drafting error in SR 2003 No. 342.
03/12/2004	England	SI 2004 No. 2888	The Air Quality Limit Values (Amendment) (England) Regulations 2004. Amendments relating to implementation of EC Directives.

Date	Country	S.I. No.	Purpose
07/01/2005	Northern Ireland	Statutory Rule 2004 No. 514	The Air Quality Limit Values (Amendment) Regulations (Northern Ireland) 2004. Amendments relating to implementation of EC Directives.
12/04/2005	Wales	Welsh SI 2005 No. 1157 (W74)	The Air Quality Limit Values (Wales) (Amendment) Regulations 2005 Amends definition of the "public" and makes provision for the use of demonstrated equivalent methods of PM_{10} monitoring.
15/02/2007	England	SI 2007 No. 64	The Air Quality Standards Regulations 2007. Transpose 1st, 2nd, 3rd & 4th Daughter Directives and introduce requirement to monitor $PM_{2.5}$, ozone precursor substances and certain polycyclic aromatic hydrocarbons.
15/03/2007	Wales	Welsh SI 2007 717 (W63)	Air Quality Standards (Wales) Regulations 2007. Transpose 1st, 2nd, 3rd & 4th Daughter Directives and introduce requirement to monitor $PM_{2.5}$, ozone precursor substances and certain polycyclic aromatic hydrocarbons.
29/03/2007	Scotland	SSI 2007 No. 182	the Air Quality Standards (Scotland) Regulations 2007 Transpose 1st, 2nd, 3rd & 4th Daughter Directives and introduce requirement to monitor $PM_{2.5}$, ozone precursor substances and certain polycyclic aromatic hydrocarbons.
28/05/2007	Northern Ireland	Statutory Rule 2007 No. 265	The Air Quality Standards Regulations (Northern Ireland) 2007. Transpose 1st, 2nd, 3rd & 4th Daughter Directives and introduce requirement to monitor $PM_{2.5}$, ozone precursor substances and certain polycyclic aromatic hydrocarbons

Appendix A6- calculation methods, statistical methods and measurement uncertainty

Here we provide essential information on measurement accuracy, trend calculation and the mathematical methods used to calculate measurement statistics.

A 6.1 Statement on accuracy of air quality measurements

The EC Air Quality Directives now specify a required level of data accuracy (uncertainty). The accuracy requirements for the various parameters are summarised in Table 1 below. Please note that there is also a requirement for 90% data capture in each year.

A common approach to determining measurement uncertainty for all pollutants is provided by a CEN (The European Centre for Standardisation) report entitled: 'Air quality – approach to uncertainty estimation for ambient air reference methods'[R1]. CEN has produced a series of standards setting out how National Networks in Member States should operate analysers in order to meet the required uncertainty of ±15% for NO_2, SO_2, CO and O_3 and ±25% for benzene and PM_{10} particulate matter (at the 95% confidence level).

The standards include a set of performance characteristics against which analysers need to be assessed for official approval, as well as activities required for ongoing Quality Assurance and Control (QA/QC). Four analyser types have currently been submitted and successfully passed the type-approval tests in the UK. These are API (models E/A), Horiba 370, Monitor Europe / Monitor Labs and Thermo Fisher. It is estimated that these type approvals cover approximately 50% of the analysers currently in use in the UK Automatic and Rural Monitoring Network (AURN).

The situation with particulate measurements is more complicated. This is because of the widescale use of analysers that do not conform to the EU Reference Method for PM_{10} monitoring. Much work is being undertaken- both within Member States and at the EU level- to assess the performance of the different analysers and techniques used for measurement of PM_{10}.

Measurement uncertainty objectives given in EU Air Quality Directiv

Pollutant	Uncertainty for Continuous Measurement (listed as accuracy in the Directive)
NO_2, NO_x	15%
SO_2	15%
PM_{10} Particulate Matter	25%
CO	15%
Benzene	25%
O_3	15%

Note: The percentages given in the table are for individual measurements averaged over the period considered by the limit or target value, at concentrations close to the limit or target value, for a 95% confidence interval.

A 6.2 Calculation methods

A6.2.1 Introduction

The intention of this section is to provide all the information required to reproduce the statistics contained in this report from the original hourly dataset. This dataset is now available from the UK National Air Quality Archive on the World Wide Web- www.airquality.co.uk.

The definition of standard statistical functions, such as means, percentiles, regressions and standard errors can be obtained from a number of statistical references. A description of log-normal distributions and related statistics has also been provided elsewhere[R2].

Various air quality guidelines and statistics are defined in the documentation published by the UK Government [R3], the European Community[R1,R4-R5], the World Health Organisation[R6-R9] and The Expert Panel on Air Quality Standards (EPAQS) [R10-18]. This section describes how these statistics are calculated from the original dataset. All exceedence statistics in this report are calculated using methods that are compliant with the requirements of each air quality standard.

Where the exact method of calculation of a statistic has not been precisely defined by the above bodies, a method has generally been chosen that leads to a more stringent air quality guideline.

These calculation methods have been developed over time and are not necessarily those that were used in previous reports of this series.

A6.2.2 Definitions

Basic reporting unit

The basic reporting unit for the national automatic monitoring networks is the hourly average (the terms "mean" and "average" are taken to be equivalent in this report). All statistics of greater than one-hour duration are based on hourly averages. For example, the annual mean is the arithmetic mean of the hourly means during the year. Hourly means that are invalid, for any reason, are ignored.

Hourly averages are derived from:

- At least three 15-minute averages per hour in the AURN for all gaseous analysers and original TEOMs.
- Hourly measurements from MetOne BAMs and TEOM FDMS units.
- 30-minutes of sampling in the Hydrocarbon Network

Although 15-minute averages are used in the UK National Air Quality standard for SO_2 and the WHO CO guidelines, 15-minute averages are not the basic reporting unit. Annual means, for example, based on 15-minute average may not be equal to those based on hourly averages since there may be, on occasion, insufficient 15-minute data to make a valid hourly mean. 15-minute data are only used to calculate hourly means and any statistic specifically related to 15-minute means.

Mass units

The units that used to measure the concentrations are not always the same as those used to calculate and report statistics. For example, ozone is measured by the instrumentation in

parts per billion (ppb) and the statistics are reported here in terms of the µg m^{-3} mass units. Particulate matter PM_{10}, on the other hand, is measured and reported in terms of µg m^{-3}.

To calculate statistics, therefore, the measured data are first converted into the reporting units; the statistics are then calculated. Comparison with any limit values is only performed in terms of mass units. This method will give slightly different results, due to rounding errors, to calculations using data in ppb and comparing with limit values converted into ppb.

Dates and times

All data are recorded as Greenwich Mean Time (GMT). Please note that diurnal variations are calculated in local time.

Daily means are defined as midnight to midnight; 24-hour running means are means over any 24-hour period, for example 0800 to 0759.

Data precision

All concentrations are recorded and reported to a number of decimal places that is greater than or equal to the measurement precision of individual hourly means. For example:

- Ozone is measured to 2 ppb and reported to 1 ppb or 2 µg m^{-3}
- Benzene is measured to 0.1 ppb and reported to 0.1 ppb or 0.3 µg m^{-3}

Note that 15-minutes means, where available, are also recorded to the same data precision as hourly means.

Percentiles

Percentiles of SO_2 daily means are calculated using the method described in the European Council SO_2 Directive (repealed at end of 2005)[R19] .

All other percentiles use the method described in the 1985 NO_2 Directive (85/203/EC)[R20] which was superseded by the 1st Daughter Directive[R21], 1999/30/EC, and subsequently by the most recent Directive on ambient air quality and cleaner air for Europe (2007/50/EC)[R4] but remains in force until fully repealed in January 2010.

For example: after sorting the data into ascending numerical order, the 98th percentiles are at the following ranks:

SO_2	0.98 times the number of valid means rounded up to the nearest integer
NO_2	0.98 times the number of valid means rounded to the nearest integer

For example, the 98th percentile of 365 daily means (rank 357.7) is the 8th highest concentration using the SO_2 Directive method and also the 8th highest concentration using the NO_2 Directive method.

Data capture threshold

A 75% data capture threshold is set for all short-term averages of up to the duration of a month. For example:

- An hourly mean requires at least three 15-minute means
- A monthly mean requires at least 75% of daily means and each daily mean requires at least 18 hours of data

Note that it is possible to have a month with 75% data capture for hourly means, but with less than 75% daily means.

Annual and seasonal statistics, such as the summer mean and the annual 98th percentile of hourly means, should be interpreted with respect to the quoted data capture. These statistics are generally not shown if the data capture is less than 25%. However, some short-term values such as the date of the annual maximum hourly mean are shown, since these may still be of interest.

Air quality standards and guidelines

Air quality guidelines used in this report are those defined in the documentation published by the UK Government[R3], the European Community[R1,R4-R5], the World Health Organisation[R6-R9].

The following conversion factors from measured units to mass units are defined in the EU Decision on Exchange of Information[R22]; these have now been incorporated into the 2007 Directive[R4]

Conversion Factors Between ppb and μg m^{-3} and ppm and mgm^{-3}

Pollutant	WHO	EC
	25°C and 1013mb	20 °C and 1013mb
Ozone	1 ppb = 1.9622 μg m^{-3}	1 ppb = 1.9957 μg m^{-3}
Nitrogen dioxide	1 ppb = 1.8804 μg m^{-3}	1 ppb = 1.9125 μg m^{-3}
Carbon monoxide	1 ppm = 1.1447 mg m^{-3}	1 ppm = 1.1642 mg m^{-3}
Sulphur dioxide	1 ppb = 2.6163 μg m^{-3}	1 ppb = 2.6609 μg m^{-3}
Benzene	1 ppb = 3.189 μg m^{-3}	1 ppb = 3.243 μg m^{-3}
1,3-butadiene	1 ppb = 2.2075 μg m^{-3}	1 ppb = 2.2452 μg m^{-3}

Additional conversion factors used in the UK are as follows:

- NO_x in μg m^{-3} is expressed as NO_2, i.e. (NO ppb + NO_2 ppb)* 1.91 = NO_x μg m^{-3}

Note that the minimum data period that can be compared to a guideline is fifteen minutes, since this is currently the time resolution of most UK automatic data. The WHO 10-minute SO_2 guideline is not, therefore, reported.

Running means

Wherever possible, running means, rather than simple means, are used for comparison with air quality standards.

For example: the Air Quality Standard CO 8-hour standard in this report is based on all possible 8-hour means during a year. Calculating all possible means can produce twenty-four possible exceedences every day. This is a more stringent method than taking simple, non-overlapping, means – for example, three 8-hours means in a day.

Please note that in this report:

- The WHO 30-minute guideline is calculated as a running mean based on 15-minute averages
- The UK National Air Quality standard running annual means for benzene and 1,3-butadiene requires a 75% data capture. Newly established sites cannot, therefore, report the running annual mean.

Exceedences

An exceedence of an air quality guideline is generally defined in this report as a concentration **greater than** the guideline threshold. This definition was changed from "**greater than or equal"** the guideline threshold, in order to be consistent with EC Directives.

There is one exception, which is in the calculation of exceedences of the Air Quality Bandings. In this case the "**greater than or equal" definition** continues to be used, in order to afford maximum public health protection.

Exceedence counting

The following method is used where an air quality guideline is based on an average:

1. Calculate the average
2. Apply the 75% data capture threshold
3. Round the average to the data precision
4. Compare with the guideline

For example: at stage 3, an 8-hour average ozone concentration of 100.4999 µg m^{-3} is rounded to 100 µg m^{-3}. This does not exceed the UK National Air Quality standard running 8-hour ozone mean of 100 µg m^{-3}.

However, if no rounding occurs, the concentration would exceed the standard. Also, if this value is the highest running 8-hour during the year, an anomaly would occur in the report since the maximum would be reported as 100 µg m^{-3} yet there would be an exceedence.

To calculate the number of days with an exceedence, the date (in GMT) of the last hour of the running mean is used.

Diurnal variations

Diurnal variations are the average concentration for each hour of day during the period of interest. Local time is used, rather than GMT, since this will more closely reflect the daily cycle of manmade emissions.

Long-term trends

Long-term trends reported here are based a non-parametric linear regression method which has the following stages:

- The gradient is calculated by "Theil's incomplete" method[R23]
- The null hypothesis (i.e. the statistical significance of the trend) is tested by the Spearman's rank correlation coefficient[R24]
- The 95th confidence interval for the gradient is given by Kendall's Tau[R25]

Values for the Spearman's rank correlation coefficient used in this report are as published by Conover[R26].

This method does not assume that the errors on the data points are normally distributed and is, therefore, more appropriate than simple linear regression by least squares. However, the results obtained have been demonstrated to be broadly similar[R27].

Exponential regressions may be appropriate for some time series, e.g. SO_2 in London, but for the majority of cases a linear trend over recent years is of most interest. Only linear trends are provided in this report.

Trends are reported for sites where there are at least five valid annual measurements. A valid measurement requires a data capture of at least 50%.

Where a site has a statistically significant trend of more than five years, the five-year trend and the trend over the full monitoring period are reported. Ten-year trends are highlighted in the summary table in Appendix 4.

Particulate measurements and conversion factors used in this report

With gaseous pollutants, it is possible to express concentrations as an amount fraction – the ratio of pollutant molecules to the total number of air molecules – for example, parts per billion (ppb). This is not possible for particulate matter (PM), and measurements are always given in units of particulate mass per unit volume of air (typically μgm^{-3}). When these units are used without specifying the temperature and pressure of the air, the same 'packet' of air will have a different concentration as these properties of the air change.

The European legislation for PM measurement therefore requires that the air volume used must be at the same ambient air temperature and pressure as at the time of sampling. In practice, this means that appropriate corrections need to be made if the flow rate used to calculate the sampled volume is not based on the actual volume of sampled air.

Different measurement techniques, although nominally measuring the same PM, may treat the airstream in different ways, leading to significantly different results. For clarity, all mass measurements of PM_{10} and $PM_{2.5}$ in this report are expressed as $\mu g\ m^{-3}$ for both gravimetric and TEOM analysers.

The EU First Air Quality Daughter Directive (1999/30/EC) specifies that measurements of PM_{10} should be carried out using the reference method, as defined in European Standard EN12341. This standard refers to three sampling devices that may be used:

- Superhigh volume sampler – the WRAC (Wide Range Aerosol Classifier);
- High-volume sampler – the HVS PM_{10} sampler ($68\ m^3\ h^{-1}$);
- Low-volume sampler – the LVS PM_{10} sampler ($2.3\ m^3\ h^{-1}$).

None of these instruments can provide real-time (continuous hourly) measurements.

During 2008, the Tapered Element Oscillating Microbalance (TEOM) analyser continued to be widely used in both the UK and throughout the rest of the world for measuring continuous concentrations of PM. The instrument is based on the principle that the frequency of oscillation of a tapered glass tube (the tapered element) is dependent on its mass. In the TEOM, particles are sampled onto a small filter fixed to the end of this element. This deposition of particles changes the mass, resulting in a change in the resonant frequency.

Note: all TEOM analysers in the AURN, for both PM_{10} and $PM_{2.5}$ are set to report concentrations corrected to 293K and 101.3 kPa. In addition, they are also set up to apply a default adjustment factor (1.03 * TEOM reading + 3 μgm^{-3}) to the raw data. This factor is necessary in order for the TEOM to be used as a USEPA-equivalent method for PM_{10} measurement in the United States, and is therefore programmed in by the TEOM's US-based supplier.

Changes in humidity can affect the mass measurement, by altering the amount of moisture in the particles collected on the filter. To eliminate this source of uncertainty, the sample filter in the TEOM maintained at a constant temperature of 50 Celsius. This has led to reported differences in concentrations of PM between the TEOM and the European reference sampler (Allen *et al*., 1997; Ayers *et al*., 1999; Soutar *et al*., 1999;

Salter and Parsons, 1999; Cyrys *et al*., 2001; Williams and Bruckmann, 2001 all cited in AQEG's 2005 report on particulate matter in the United Kingdom[R28].

This is largely attributed to the loss of volatile species such as ammonium nitrate. As an interim measure, a default 'scaling factor' (also known as correction factor) of 1.3 used to be applied to TEOM PM_{10} data, as recommended by the EC Working Group on Particulate Matter (2001), to convert to indicative gravimetric equivalent.

However, UK equivalence trials for particulate instruments in 2005 (reported in June 2006) established that the TEOM did not meet the equivalence criteria, even after application of the scaling factor of 1.3. Therefore, the original TEOMs are being phased out of the UK monitoring networks. This has been an ongoing process during 2007 and 2008, where the original instruments have been either replaced or upgraded to "Reference Equivalent" TEOM by retrofitting an FDMS (Filter Dynamics Measurement System) to the instrument instrument.

The FDMS upgrade to the TEOM enables the measurement and reporting of both the volatile and non-volatile components of particulate matter. (The TEOM FDMS model B system has demonstrated equivalence with the PM_{10} reference method, as also has the Met-One Beta Attenuation Monitor BAM 1020 and the gravimetric R&P Partisol daily sampler).

Once the upgrade and replacement programme is complete, this will mean that results can be directly compared, with full confidence, against the EC Directive limit values and objectives.

Meanwhile, the problem remains of how to deal with data from unmodified TEOMs. While the equivalence trial of 2005 was underway, King's College London undertook a research programme to identify a relationship between data from the unmodified TEOM instrument (in which the volatile component is lost) and the newer (modified) TEOM FDMS instrument (in which the volatile component is measured). King's College London successfully identified a relationship, and used this as the basis of a web-based tool (the Volatile Correction Model, VCM).

The Volatile Correction Model (see section 3.6 of the main report) allows data from unmodified TEOMs to be corrected to gravimetric equivalent data. Defra has given its approval for Local Authorities to use the VCM for Local Air Quality Management purposes, to correct data from older TEOM instruments which do not meet the equivalence criteria. The VCM can be used for any TEOM which is within 130 km of an FDMS modified TEOM.

The PM_{10} datasets for 2008 reported in the current report are therefore based upon the official UK dataset (as reported to the European Commission) and comprise the following:

1. Data from reference equivalent methods – e.g. gravimetric methods, BAM or FDMS-modified TEOMs where these are installed.
2. VCM-corrected TEOM data where the above are not available, but with the VCM correction based on AURN sites only, with the distance extended to 200 km.
    - Where neither of the above options are available, no TEOM data has been included. The old scaling factor of 1.3 has not been used.

Only AURN sites have been used in the VCM correction of this dataset, because data from non-AURN sites may not necessarily be produced to the same consistent quality standards.

Because the programme of upgrading the TEOMs within the AURN was ongoing throughout 2007 and 2008, it is possible that - for some sites - the 2008 dataset comprises a mixture of the above two options. For example, if an AURN site had an unmodified TEOM in place at the beginning of 2008, and there were no AURN FDMS TEOMs within 200 km, then no data would be included for the first part of the year. If, part way through the year, an FDMS was installed at an AURN site within 200 km

(making it possible to correct the data using the VCM) then VCM-corrected data would be provided from that point in time onwards. If, later in 2008, the TEOM was upgraded by means of an FDMS retrofit (or was replaced with another technique, such as the BAM, which has demonstrated equivalence to the reference method), then final part of the annual dataset would consist of data from the reference equivalent method.

The upgrading programme continues, and its aim is to have the entire AURN upgraded by the end of 2010, but in the intervening period the dataset presented in this series of reports will continue to consist of a mixture of the above types of data.

A 6.3 'box and whisker' plots

Box and whisker plots – such as that in Figure 6.3 of the present report - are used to illustrate measured concentrations at air quality monitoring stations around the UK and how they compare with the UK's Air Quality Strategy Objectives. For each objective, the average concentration (of the appropriate metric) for all of the sites is shown, together with the highest concentration from that group of sites.

Data for each pollutant are obtained from the national networks. This is mainly from the Automatic Urban and Rural Network (AURN) but also from the Hydrocarbons Network, Heavy Metals Network and PAH Network where applicable to that pollutant. The data represent a broad range of monitoring environments including roadside and background sites. All data used in the calculations undergo a rigorous quality assurance procedure and are fully ratified prior to analysis.

The checked and validated data are used to calculate the appropriate metric (annual average, maximum daily running 8-hour concentration, and so on). The metrics presented generally correspond to those on which the legislation is based. This allows a direct comparison of measured levels against the objectives.

Some objectives allow for a specific number of permissible exceedences. It is more difficult to analyse progress against these objectives, because the metric provides no indication of air quality below the number of permissible exceedences. For this reason, an equivalent percentile is used. For example, the SO_2 15-minute objective allows up to 35 exceedences in a calendar year; the corresponding percentile would be 99.9% of 15-minute means. If this value is below the 266 $\mu g\ m^{-3}$ objective, then there are fewer than the 35 permissible exceedences and the difference will provide an indication of how far below the objective the measured values are. This allows us to meaningfully average concentrations from a range of sites and to compare them directly against the objective.

Data capture statistics are used to screen out sites where the volume of data is too low to provide meaningful comparisons against the legislative objectives. A data capture threshold of 75% has been used for this purpose, below which data are omitted from the analysis.

When the data have been screened to include only those sites with 75% or more, the data range is sorted in order to group sites into their respective countries. The average and maximum concentrations are then calculated for the appropriate group of sites to which specific objectives apply. These are presented in simple box and whisker ('cricket bat' plots), where the bar represents the average concentration of all the sites in the range and the whisker represents the site with the highest concentration. These can also be presented in simple line charts to show the same information in a time series - as in Figure 6.4 in this report.

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General information on Air Quality

The UK Air Quality Information Archive:
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The National Atmospheric Emissions Inventory:
www.naei.org.uk

The Defra air quality information web resource:
www.defra.gov.uk/environment/airquality/index.htm

The Scottish Executive Air Quality pages:
www.scotland.gov.uk/Topics/Environment/Pollution/16215/4561

The Welsh Assembly Government Environment link:
www.wales.gov.uk/subienvironment/index.htm

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